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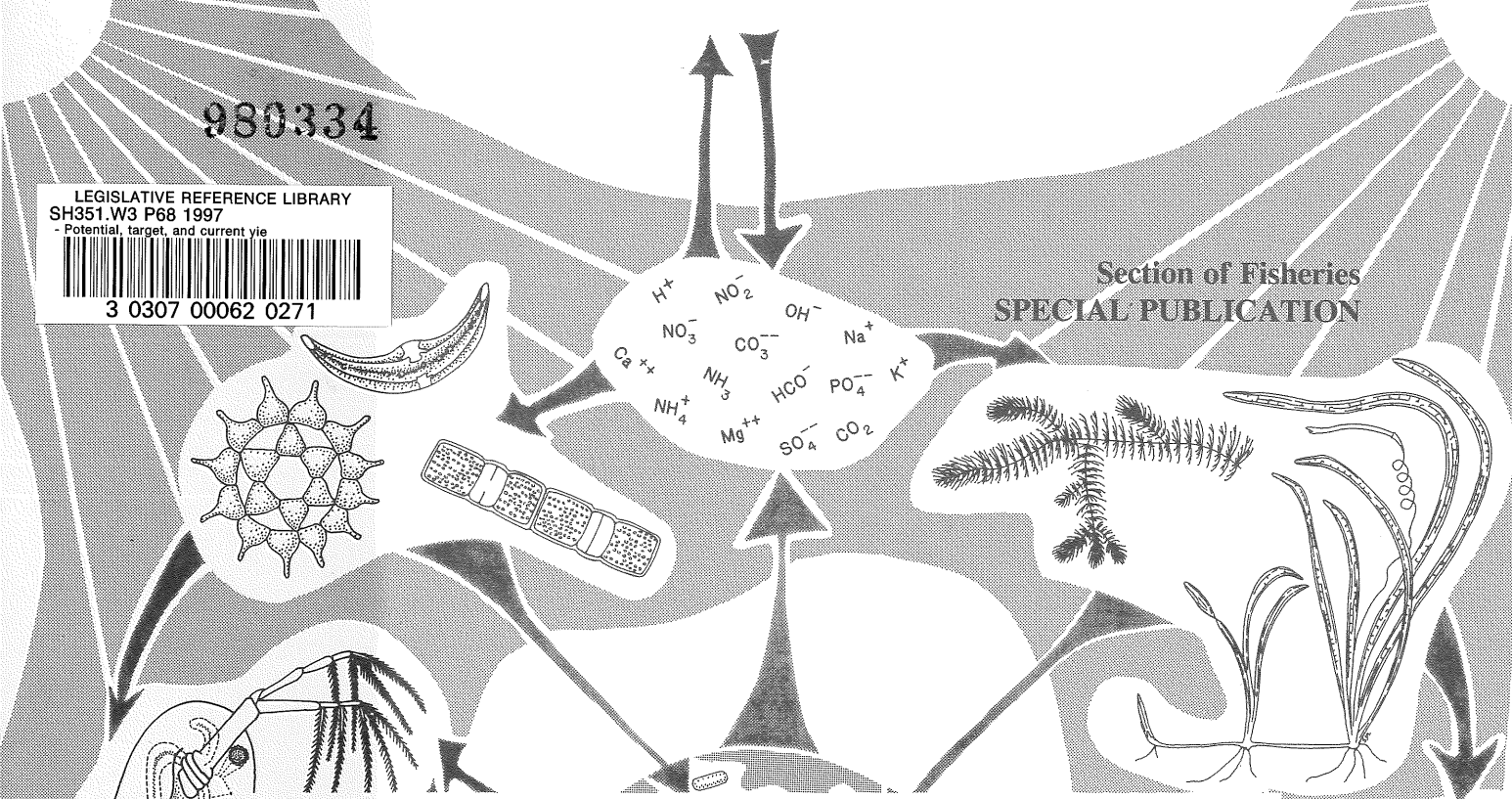

No. 151

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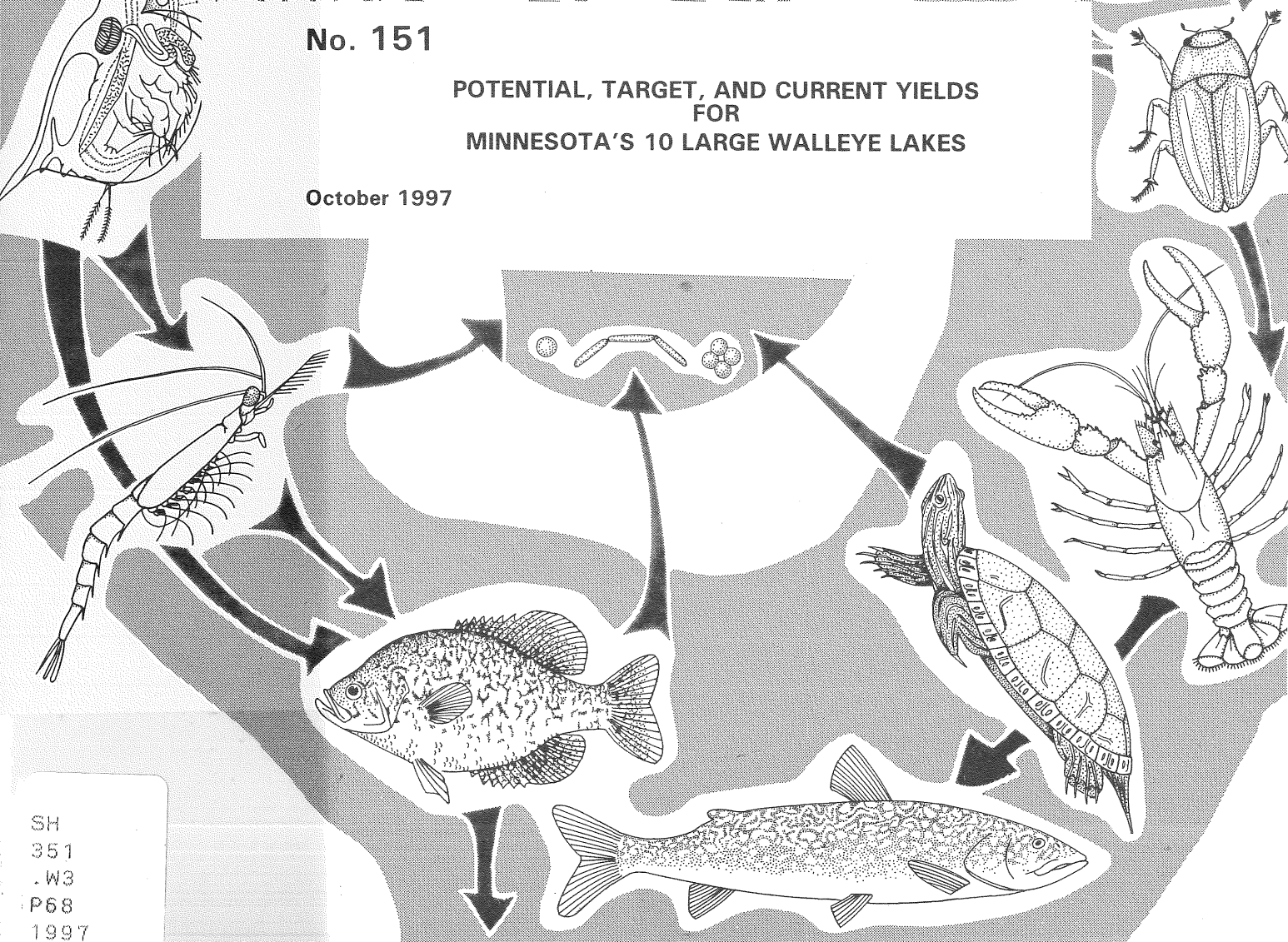
October 1997



POTENTIAL, TARGET, AND CURRENT YIELDS FOR MINNESOTA'S 10 LARGE WALLEYE LAKES

Special Publication Number 151

Minnesota Department of Natural Resources
Section of Fisheries
500 Lafayette Road
St. Paul, MN 55155

October 1997

Preface

Minnesota's 10 largest walleye lakes are considered by many to be the crown jewels of our statewide lake resource. They are the most important fishing waters in the state, accounting for about 40 percent of the statewide walleye harvest. The significance of these waters led the Fisheries Section to establish the Large Lake Monitoring Program (LLP) in 1983. The information gathered by the LLP has been invaluable for keeping the public informed on the status of fish populations and level of harvest but is taking on much greater significance in dealing with management issues such as regulation of harvest and correction of environmental problems.

This publication is intended to synthesize similar information for each of the 10 lakes. Of special significance is the use of predictive models to estimate potential fish yields as a basis for establishing target harvest levels for key fish species. This work is an essential step if the fish populations in these waters are to be managed in a more intensive manner than in the past. The Minnesota angling community has asked for a stronger focus on the use of appropriate regulations to control harvest at levels that protect or enhance angling quality.

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Introduction

Program History

Minnesota's 10 largest natural walleye *Stizostedion vitreum* lakes have a combined surface area of more than 825,000 acres of water (Table 1). The estimated annual harvest of walleye from these waters is 1.5 million pounds or approximately 40% of the entire statewide walleye harvest (D. Schupp personal communication). The economic value and significance of these waters to the State of Minnesota are immense. In 1983, the Minnesota Department of Natural Resources (MNDNR) Section of Fisheries increased its commitment to managing these waters by establishing the *Large Lake Monitoring Program* (LLP). The LLP includes the state's 10 largest walleye lakes and Lake Superior, which is primarily managed for coldwater species such as trout and salmon (Figure 1).

Prior to 1983, monitoring of the large lakes generally followed the sampling protocols and survey frequencies prescribed in the lake survey manual (Scidmore 1970). In addition, research biologists were periodically assigned to undertake lake-specific studies in response to perceived fishery management problems. With the inception of the LLP in 1983, large lake specialists were assigned to each of the 11 large lakes. Their primary responsibility included annual collection, analysis, and reporting of fish population data, monitoring long term population trends, development of management recommendations, and public outreach. The Section of Fisheries currently invests about 5% ($850,000) of its annual budget in the LLP.

In 1984, the Section of Fisheries and the Ontario Ministry of Natural Resources jointly published the first *Minnesota-Ontario Boundary Waters Fisheries Atlas* for Lake of the Woods, Rainy Lake, and the Rainy River

Table 1. Physical and chemical characteristics of Minnesota's 10 large walleye lakes.

Lake Name	Lake Area (acres)	Mean Depth (feet)	Max. Depth (feet)	Secchi (feet)	Chlorophyll-a (ug/l)	Alkalinity (mg/1 $CaCO_3$)	Phosphorous (ug/l)
Cass	15,600	24.9	120	9.2	7.8	148	27.6
Kabetogama	25,760	29.9	80	7.7	11.8	37	25.5
Lake of the Woods	317,000[1]	24.3	38	4	22.7	44	37.3
Leech	111,527	16.8	156	7.5	1.6	133	21.0
Mille Lacs	132,516	21	42	7.7	7	84	30.8
Pepin	25,060	21	60	2.1	18.7	165	210.0
Rainy	54,140[2]	32	161	8.6	4.6	16	14.0
Upper Red	48,000[3]	12.9	18	2.3	12.4	106	58.0
Vermillion	40,557	20	76	9.0	10.9	28	24.0
Winnibigoshish	58,444	15.1	70	6.8	13.4	136	32.4

[1] Minnesota waters only. Total lake area for Lake of the Woods is 951,337 acres.
[2] Minnesota waters only. Total lake area for Rainy Lake is 220,800 acres.
[3] Off reservation waters only. Total lake area for Upper Red Lake is 108,000 acres.

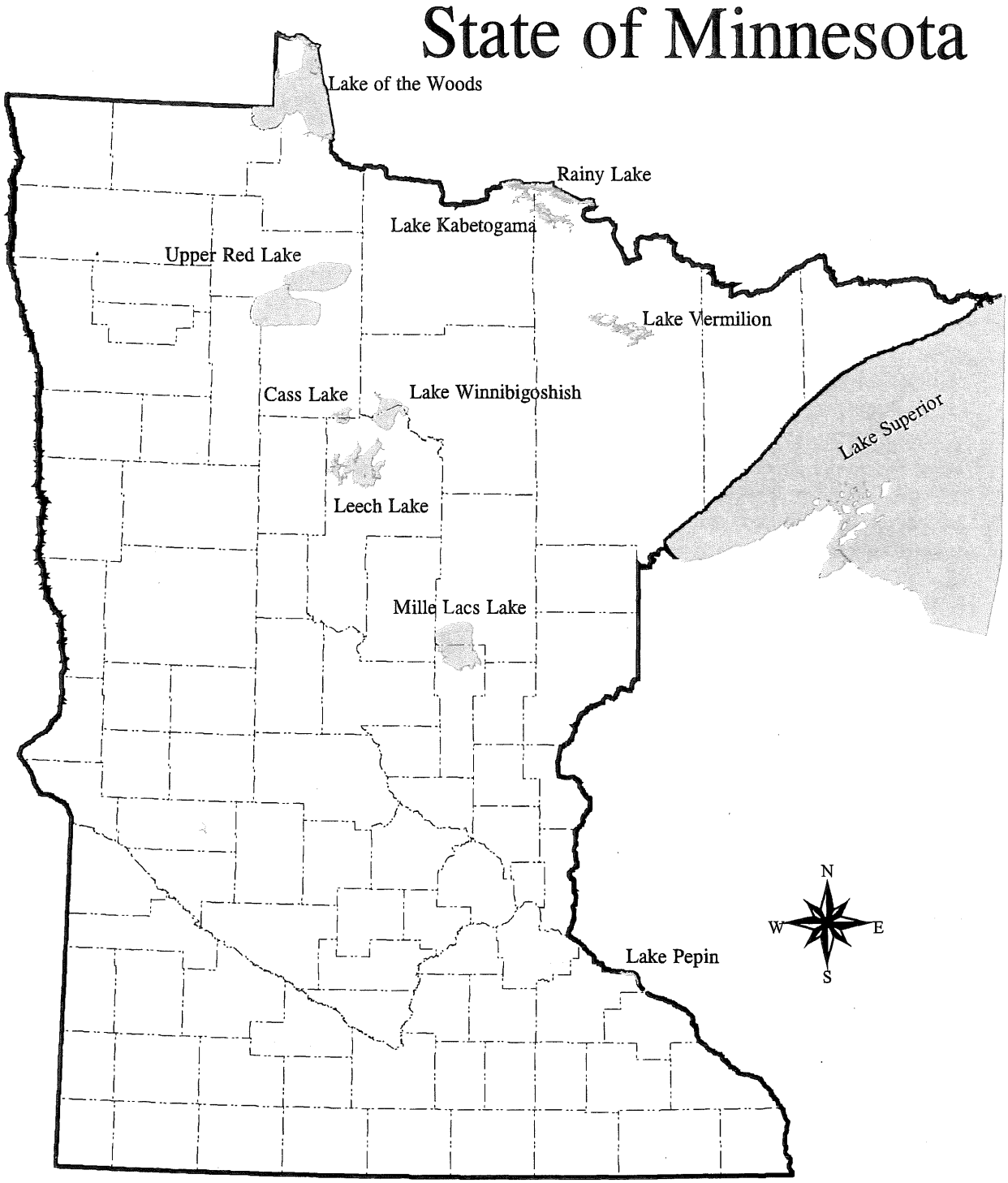

Figure 1. Location of lakes included in the Large Lake Monitoring Program

(ONMNR and MNDNR 1984). That document characterized the status of the stocks at the time, estimated potential safe yields, established management goals (e.g. target harvests), assembled economic data, and identified significant research needs. In essence, the Boundary Waters Atlas served as the management plan for Lake of the Woods and Rainy Lake. The "Atlas" model has proven a very effective tool for prioritizing management activities, setting harvest regulations, and communicating fisheries information to the general public. This publication is intended to synthesize similar information for the 10 large walleye lakes included in the LLP. Management goals for Lake Superior are contained in the Lake Superior Management Plan (Schreiner et al. 1995).

Sampling Protocol

Collection of systematic long-term data is the cornerstone of the LLP. A standardized sampling protocol for the large lakes is described in the *Large Lake Sampling Guide* (Wingate and Schupp 1984). Standard sampling includes annual gill netting, trawling, and seining. Mutifilament gill nets (250 foot experimental gang of five mesh sizes) are the primary gear for sampling adult walleye, sauger *Stizostedion canadense*, yellow perch *Perca flavescens*, and northern pike *Esox lucius*. Gill net data is used to monitor population abundance and size structure, determine age composition, and monitor growth rates. Seining is used to determine abundance and growth of young-of-the-year (YOY) walleye and key forage species. Trawling is used to determine abundance and growth of YOY and juvenile walleye, and abundance of key forage species.

In recent years electrofishing and trap netting have been added on many of the large lakes to supplement standard sampling. Trap netting at ice-out has proven an effective way to collect population data for adult muskellunge *Esox masquinongy* and northern pike. Fall electrofishing is becoming the method of choice on some of the large lakes for assessing YOY walleye growth and abundance. Electrofishing and trap netting are also being used on some lakes to collect data on bass and panfish populations which are not sampled effectively with standard large lake sampling gear.

Water chemistry sampling is also part of the standard sampling protocol for the large lakes. Standard chemical parameters (e.g. alkalinity, chlorophyll-a, total dissolved solids, secchi transparency) and dissolved oxygen-temperature profiles are collected in midsummer. Chlorophyll-a, as a measure of lake productivity, has been used in some of the yield modeling work that contributed to the development of this report. There is interest in expanding the breadth of the chlorophyll-a sampling on the large lakes to refine the chlorophyll-a yield model.

Angler use and harvest (creel survey) data are an extremely important component of the LLP. The *Large Lake Sampling Guide* recommends creel surveys be conducted two consecutive years out of six. At present, this rotation is employed on all of the large lakes except Lake of the Woods, Mille Lacs, Superior, and Rainy which are surveyed annually.

Potential and Target Yields

Methods for Estimating Potential Production

Thirteen empirical equations were evaluated for estimating potential production for all fish species and for walleye in the large lakes (Table 2). Walleye production was estimated at 32% and 45% of total fish production, following Ontario Ministry of Natural Resources (1982; SPOF 12) and Oglesby et al. (1987), respectively. These methods are designed for use when detailed fishery information is not available (Ryder 1965). While the LLP provides considerable population data, the program (with the exception of Mille Lacs) has not matured to the point where we can apply detailed stock assessment techniques. We therefore applied these predictive equations to provide a starting point for determining potential yields. The

Table 2. Empirical predictors of fish yield with references for estimating yearly total and walleye harvestable production.

Variables Used	Reference
MEI (Total dissolved solids & mean depth)	Ryder 1965
Total dissolved solids & mean depth	Matuszek 1978
MEI, mean annual air temperature	Schlesinger and Regier 1982
Mean annual air temperature, MEI	Schlesinger and Regier 1983
Area, Total dissolved solids	Youngs and Heimbuch 1982
Area, Volume, Total dissolved solids	Rempel and Colby 1991
Mean summer Chlorophyll-a	Oglesby et al. 1987
TDS, Walleye Thermal Habitat Area	Christie and Regier 1988
Total Phosphorus, Total dissolved solids, and mean depth	Hanson and Leggett 1982

primary assumption with these predictive equations is that lakes are similar and therefore conform biologically to the equation. This is an approximation, thus these first order predictors are simply a starting point.

A major difference between the large lakes is in composition of the fish assemblages. While walleye is the primary predator in these lakes, it is more dominant in some lakes such as Mille Lacs than in others such as Leech Lake, where northern pike are nearly as ecologically important. Therefore, the second step in deriving potential yield estimates for each lake involved incorporating lake-specific population data, historical harvest data, and local knowledge about a given lake. The incorporation process is subjective, and thus prone to bias. Potential yield estimates presented here should be viewed as preliminary and subject to review over the next five years. As the LLP matures, we hope to incorporate more objective tools for predicting fishery yields.

Several of the empirical equations that were reviewed show some promise for enhancing our ability to estimate potential yields. The Thermal Habitat Area (THA) and chlorophyll-a equations worked well for some lakes but not for others. The lack of reliable chlorophyll-a and temperature data limited a full assessment of these equations. To remedy this situation, seasonal values for chlorophyll-a will be measured on seven of the lakes. We are also working with Dr. Stefan at the University of Minnesota to obtain better water temperature data. We will also be able to better assess the accuracy of our potential yields with additional creel data gathered over the next five years. Finally, more advanced tools that we hope to apply in the near future include a method to estimate walleye population abundance from gill net assessment data. This tool may provide us with the ability to forecast walleye yields one year in advance, and better estimate sustainable yields.

Summary of Potential, Target, and Current Yields

After potential yields were derived for each lake, the next step was to establish target harvest levels for key sport fish species and characterize the current harvest. Current harvest was often described as the mean or median of several recent creel surveys. This approach reduces the effect of particularly good or poor angling seasons in describing current harvest. In some instances (e.g. Leech

Table 3. Current, potential, and target yields (pounds) for Minnesota's 10 large walleye lakes.

Lake Name	SPECIES									
	Walleye	Sauger	Yellow Perch	Northern pike	Black Crappie	Smallmouth bass	Cisco	White bass	Bluegill	Other
Cass										
Potential Yield	31,000		37,000	14,000			1,000			5,000
Target Harvest	31,000		37,000	14,000			1,000			5,000
Current Harvest	25,700		29,900	6,900			tr.			5,600
Kabetogama										
Potential Yield	91,700	11,200	4,300	33,000	1,900	6,000				
Target Harvest	91,700	11,200	4,300	33,000	1,900	6,000				
Current Harvest	66,800	3,400	800	16,700	1,600	3,400	tr.			
Lake of the Woods										
Potential Yield	430,100	134,400	67,200	268,800		67,200				
Target Harvest	430,100	107,500	67,200	100,000		67,200				
Current Harvest	434,000	141,000	28,000	70,000		tr.				
Leech										
Potential Yield	209,000		98,000	163,000			130,000			52,000
Target Harvest	209,000		98,000	163,000			130,000			52,000
Current Harvest	182,500		83,100	143,200			78,000			36,700
Mille Lacs										
Potential Yield	430,000		174,000	29,000			29,000			
Target Harvest	320,000*		174,000	23,000			29,000			
Current Harvest	430,000		174,000	29,000			29,000			
Pepin										
Potential Yield	29,000	53,000		13,000				50,000		35,000
Target Harvest	29,000	53,000		13,000				50,000		35,000
Current Harvest	29,000	53,000		13,000				50,000		35,000
Rainy										
Potential Yield	32,900	2,000	1,000	22,000	10,900	7,800	26,400			1,900
Target Harvest	20,000	2,000	1,000	22,000	10,900	7,800	26,400			0
Current Harvest	28,100	1,600	300	15,700	3,800	1,700	22,500			tr.
Upper Red										
Potential Yield	151,000		64,000	32,000			32,000			48,000
Target Harvest										
Current Harvest	18,300		200	1,900						1,800

Table 3 Continued.

Lake Name	SPECIES									
	Walleye	Sauger	Yellow Perch	Northern pike	Black Crappie	Smallmouth bass	Tullibee	White bass	Bluegill	Other
Vermillion										
Potential Yield	76,000		10,000	34,000	11,000	12,000	15,000		15,000	3,000
Target Harvest	76,000		10,000	29,000	11,000	12,000	15,000		15,000	3,000
Current Harvest	69,000		2,000	26,000	5,000	10,000	20,000		12,000	2,000
Winnibigoshish										
Potential Yield	180,000		400,000	140,000			164,000			8,000
Target Harvest	168,000		400,000	140,000			164,000			8,000
Current Harvest	165,000		383,000	114,000			tr.			tr.

*Target harvest for Lake Mille Lacs will vary annually depending on abundance, it will approximate 24 percent of the catchable population.

Table 4. Current (1996) and historical (1983-1996 mean) catch statistics for experimental gill net sampling on Minnesota's 10 large walleye lakes.

Lake	Species				
	Walleye	Sauger	Yellow Perch	Northern Pike	Cisco
Cass					
1996 No./lift	15.30		38.80	2.80	14.50
1996 $\bar{x}$ weight	1.18		0.18	3.46	0.60
1983-96 $\bar{x}$ No./lift	11.00		56.73	2.56	11.99
Kabetogama					
1996 No./lift	7.40	4.10	4.70	2.85	0.90
1996 $\bar{x}$ weight	1.25	0.61	0.19	2.94	0.86
1983-96 $\bar{x}$ No./lift	10.16	3.97	4.94	2.09	3.56
Lake of the Woods					
1996 No./lift	8.90	6.13	26.48	2.21	19.48
1996 $\bar{x}$ weight	1.60	0.95	0.13	3.74	0.39
1983-96 $\bar{x}$ No./lift	13.90	11.42	16.26	1.65	13.56
Leech					
1996 No./lift	9.50		25.60	4.80	4.70
1996 $\bar{x}$ weight	0.88		0.24	2.35	0.64
1983-96 $\bar{x}$ No./lift	7.64		21.47	4.66	7.96
Mille Lacs					
1996 No./lift	13.13		78.06	1.13	15.28
1996 $\bar{x}$ weight	1.77		0.24	5.84	0.46
1983-96 $\bar{x}$ No./lift	16.52		34.96	1.21	16.37
Pepin					
1996 No./lift	4.60	21.10	3.00	0.40	
1996 $\bar{x}$ weight	1.43	1.19	0.23	4.50	
1983-96 $\bar{x}$ No./lift	2.80	21.30	4.40	0.40	
Rainy					
1996 No./lift	7.25	4.30	1.05	2.30	0.10
1996 $\bar{x}$ weight	0.93	0.37	0.16	1.37	0.40
1983-96 $\bar{x}$ No./lift	4.56	3.24	5.40	2.25	0.89
Upper Red					
1996 No./lift	3.40		6.30	2.90	
1996 $\bar{x}$ weight	1.50		0.27	2.55	
1983-96 $\bar{x}$ No./lift	13.02		12.88	1.83	
Vermilion					
1996 No./lift	13.20		29.60	1.40	9.70
1996 $\bar{x}$ weight	0.80		0.21	2.64	0.61
1983-96 $\bar{x}$ No./lift	12.13		27.67	1.03	10.89
Winnibigoshish					
1996 No./lift	3.20		92.00	7.30	28.00
1996 $\bar{x}$ weight	1.19		0.20	3.33	0.33
1983-96 $\bar{x}$ No./lift	4.41		97.85	7.93	30.95

Lake), angling pressure and harvest have not changed appreciably through time, hence, all available creel survey data set was used to characterize current harvest levels.

Target harvest levels were most often set at the potential yield unless population metrics (e.g. abundance, growth, age at maturity) or creel data suggest the stock is being harvested at a level that cannot be sustained. Target harvest levels were generally set below the potential yield if the population was showing signs of stress. Annual harvests that routinely exceed established targets would suggest the need for intensive management using regulations designed to reduce harvest. Annual harvests that exceed target or potential levels on an infrequent basis would generally not be cause for concern. Annual harvests that routinely exceed the potential yield without indication of population stress, would suggest the potential and target yields should be reevaluated.

A summary of the current, potential, and target yields for Minnesota's 10 large walleye lakes is presented in Table 3. For those lakes where Minnesota shares jurisdiction (Lake of the Woods, Rainy, and Upper Red Lakes) yields are estimated only for the area managed by the State of Minnesota. Gill net catch indices from 1996 and historical averages (1983 - 1996) are summarized in Table 4. More detailed information for each lake is presented in the following chapters.

Cass Lake

Description of the Fishery

Cass Lake is a 15,600 acre lake located on the headwaters of the Mississippi River. The lake has an irregular shoreline with substrates consisting of sand, gravel or larger rock. Most marshy areas are found in Allen's Bay near the inlet of the Mississippi River. Numerous shallow bars with steep drop-offs are found throughout the lake. Shorelines are generally gentle to moderately sloped with the sharpest drop-off on the east side of Cedar Island. Several sub-basins within Cass Lake experience thermal stratification at different periods during the summer and at different depths. Water levels are affected by the operation of two dams, one on the outlet of the Mississippi River (Knutson Dam), and another upstream about 6 miles on the Mississippi River above Big Wolf Lake (Otter Tail Power Company). Cass Lake lies entirely within the Leech Lake Indian Reservation and largely within the Chippewa National Forest.

Cass Lake sustains a fish community typical of mesotrophic, temperate lakes in North America dominated by percids (walleye, yellow perch), esocids (northern pike, muskellunge), and coregonids (cisco *Coregonus artedii*, lake whitefish *Coregonus clupeaformis*). Other species present include rock bass *Ambloplites rupestris*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, bluegill *Lepomis machrochirus*, pumpkinseed *Lepomis gibbosus*, white sucker *Catostomus commersoni*, burbot *Lota lota*, bowfin *Amia calva*, yellow bullhead *Ameiurus natalis*, brown bullhead *Ameiurus nebulosus*, and black bullhead *Ameiurus melas*. Smaller nongame species present include various minnows, troutperch *Percopsis omiscomaycus*, logperch *Percina caprodes*, and tadpole madtom *Noturus gyrinus*. Summer sport angling pressure on Cass Lake has generally fluctuated from 10-20 angler hours/acre and has shown a long-term increasing trend similar to many other lakes. The winter sport fishery is relatively insignificant, and prior to January 1988 consisted primarily of spearing northern pike and lake whitefish.

Walleye comprise a substantial portion of the sport fishing yield (lbs/acre) averaging about 34% of the total yield over 10 years of creel surveys (Table 5). The median experimental gill net catch of walleye was 12.0 fish/net from 1983-1996 (Figure 2). The walleye population has shown consistently good recruitment for the last 10 years (Figure 3) and appears to be more abundant than during the 1970s and early 1980s.

Yellow perch are the dominant species in the sport fish harvest averaging about 48% of the total yield (lbs/acre) and 71% of the total fish harvested over the 10 years of creel

Table 5. Historical creel survey estimates by species for Cass Lake

Winter - Summer	- 1996	- 1994	- 1993	- 1987	- 1986	- 1975	- 1974	- 1973	- 1972	- 1971
Total angler-hours	315,645	213,049	236,883	174,022	146,874	176,285	163,105	204,919	192,974	157,009
Walleye										
Total number harvested	19,986	22,856	21,457	28,504	23,228	36,568	27,712	36,725	33,916	23,387
Total pounds harvested	24,682	26,300	22,438	33,543	25,090	29,252	22,585	33,785	31,943	25,449
Mean weight (pounds)	1.23	1.15	1.05	1.18	1.08	0.80	0.81	0.92	0.94	1.09
Harvest rate (fish/angler hour)	0.06	0.11	0.09	0.16	0.16	0.21	0.17	0.18	0.18	0.15
Yellow Perch										
Total number harvested	162,102	140,291	91,590	84,336	84,907	105,910	69,933	112,722	111,019	73,428
Total pounds harvested	58,296	46,259	28,349	30,669	29,192	43,422	28,672	46,216	45,518	32,301
Mean weight (pounds)	0.36	0.33	0.31	0.36	0.34	0.41	0.41	0.41	0.41	0.44
Harvest rate (fish/angler hour)	0.51	0.66	0.39	0.48	0.58	0.60	0.43	0.55	0.57	0.47
Northern Pike										
Total number harvested	3,330	1,080	1,377	3,997	2,915	4,750	4,727	6,976	6,517	5,749
Total pounds harvested	9,202	3,035	3,329	11,517	8,745	12,861	13,897	18,136	13,517	14,025
Mean weight (pounds)	2.76	2.81	2.42	2.88	3.00	2.71	2.94	2.60	2.07	2.44
Harvest rate (fish/angler hour)	0.011	0.005	0.006	0.023	0.020	0.027	0.029	0.034	0.034	0.037

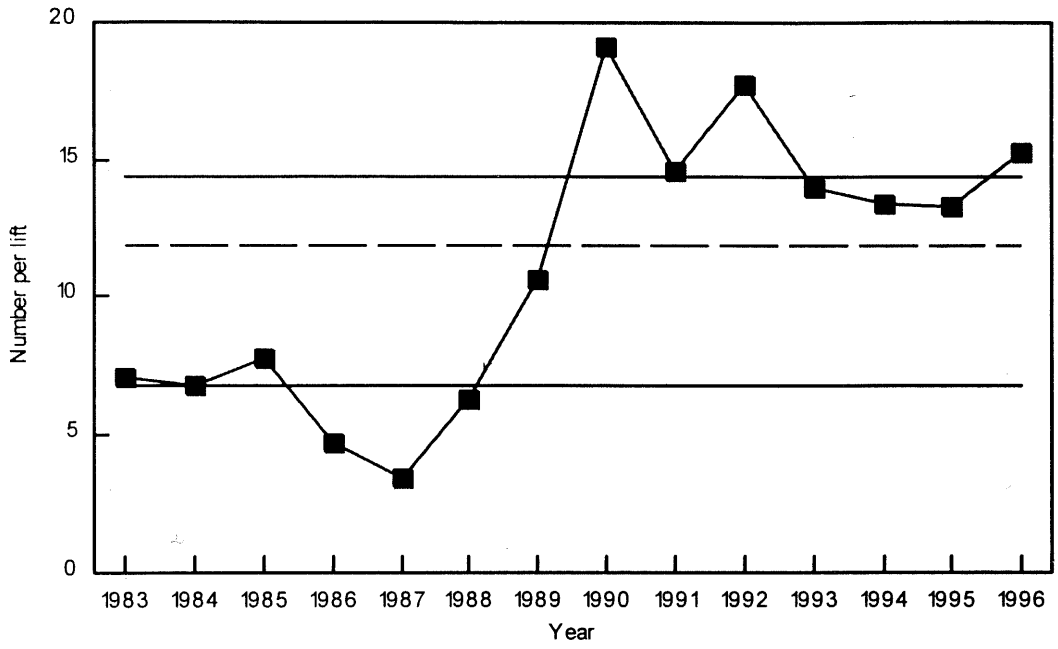

Figure 2. Walleye gill net abundance (1983-1996) for Cass Lake. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

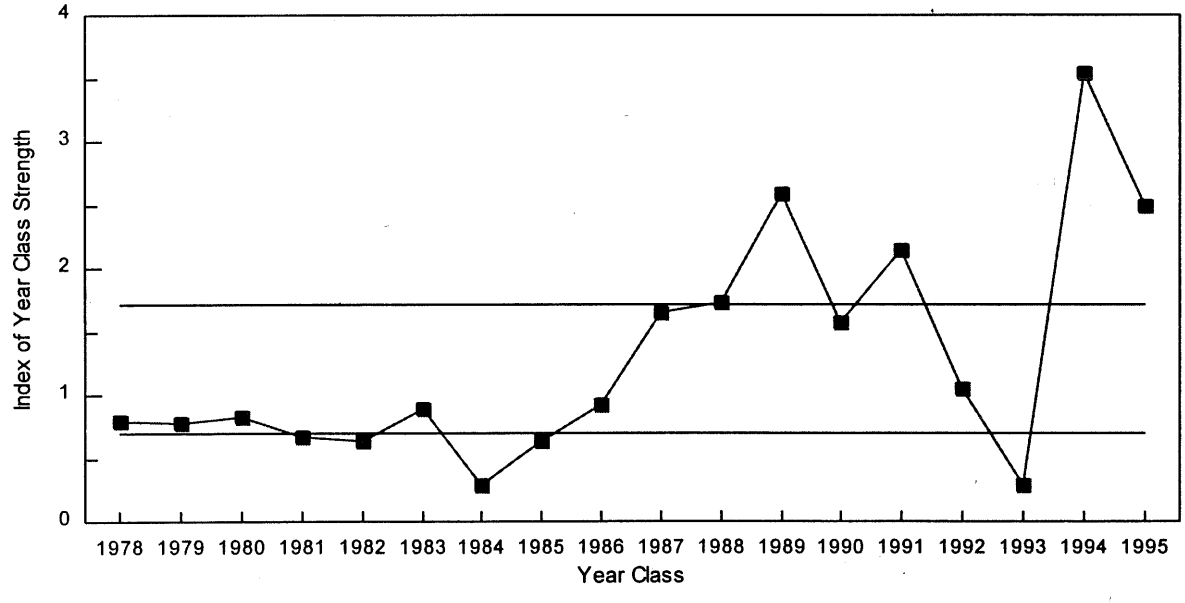

Figure 3. Index of year class strength for walleye from Cass Lake for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

surveys. Yellow perch are the most abundant sport fish in the lake with a median gill net catch of 41 fish/net during 1983-1996. Yellow perch catch rates in the gill nets can vary considerably from year to year reflecting both sampling and recruitment variability. Approximately 20% of summer angling parties are seeking yellow perch as the primary species.

Northern pike comprised a major portion of the angling yield prior to 1993-1994. Since that time most pike caught have been released. The mean catch of pike in experimental gill nets has been stable since 1971 fluctuating between 1.8-3.9 fish/net. A relatively small percentage of angling parties indicate they are seeking northern pike (<5%).

Muskellunge, although low in abundance compared to other species in Cass Lake, are sought by increasing numbers of anglers. In 1986-1987, anglers seeking muskie comprised about 3% and by 1993-1994 averaged 10-12% of the total angling effort. Cass Lake supports one of Minnesota's premier fisheries for this trophy species, and several fish over 50 inches are reported annually. Few muskellunge are harvested.

Rock bass are often caught by anglers but are usually incidental, and most are released although harvest has increased the last several years. Other centrarchids are caught and harvested in relatively low numbers in Cass Lake and have localized populations in areas of dense vegetation (primarily Allen's Bay). Anglers often seek centrarchids in connected lakes such as Buck, Windigo, and Kitchi.

Management History

A variety of sampling methods and programs have been used to evaluate fish populations of Cass Lake. An initial survey was conducted in 1936 followed by others in 1943 and 1948 using gill nets, seines, and hoop nets. The 1943 and 1948 surveys included evaluations of fish habitat. Natural reproduction of walleye was assessed using beach seines on an irregular basis from 1965-1979. A research study involving tagging, netting (trawl, seine, gill net), and creel surveys was carried out from 1971-1975. The large lake sampling protocol was initiated on Cass Lake in 1983. Sampling consists of gill netting (20 sets at five stations), seining (27 hauls at nine locations), trawling (20 hauls at 10 stations), and creel surveys (two out of six years). In 1988, an experimental regulation prohibiting spearing of northern pike was put in to place for a 10 year period. Data from standard and specialized sampling will be used to evaluate the effects of this regulation on the fish community with emphasis on northern pike and muskellunge. Sampling methods directed at esocids for this evaluation have included spring trap netting and fall electrofishing. Assessments of muskellunge natural reproduction and nursery areas were attempted by dip netting and seining from 1988-92. Comprehensive shoreline habitat sampling was completed during 1994.

Cass Lake is entirely within the Leech Lake Indian Reservation (LLIR). The Leech Lake Band allows subsistence netting for band members and also operates a commercial fishery for bullhead, cisco, white sucker, and lake whitefish. The Leech Lake Band of Chippewa stock fingerling lake whitefish into Cass Lake on an annual basis. Several fish species of varying sizes were stocked into Cass Lake prior to 1985 by the MNDNR. However, all species present are self-sustaining, and it is doubtful that stocking has contributed much to the populations.

Potential and Target Harvest

Potential yields were estimated by using the median of the 13 predicative models. Potential yields were partitioned between species as described in SPOF 12 (Ontario Ministry of Natural Resources 1982). Estimates for cisco, lake whitefish, and "others" were made using available population and harvest data. Target yields were estimated using the potential yield as a starting point with modification based on particular characteristics of the lake. Current harvest levels for walleye, yellow perch, northern pike, cisco, lake whitefish, and "other" species were based on the

median of four creel surveys conducted during 1986-1987 and 1993-1994.

Walleye. Potential and target yields for walleye were set at 31,000 pounds. The current harvest of walleye is 25,700 pounds. Summer night and private cabin angling, and trips completed on lakes other than Cass Lake have not been quantified, nor has subsistence netting by Leech Lake Band members. These additional harvests might push the current harvests for walleye and other species nearer the targets. Cass Lake is an impoundment, part of a chain of lakes in a river system, and may be more productive than the predictive models suggest. There are no indications the walleye population is under any significant stress.

Yellow perch. Potential and target yields for yellow perch were set at 37,000 pounds. The current harvest of yellow perch is 29,900 pounds. Yellow perch are the major component of the sport fishery, but there are no indicators that the population is suffering significantly from excessive harvest. Average size declined from 0.41-0.44 pounds during the 1970s to 0.31-0.36 pounds during the 1980s and 1990s, but has remained stable during the latter period.

Northern pike. Potential and target yields for northern pike were set at 14,000 pounds. The current harvest of northern pike is 6,900 pounds. Northern pike abundance, size structure, maturity, and growth have not changed noticeably over 20 years of experimental gill netting. Few anglers fish for northern pike, and most are released.

Cisco and Lake whitefish. Potential and target yields for cisco and lake whitefish combined, were set at 1,000 pounds. Winter angling is negligible for these species and spearing is currently prohibited for non-Band members. Data collected prior to 1988 indicated some coregonid harvest but probably much less than the target level.

Other species. Potential and target yields were set at 5,000 pounds. Small numbers of anglers fish for centrarchids in Cass Lake and most fish are released. As pressure on other species increases and harvest rates decrease, centrarchids may receive more directed effort.

Future Management

Stock Assessment. Standard sampling according to the *Large Lake Sampling Guide* should be continued. Evaluation of some methods (seining, trawling) may result in modifications to provide better information or improve efficiency. Fall electrofishing should be considered as a method to sample young-of-the-year walleye. The significance of the muskellunge fishery may require sampling on a periodic basis using voluntary diaries, specialized field sampling or perhaps a combination of methods to monitor this population.

Experimental Regulations. The only special regulation in effect for Cass Lake is the ban on winter spearing. This regulation is due to be reevaluated in January 1998. If summer angling pressure and harvest continue to increase and any species begins to show signs of stress, additional harvest restrictions (voluntary or involuntary) may need to be considered.

Stocking. No stocking (aside from lake whitefish fingerlings) occurs in Cass Lake, and none appears needed. Some fish are stocked into connected waters where some unknown fraction may move into Cass Lake to be caught by anglers. There are no plans to reopen the northern pike spawning area previously operated on the north shore of Allen's Bay.

Habitat Management. Most development of the Cass Lake shoreline occurs on the western half of the lake. The area from Norway Beach to the Turtle River inlet has little development aside from the area near Chippewa Paws Resort and leased cabins south of Knutson Dam. The U. S. Forest Service leases cabin lots on Star Island near Stony Point, Norway Beach, and Knutson Dam. Much of the shoreline is under public ownership. Public ownership of shoreline, particularly areas important for spawning and nursery areas, should be maintained. Dam operation should be continued on its present schedule allowing for a rising water level in the spring, general stability during June and July, followed by a slow drawdown into the fall.

The shoreline information collected in 1994 and historical water chemistry data should be summarized in a written report. Cass Lake depth contours are scheduled to be mapped in 1997. This will be beneficial to anglers, MNDNR staff, and others interested in the lake.

Kabetogama

Description of the Fishery

Lake Kabetogama is a natural reservoir in a drainage system that begins in northeastern Minnesota and ends in Hudson Bay. The surface area is 25,760 acres with a shoreline length of approximately 382 miles. Maximum depth is 80 feet and the average depth is 30 feet. About 30% of the lake is less than 15 feet deep. The morphology of most of Lake Kabetogama is typical of the Canadian Shield. The lake basin is composed of bedrock and much of the shoreline is rocky and irregular. Low bog areas, remnants of glacial Lake Agassiz, form the extreme western shore. The shoreline is heavily forested.

Lake Kabetogama, along with four other lakes, make up the Namakan Reservoir. Water levels on the Namakan Reservoir were originally controlled by rock sills at the outlet of Namakan Lake. The water level is currently controlled by dams constructed at Kettle Falls and Squirrel Falls in 1913. Water levels fluctuate an average of nine feet per year. The lake lies entirely within the boundaries of Voyageurs National Park (VNP).

From 1984 to 1994, anglers spent an average of 424,000 hours fishing Lake Kabetogama during the summer. Since 1993, however, effort has declined dramatically, and in 1994 reached an all-time low of 258,000 hours. No estimates for 1995 or 1996 are available, however, it is believed that effort remained low. Typically, about 10% of the anglers fishing Lake Kabetogama live within 30 miles of the lake, 50% live further from the lake within Minnesota, and 40% are nonresidents. Walleye dominate the fishery composing 65% of the harvest by number and weight. Other species caught by anglers include northern pike, sauger, smallmouth bass *Micropterus dolomieu*, yellow perch, black crappie and to a lesser extent rock bass, white sucker, burbot and cisco.

Historically, Lake Kabetogama has exhibited high walleye abundance. During the 1970s and 1980s, assessment gill net catches averaged 12.1 walleye per net (Figure 4). Angler harvests have reflected this high abundance (Table 6). Walleye yields averaged nearly 4.0 pounds per acre from 1984-90 reaching an all-time high of 6.7 pounds per acre in 1989. During 1989, the catch rate of anglers targeting walleye was 0.52 fish per hour. During the 1990s, however, abundance has declined. The mean gill net CPUE from 1990-96 was 9.4. Assessment netting reached a low of 7.4 walleye per net in 1996. No strong year-classes are present in the fishery (Figure 5). Complaints of poor fishing have increased. Other indicators of a stressed population have not been demonstrated.

Northern pike are an important component of the Lake Kabetogama fishery comprising 19% of the total yield. The estimated annual harvest of northern pike from 1984-94 was 26,200 pounds. Northern pike recruitment appears to be strongly influenced by spring water levels. Springs with high water produce stronger year-classes. Several strong year-classes are currently present in the fishery and abundance has increased since 1987.

Sauger are also an important component of the fishery. From 1984-94, anglers harvested approximately 9,700 pounds per year. The mean gill net catch from 1983-96 was 4.0 fish per net and the population is stable.

Smallmouth bass and black crappie are minor components of the Lake Kabetogama fishery. The estimated annual harvest of these species from 1984-94 was 7,000 and 2,300 pounds, respectively. If the unusually high harvest of 28,900 pounds recorded in 1990 was excluded, the average harvest of bass would have been 4,300 pounds. It is doubtful that either species is native to Lake Kabetogama. The presence of smallmouth bass cannot be substantiated until 1973. Black crappie were stocked in 1920. Little is known about the

Table 6. Historical creel survey estimates by species for Lake Kabetogama.

Winter / Summer	1994	1993	1992	1990	1989	1988	1987	1986	1985	1984	1983	1981	1978
Total angler-hours	258,008	332,922	422,671	491,695	469,729	420,130	492,236	459,540	425,193	469,032	386,644	410,072	602,784
Walleye													
Total number harvested	32,999	41,044	71,645	91,244	142,898	56,510	71,941	94,579	43,746	63,671	47,112	47,979	138,306
Total pounds harvested	42,954	56,568	100,877	118,671	172,392	70,892	92,006	115,992	61,812	80,989	58,325	54,312	172,109
Mean weight (pounds)	1.30	1.38	1.41	1.30	1.21	1.25	1.28	1.23	1.41	1.27	1.24	1.13	1.24
Harvest rate (fish/angler hour)	0.128	0.123	0.170	0.186	0.304	0.135	0.146	0.206	0.103	0.136	0.122	0.117	0.229
Sauger													
Total number harvested	3,399	4,095	4,888	27,085	10,653	12,423	15,681	15,465	18,504	13,102	10,689	24,604	17,764
Total pounds harvested	3,227	3,447	3,649	17,889	10,284	12,682	13,872	12,749		9,708	8,680	21,209	16,863
Mean weight (pounds)	0.95	0.84	0.75	0.66	0.97	1.02	0.88	0.82		0.74	0.81	0.86	0.95
Harvest rate (fish/angler hour)	0.013	0.012	0.012	0.055	0.023	0.030	0.032	0.034	0.044	0.028	0.028	0.060	0.029
Yellow Perch													
Total number harvested	1,349	1,003	2,764	14,074	6,818	17,165	6,794	4,870	8,729	5,744	9,048	15,583	10,558
Total pounds harvested	782	525	1,195	6,720	3,255	9,223	3,567	2,491		2,729	4,289	7,542	6,085
Mean weight (pounds)	0.58	0.52	0.43	0.48	0.48	0.54	0.53	0.51		0.48	0.47	0.48	0.58
Harvest rate (fish/angler hour)	0.005	0.003	0.007	0.029	0.015	0.041	0.014	0.011	0.021	0.012	0.023	0.038	0.018
Northern Pike													
Total number harvested	5,350	5,287	5,862	14,940	9,125	12,038	10,131	7,441	9,090	12,740	13,838	15,583	31,276
Total pounds harvested	18,545	13,813	17,688	48,620	26,831	35,006	25,883	25,148	22,786	27,888	29,835	29,997	71,533
Mean weight (pounds)	3.47	2.61	3.02	3.25	2.94	2.91	2.55	3.38	2.51	2.19	2.16	1.92	2.29
Harvest rate (fish/angler hour)	0.21	0.016	0.014	0.030	0.019	0.029	0.021	0.016	0.021	0.027	0.036	0.038	0.052
Black Crappie													
Total number harvested	2,296	568	1,807	16,716	1,345	4,059	3,904	1,143	2,072	4,265	1,092	102	1,633
Total pounds harvested	2,707	476	1,513	4,048	1,656	3,711	2,837	915		2,546	830	78	1,633
Mean weight (pounds)	1.18	0.84	0.84	0.24	1.23	0.91	0.73	0.80		0.60	0.76	0.76	1.00
Harvest rate (fish/angler hour)	0.009	0.002	0.004	0.034	0.003	0.010	0.008	0.002	0.005	0.009	0.003	0.000	0.003
Smallmouth Bass													
Total number harvested	1,514	1,365	5,838	18,935	2,704	5,737	3,328	2,916	4,361	5,720	3,317	2,050	3,679
Total pounds harvested	2,584	1,826	5,854	28,855	3,870	9,781	3,841	2,187		4,519	2,471	2,170	4,471
Mean weight (pounds)	1.71	1.34	1.00	1.52	1.43	1.70	1.15	0.75		0.79	0.74	1.06	1.22
Harvest rate (fish/angler hour)	0.006	0.004	0.014	0.039	0.006	0.014	0.007	0.006	0.010	0.012	0.009	0.005	0.006

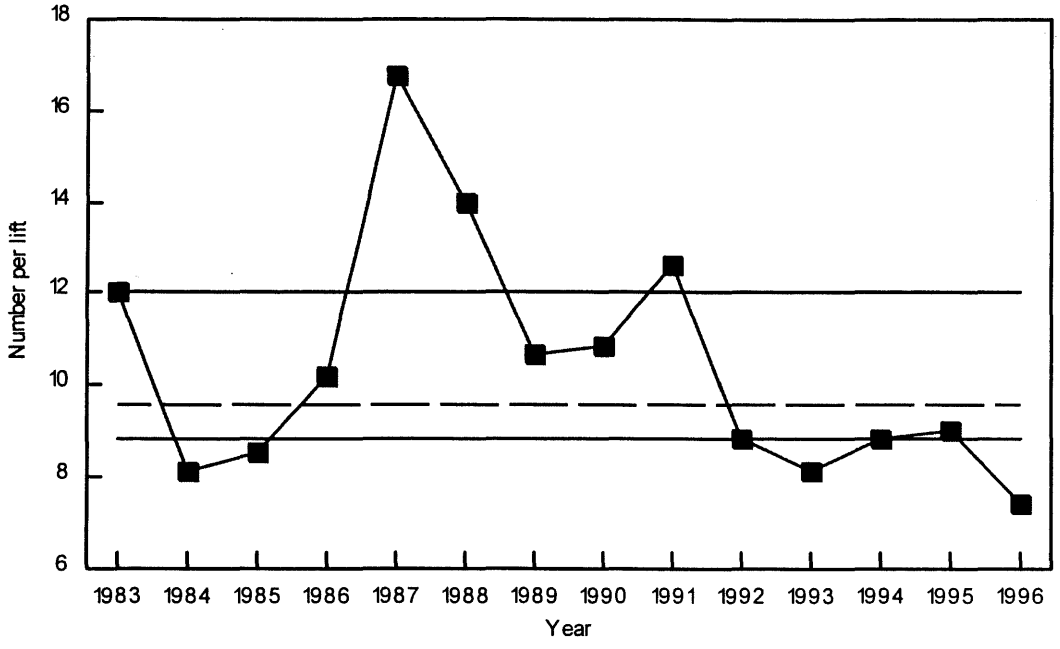

Figure 4. Walleye gill net abundance (1983-1996) for Kabetogama Lake. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

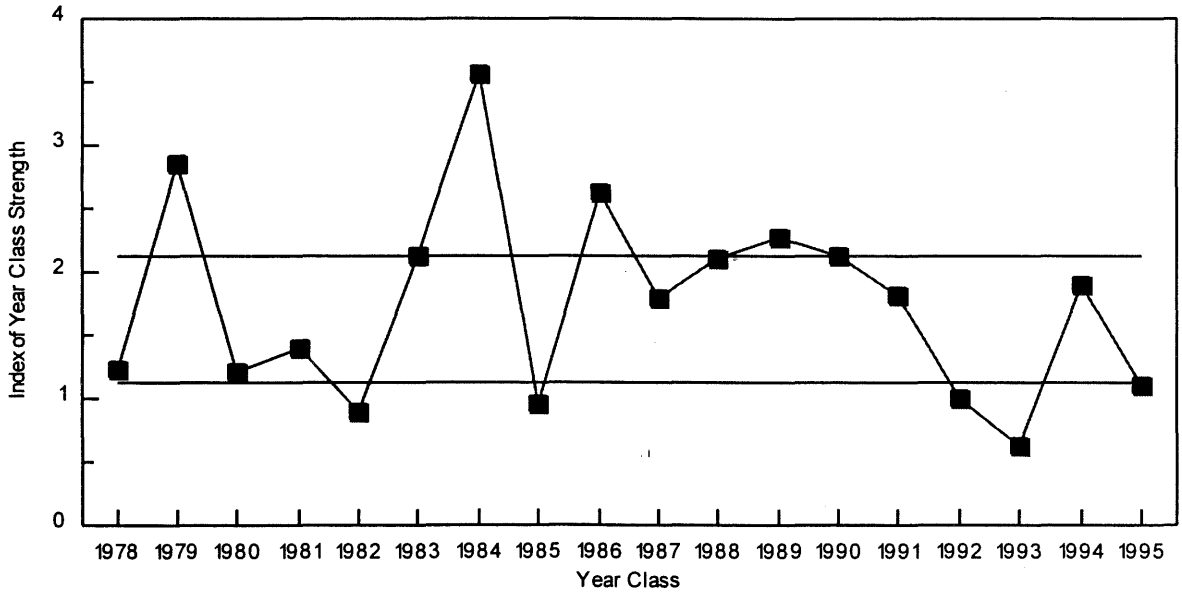

Figure 5. Index of year class strength for walleye from Kabetogama Lake for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

current status of either of these species as assessment work has been lacking.

Yellow perch appear to be more important to the fishery as forage than a species sought by anglers. On average, yellow perch contribute 2% to the total angler yield. Yellow perch harvested by anglers have a large average size (> 10 inches). The mean gill net catch rate since 1983 is 4.9 fish per net and the population appears stable.

Management History

Numerous fishery surveys and other investigations have been completed on Lake Kabetogama. Fish populations were first assessed in 1936 and 1937 (Sharp 1941). The effects of water level fluctuations were first investigated in 1940 (Sharp 1941). Fish stocks, as well as physical and chemical characteristics of the lake, were surveyed in 1946. The removal of an area of bog in Gold Portage was investigated in 1950 (Appleget 1950). As part of an investigation into the effects of commercial fishing on fish populations, the lake was trap netted in 1955 (Burrows 1955). Potential spawning habitat for smallmouth bass was assessed in 1960 (Scidmore 1960). Spawning areas and their use by walleye were evaluated in 1961 (Johnson 1961). Fish stocks were again assessed in 1966 due to complaints of poor fishing (Johnson 1966).

The International Falls Fisheries Office, established in 1969, conducted gill net assessments in 1970, 1973, 1977 and 1980. Annual monitoring began in 1983 following the methods described in the *Large Lake Sampling Guide*. The MNDNR has periodically conducted additional sampling including spring trap netting and electrofishing. The aquatic biological unit at VNP has assisted greatly with the assessment program. The biological unit also has conducted investigations of its own including spring trap netting for a walleye and northern pike population estimate (Kallemeyn 1986), age-0 walleye food habits (Levar 1986), trap netting to assess black crappie stocks and electrofishing and trap netting for age-0 northern pike (Kallemeyn 1987).

The first creel survey data for Lake Kabetogama was collected in December of 1940. Additional data was collected in July of 1941. The first complete summer creel survey occurred in 1946. The walleye "catch" rate (it is not clear if these were actually harvest rates) reported from the 1946 creel was 0.58 fish per hour. With the establishment of VNP in 1974, angling effort was expected to increase on the lakes within the park. As a result, creel surveys were conducted in 1977 and 1978 to document "baseline" conditions (Ernst and Osborn 1980). Since then, creel surveys were conducted in 1981 (Osborn 1981) and annually from 1983-90 and 1992-94 (Wingate 1987; Kingsley 1989; Eibler 1990, 1991, 1993, 1994 and 1995).

Several studies have concluded that water level fluctuations created by the operation of the dams at Kettle Falls and Squirrel Falls have had negative impacts on the Lake Kabetogama aquatic community (Sharp 1941; Chevalier 1977; Johnson 1967; Johnson, et al., 1966; Osborn, et al. 1978; Osborn, et al. 1981; Cohen et al.1991; Kallemeyn 1987; Kallemeyn and Cole 1990). As a result, a committee made up of private and public representatives was formed to investigate alternative water level management. The committee adopted a compromise rule curve after attempting to incorporate the interests of all user-groups. The International Joint Commission (IJC), the body that governs water levels on the Namakan Reservoir, is currently conducting its own review of the curve before considering implementation.

Commercial fishing took place on Lake Kabetogama in the early part of this century. However, due to the numerous resorts on the lake, based largely on the walleye sport fishery, commercial fishing for game fish ended in 1926. Commercial harvest of cisco, whitefish and burbot ended entirely in 1959 when the cisco and whitefish caught in Lake Kabetogama were deemed "unfit for human consumption due to infestations of parasites." Several permits have been issued for the removal of white suckers. From 1971 to 1979, about 24,400 pounds were removed.

Various species have been stocked in Lake Kabetogama since 1918. From 1918 to 1943 over 79,000,000 walleye fry were stocked. These fry were apparently hatched at Ranier. Beginning in 1982, House Pond, a cooperative rearing pond with the Kabetogama Lake Association, was used to raise fingerlings. From 1982 to 1991 approximately 38,800 walleye fingerlings were stocked in Lake Kabetogama. Most of these fingerlings were reared in House Pond, however, some were from the Little Falls area or Bartlett Lake near Northome. In 1969 and 1975, a total of 2,561 Shoepack strain muskellunge fingerlings were stocked. No records exist of muskellunge being caught by anglers or assessment gear. Other species stocked between 1920 and 1954 include largemouth bass, sunfish, crappie, yellow perch, and catfish.

Beginning in 1994, due to a growing concern over the sustainability of the Lake Kabetogama walleye fishery, length-based regulations were investigated. The purpose of this investigation was to determine what effect various regulation scenarios may have in reducing harvest while increasing catch rates, particularly on medium to large fish, and providing a more stable fishery. Based on simulations, a number of regulations were identified that should meet these goals. However, no proposal was pursued because fishery managers felt the walleye stock was not in immediate danger of collapse and there was a lack of support by the resort community. In 1996, with the continuing decline in walleye abundance, the resort community as well as other property owners again approached the MNDNR concerning a regulation change. An experimental regulation that would reduce the walleye harvest is currently being considered for implementation beginning in 1998.

Potential and Target Harvest

None of the 13 predictive models approximated the yield observed on Lake Kabetogama. Observed yields were consistently higher than estimates derived from the predictive equations. Potential and target yields, therefore, were based on the mean of the 14 harvest estimates from creel surveys conducted since 1977 (Table 3). Current harvest levels were described as the mean of the three most recent angler creel surveys (1992, 1993 and 1994).

Future Management

Stock assessment. Standard assessment netting based on the *Large Lake Sampling Guide* will be continued. Additional sampling should include assessments of black crappie and smallmouth bass stocks and methods to quantify age-0 walleye abundance and growth. Creel surveys should be conducted at least two out of every six years. The next creel survey is scheduled for the summer of 1998.

Experimental Regulations. No special regulations are currently in place on Lake Kabetogama. However, due to local public support and declining stock abundance, an experimental regulation designed to reduce the walleye harvest is being proposed for implementation in 1998. The goal of this regulation is to reduce harvest, increase population biomass, and improve catch rates, particularly of mid-sized to large fish.

Regulations designed to improve abundance or size structure of northern pike or smallmouth bass may be considered if support among user groups develops or if target yields are routinely exceeded.

Stocking. No stocking is currently planned for Lake Kabetogama. Stocking will only be considered as a viable management tool if spawning stock size declines to a point where recruitment is impaired.

Habitat Management. Support should continue for the process that began in the early 1990s to alter the present water level management regime to one that is more favorable for the production of aquatic organisms. As part of the IJC's review process, two independent fisheries scientists have each concluded separately that the steering committee's proposed rule curve would be beneficial to fisheries resources. Other aspects of the proposed curve are currently under review. This process should be supported and expedited wherever possible.

Most of the shoreline of Lake Kabetogama is located within the boundaries of VNP and therefore protected from development. Heavy development, however, does exist on the south shore. Permit applications for shoreline alterations should be closely scrutinized to preserve aquatic habitat wherever possible. Public education should be used to encourage ecologically sound shoreland management. In addition, present development should be inventoried to better monitor changes that might affect aquatic resources.

A lakewide aquatic vegetation survey should be conducted to inventory present conditions. Such a survey has never been conducted. This inventory would be valuable in locating important spawning habitat and document baseline conditions for future assessments.

Lake of the Woods

Description of the Fishery

Lake of the Woods lies within the Hudson Bay drainage at a latitude of 49° N, and is shared by Manitoba, Ontario, and the state of Minnesota. The total surface area is 951,337 acres of which 317,000 is managed by the State of Minnesota, including Muskeg, Big Traverse, and Little Traverse Bays. Big Traverse and Muskeg Bays are largely devoid of structure and islands. Little Traverse Bay is more characteristic of the Ontario waters of Lake of the Woods, with numerous islands and reefs. The surrounding drainage is characterized by glacial lake sediment and bog. Forestry and agriculture are the major land uses within the drainage basin of the Minnesota waters.

The Minnesota waters of Lake of the Woods do not stratify and have widespread, dense, blue-green algae (*Aphanizomenon* spp.) blooms, which are first evident in July and continue into September, in most years. Average depth of the Big Traverse is 24.3 feet with total dissolved solids (TDS) of 104 mg/l. Because of its location, Lake of the Woods is managed under Canada-Minnesota Border Waters regulations, rather than the general statewide regulations.

Though known primarily as a walleye lake, Lake of the Woods really has two distinct primary fisheries. The first is a summer fishery is dominated by anglers seeking walleye. The second is a winter fishery for sauger. Species of lesser importance are northern pike, yellow perch and smallmouth bass. Other important components of the Lake of the Woods fishery include the spring and fall walleye fishery on the Rainy River and the spring northern pike fishery on the south shore. Angling pressure from 1981-1995 has averaged 674,504 and 671,892 angler hours for the summer and winter sport fisheries, respectively.

Walleye is the primary species of interest to anglers fishing Lake of the Woods (Table 7). In the summer 1995 creel survey, 83% of interviewed anglers reported they were fishing exclusively for walleye while another 11% reported seeking walleye and sauger. During the winter of 1994-95, 23% of interviewees reported fishing exclusively for walleye, while another 44% fished for walleye and sauger.

The walleye population on the Minnesota portion of Lake of the Woods has been quite stable (Figure 6). Notable peaks in overall abundance are attributable to strong year classes produced in 1979 and 1991 (Figure 7). Low abundance was the result of weak year classes produced in 1984, 1985 and 1986. There is potential that the weak year classes produced in 1992 and 1993, combined with a projected weak 1996 year class, will again result in low walleye abundance in the late 1990s.

The winter fishery on Lake of the Woods was developed around an abundant sauger population. From 1981 through 1995, sauger harvest averaged 177,361 pounds. Eighty-one percent of this harvest took place in the winter fishery. The nature of the winter fishery has changed since the first winter creel survey was conducted during the winter of 1982-83. Winter fishing pressure increased steadily through the 1980s until peaking in the

Table 7. Historical creel survey estimates by species for Minnesota waters of Lake of the Woods.

Winter	-	1994-95	1993-94	1992-93	1991-92	1990-91	1989-90	-	1987-88	-	-	-
Summer	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985
Total angler-hours	657,534	1,165,646	1,401,422	1,530,321	1,407,499	1,829,763	1,750,132	628,231	1,214,015	721,944	796,705	846,989
Walleye												
Total number harvested	160,055	209,206	304,250	252,558	244,581	356,963	401,319	159,167	144,788	149,176	247,010	203,695
Total pounds harvested	270,905	288,977	316,623	275,497	324,739	460,677	645,728	239,357	221,063	201,769	283,760	257,415
Mean weight (pounds)	1.7	1.4	1.0	1.1	1.3	1.3	1.6	1.5	1.5	1.4	1.1	1.3
Harvest rate (fish/angler hour)	0.243	0.179	0.217	0.165	0.174	0.195	0.229	0.253	0.119	0.207	0.310	0.240
Sauger												
Total number harvested	22,163	131,191	236,823	334,265	204,169	370,264	440,312	61,387	373,122	66,911	50,908	23,062
Total pounds harvested	17,422	85,100	117,450	158,058	113,685	223,354	229,124	51,062	271,449	41,877	35,337	15,820
Mean weight (pounds)	0.79	0.65	0.5	0.47	0.56	0.6	0.68	0.83	0.73	0.63	069	0.69
Harvest rate (fish/angler hour)	0.034	0.113	0.169	0.218	0.145	0.202	0.252	0.098	0.307	0.093	0.064	0.38
Yellow Perch												
Total number harvested	3,125	45,251	30,354	56,493	91,113	122,590	96,522	6,288	148,778	4,777	2,624	400
Total pounds harvested	1,996	19,199	11,699	23,012	36,153	48,347	38,173	3,208	89,161	2,366	1,393	250
Mean weight (pounds)	0.64	0.42	0.39	0.41	0.4	0.39	0.4	0.51	0.6	0.5	0.53	0.63
Harvest rate (fish/angler hour)	0.005	0.039	0.022	0.037	0.065	0.026	0.055	0.010	0.123	0.007	0.002	0.001
Northern Pike												
Total number harvested	3,547	6,352	7,930	6,645	7,727	7,947	11,121	7,556	4,784	6,998	8,977	7,105
Total pounds harvested	11,909	32,079	26,376	31,943	42,948	46,253	44,581	31,850	17,030	17,762	26,717	17,825
Mean weight (pounds)	3.36	5.05	3.33	4.81	5.56	5.82	4.0	4.2	3.6	2.5	2.98	2.51
Harvest rate (fish/angler hour)	0.005	0.005	0.006	0.004	0.005	0.004	0.006	0.012	0.004	0.010	0.011	0.012
Cisco												
Total number harvested		4,886	2,149	12,783	2,303	4,397	8,641		20,942			
Total pounds harvested		5,130	2,149	12,783	2,303	4,397	6,481		15,078			
Mean weight (pounds)		1.05	1.00	1.00	1.00	1.00	0.75		0.72			
Harvest rate (fish/angler hour)		0.004	0.002	0.008	0.002	0.002	0.005		0.017			
Burbot												
Total number harvested		8,835	7,620	9,650	4,137	9,276	14,762		9,459			
Total pounds harvested		22,352	22,860	32,810	14,065	31,538	35,429		22,701			
Mean weight (pounds)		2.53	3.00	3.40	3.40	3.40	2.4		2.4			
Harvest rate (fish/angler hour)		0.008	0.005	0.006	0.003	0.005	0.008		0.008			

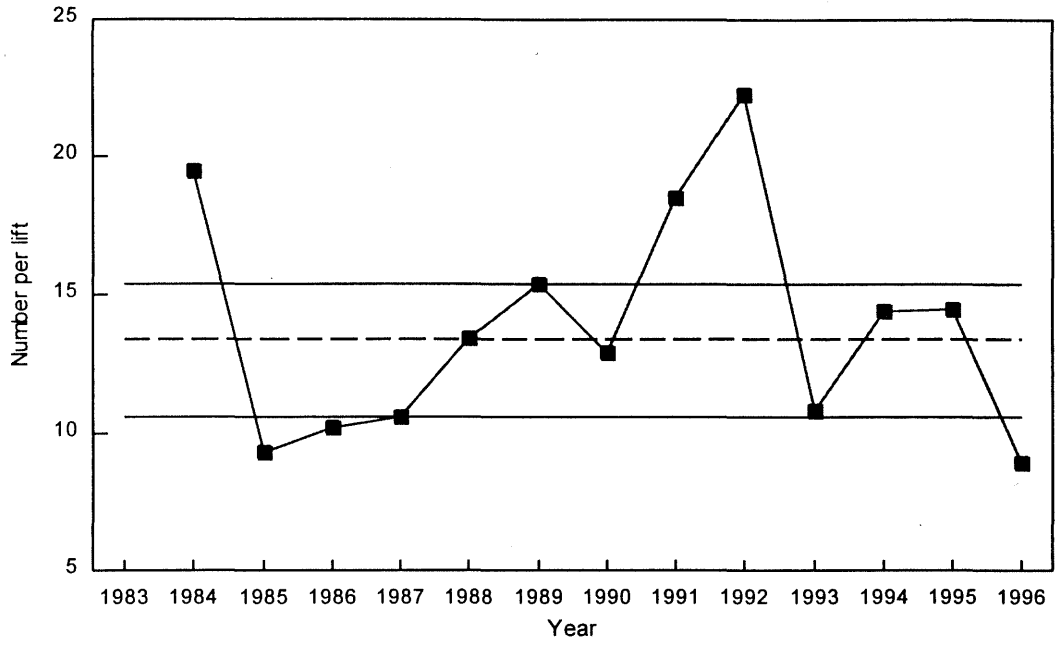

Figure 6. Walleye gill net abundance (1983-1996) for Lake of the Woods. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

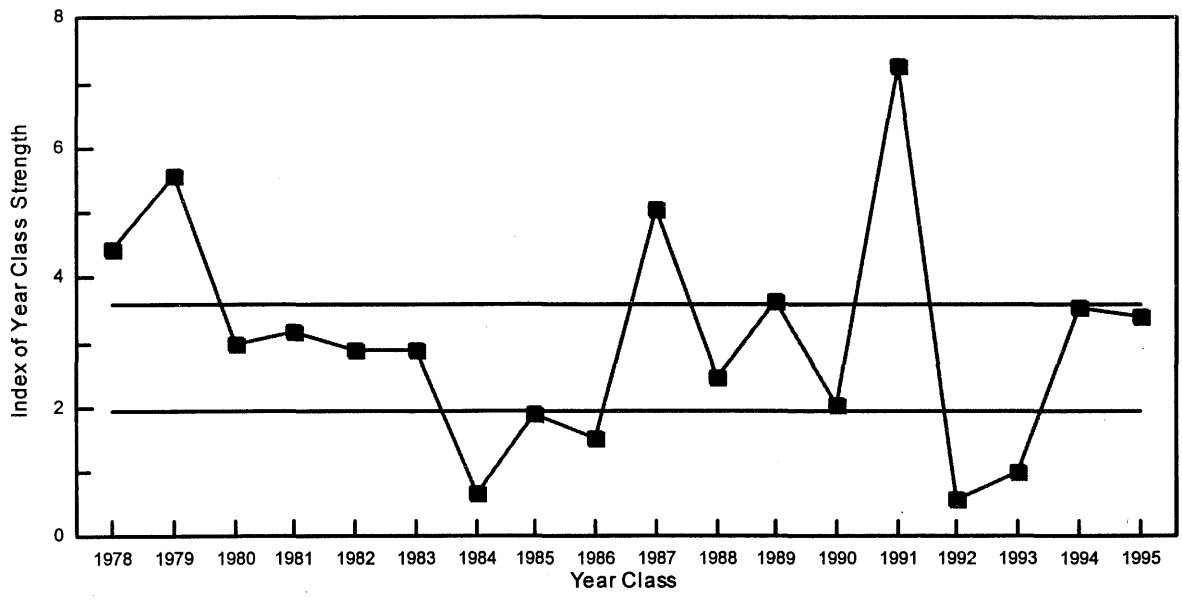

Figure 7. Index of year class strength for walleye from Lake of the Woods for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

winter of 1990-91. Since then, fishing pressure has declined steadily.

The winter fishery has undergone changes in synchrony with sauger abundance. In fact, it is likely that changes in abundance of the sauger population drive the changes in the winter fishery. Sauger abundance peaked in 1991 when the very strong 1989 and 1990 year classes recruited to the assessment gear (Figures 8 and 9). The extremely weak 1991 and 1992 year classes may be the cause of the low sauger abundance measured since 1993. Sauger recruitment is much more variable than walleye recruitment on lake of the Woods.

Northern pike have been lightly harvested in Minnesota waters since the removal of the commercial fishery. Relative to walleye and sauger, angler interest in northern pike is low. With the discovery of trophy northern pike fishing, angling pressure has increased. Most of the increase in pressure has occurred in the spring, immediately before and after ice-out. This is a segment of the pike fishery that has not historically been monitored during creel surveys. Northern pike harvest (summer and winter) has ranged from 30,000 to 50,000 pounds from 1990 through 1996.

Population monitoring depicts a northern pike population with a variety of age classes, good growth and survival, with 2-3 % of individuals reaching "trophy" size (>40 inches). Experimental regulations implemented in 1996 are designed to protect the high quality northern pike population and preserve fishing opportunity. Preliminary data from an ongoing tagging study show that most northern pike are angled from March 1 through August. Fall and winter fishing accounts for very few tag returns. The popularity of the spring northern pike fishery is expected to expand.

The current harvest of yellow perch harvest is 28,000 pounds. More than 90% of the harvest takes place in the winter. Annual index netting indicates the perch population is stable and is usually composed of nine age classes. Several strong year classes have boosted yellow perch abundance, for brief periods, since 1981.

Smallmouth bass habitat is limited in the open expanse of the Big Traverse and Muskeg Bays. Most of the smallmouth bass population, and harvest, occur around the islands of the Northwest Angle. During the three years of the Northwest Angle creel survey smallmouth bass harvest averaged 395 pounds. Smallmouth bass are not likely to become a significant part of the fish community in Minnesota waters of Lake of the Woods.

Other species harvested on Lake of the Woods include cisco, burbot, and lake sturgeon *Acipenser fulvescens*. Cisco and burbot are frequently harvested in the winter fishery. These fish, however, are usually discarded on the ice rather than consumed. Lake sturgeon are caught infrequently on the lake, but a small sport fishery exists on the Rainy River. Because of the unique character of the lake sturgeon fishery, we expect this fishery to grow.

Management History

Commercial exploitation of Lake of the Woods fish stocks began in 1888, with a pound net fishery for lake sturgeon and lake whitefish. These fisheries collapsed by the early 1900s and effort was redirected to walleye and sauger, using gill nets. Carlander (1942) reported walleye stocks were showing signs of instability, due to over-exploitation, during the late 1930s. In 1948, competition for allocation of the walleye harvest between sport and commercial fishing interests, lead to a policy of reducing participation in the commercial fishery through attrition of license holders. Despite the overall reduction in commercial license holders, Schupp and Macins (1977) commented that commercial catch per unit of effort (CPUE) had declined severely and the bulk of the harvest was dependent on individual strong year classes during the 1950s and 1960s.

Legislation passed in 1984 authorized the MNDNR to purchase the remaining commercial quotas for sport fish species as a way to accelerate removal of the commercial fishery. The last commercial harvest of sport fish occurred in 1985. Sport fishing limits and regulations were liberalized, concurrent with the elimination of the commercial fishery. In 1991, walleye and sauger limits and general

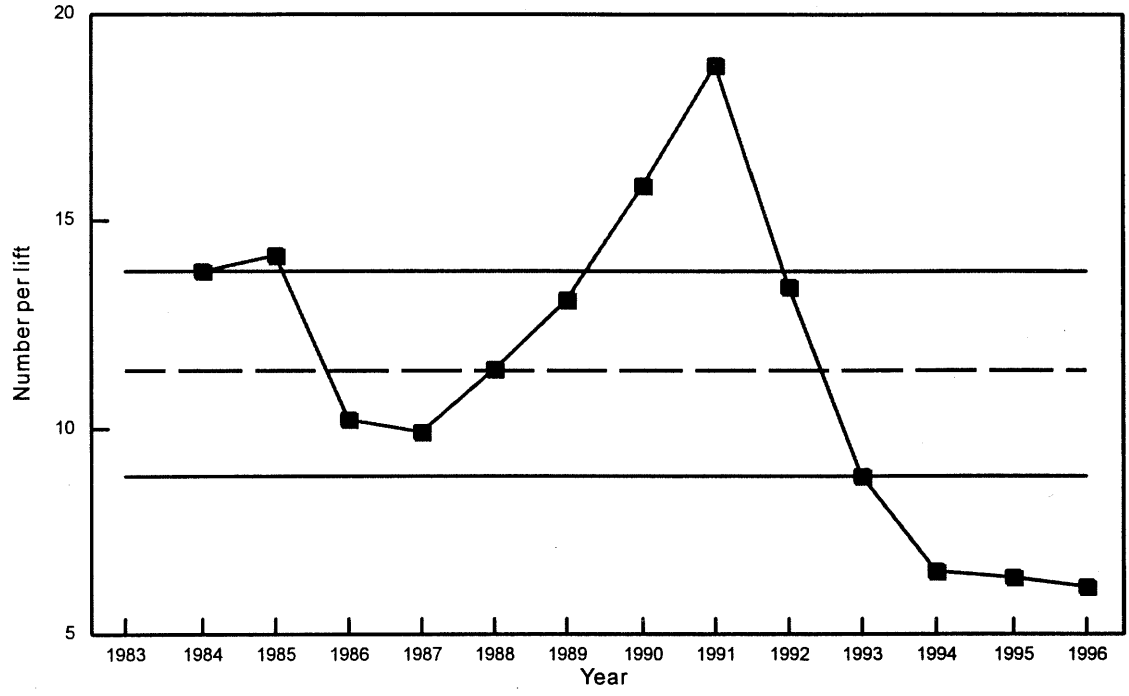

Figure 8. Sauger gill net abundance (1983-1996) for Lake of the Woods. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

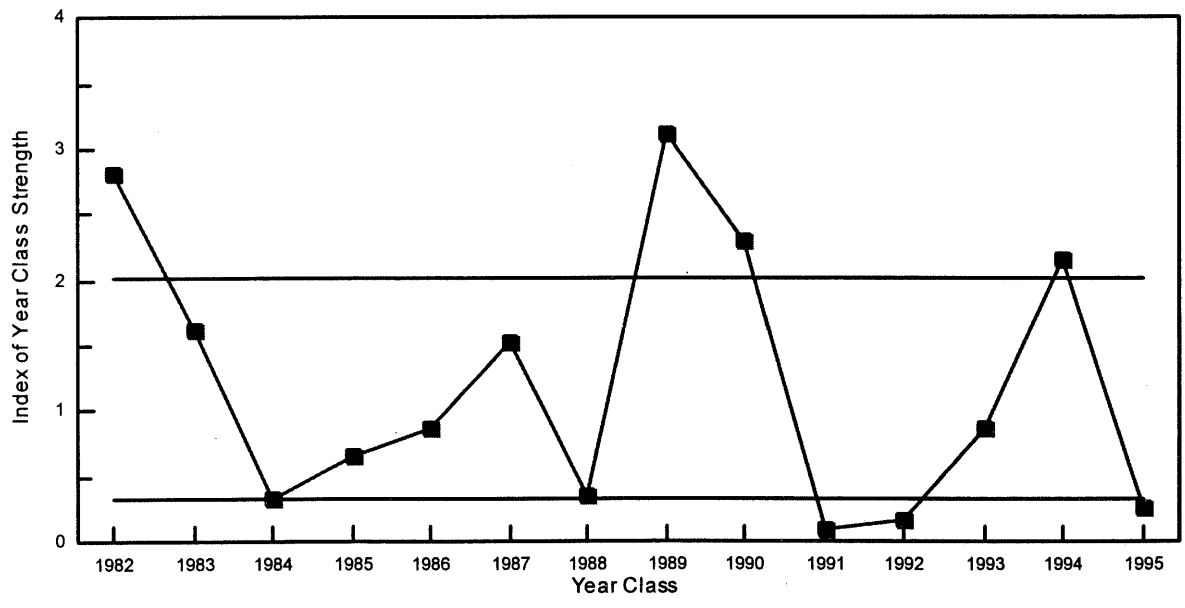

Figure 9. Index of year class strength for sauger from Lake of the Woods for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

regulations were returned to pre-1985 levels, largely in response to angler noncompliance with fish packaging regulations.

Evermann and Latimer (1910) conducted the first fish survey on Lake of the Woods. The first fish population assessment was undertaken from the summer of 1939 through the winter of 1942 (Carlander 1942). The primary focus of this survey was the commercial fisheries of the lake. Much of the sampling was of the commercial catch and harvest. Variable mesh gill nets were also used to describe the population status of a variety of species. Schupp (1973) surveyed the lake from 1968 through 1970.

Current assessment techniques are based on the methods of Schupp (1973) and are outlined in the *Large Lake Sampling Guide.* Fall gill net assessment and young-of-the-year percid assessment have been conducted annually since 1981. Summer creel surveys have been conducted annually since 1981. The winter fishery has been assessed eight times, since the winter of 1982-83. Other fisheries that have been assessed are the spring Rainy River fishery (annual since 1990), fall Rainy River fishery (1989 and 1990), spring northern pike (1996 and 1997) and the summer fishery based in the Northwest Angle area (1994-1996). Spring electrofishing for spawning walleye in the Rainy River is conducted annually. This assessment is designed to monitor the size structure of a segment of the walleye population that is not fully vulnerable to standard assessment gear. Northern pike are sampled annually on their spawning run using trap nets.

Small commercial harvests of burbot and suckers (primarily white sucker, shorthead redhorse *Moxostoma macrolepidotum*, and silver redhorse *Moxostoma anisurum*) are still permitted. The burbot fishery exists to supply burbot for winter fee-fishing operations in southern Indiana and Ohio. The sucker fishery in the Warroad River is a source of livestock feed while that in the Rainy River tributaries supplies suckers for human consumption. Neither of the sucker operations was conducted in 1997.

A maximum size limit, allowing only one walleye exceeding 19.5 inches in possession, was implemented prior to the 1995 fishing season. This deviation from the statewide one-over 24-inch regulation was enacted due to an existing one over 50 cm (approximately 19.5 inches) regulation in Ontario.

Potential and Target Harvest Levels

Potential and target harvest levels used on the Minnesota waters of Lake of the Woods are based on the potential yield estimated using the morphoedaphic index (MEI). The potential yield used for the Minnesota waters of Lake of the Woods is 10.5 pounds/acre. The potential yield was partitioned using methods described in SPOF 12.[3] The current harvest level, for each species, is described as the average annual harvest from 1990 through 1996.

Walleye. The estimated potential and target yields for walleye were set at 430,100 pounds. The current walleye harvest is 440,300 pounds. The average summer harvest, from 1990 through 1996, is 315,800 pounds. The combined harvest from the Rainy River spring and fall fisheries, the Lake of the Woods winter fishery, and the Northwest Angle fishery is 124,500 pounds. The spring and fall Rainy River fisheries have both expanded since 1990. Angling pressure in the spring fishery has grown to where walleye harvest exceeding the Rainy River management goal of 25,000 pounds has been documented.

Sauger. The potential yield for sauger based on MEI partitions is estimated at 134,000 pounds. The target harvest was set above the potential yield in 1990 (300,000 pounds) because population data suggested that the high sauger harvest observed from 1984-89 (276,000 pounds) was sustainable. Harvest peaked during the summer of 1989 and the winter of 1989-90, at 290,100 pounds. Summer and winter harvests have declined steadily since the summer of 1990. The current sauger harvest, is 145,300 pounds. The winter harvest represents 72% of the current harvest (104,600 pounds).

Annual index netting also shows a general decline in the abundance of sauger

(Figure 8). The average gill net catch of sauger from 1984 to 1996 was 11.4 fish/net, but catch rates have been below 7.0 fish/net since 1994. Cause of the decline in sauger abundance is open to speculation. Theories range from a natural phenomenon (poor recruitment or interaction with a walleye population that is more abundant and stable than in the recent past) to excessive harvest.

Due to uncertainty about the cause of the declining sauger population, the target harvest has been reduced to 80% of the potential yield (107,000 pounds). If harvests continue to exceed the target harvest level, reduction of current possession limits, or other regulatory changes designed to reduce harvest, will be considered. Data from the large lake sampling program, creel surveys and other agencies will be evaluated annually to determine the status of the sauger population and the need for harvest reductions.

Northern Pike. The northern pike potential yield is estimated at 268,000 pounds. Northern pike harvest (summer and winter) has ranged from 30,000 to 50,000 pounds from 1990 through 1996. The target harvest has been set below the potential yield to manage northern pike as a trophy fishery. The target harvest is 100,000 pounds.

Yellow Perch. The potential yield and target harvest for yellow perch were set at 67,200 pounds. The current harvest is 27,700 pounds. More than 90% of the current harvest takes place in the winter.

Future Management

Stock Assessment. Standard sampling as described in the *Large Lake Sampling Guide* should be continued. Additional sampling will be directed at increasing our understanding of sauger population dynamics. Since the total walleye harvest slightly exceeded the target harvest for the period from 1990 to 1996, it is essential that total harvest be monitored closely. The summer creel survey should be continued on an annual basis and winter creel surveys should resume in 1997 to monitor the winter sauger fishery. The spring and fall Rainy River fisheries should also be assessed because walleye harvested from these fisheries are from Lake of the Woods stocks.

Experimental Regulations. There is a one over 19.5 inch limit on walleye on Lake of the Woods and the Rainy River. This deviation from the general statewide regulation is due to a preexisting one over 50 cm (19.7 inches) regulation in Ontario. The Rainy River regulations also include a 19.5 inch maximum size limit on walleye during the extended walleye season (March 1-April 14). A reduction in the walleye limit, from six to two, is being proposed for the spring Rainy River fishery (March 1-April 14), starting in 1998. It is anticipated this limit reduction will reduce walleye harvest on the Rainy River during years when fishing success is exceptional. The sauger limit deviates from the statewide possession limit. The walleye/sauger limit is an aggregate of 14 fish, of which no more than six may be walleye.

The only experimental regulation on Lake of the Woods is the 30-40 inch protected slot (only one fish may exceed 40 inches) on northern pike. Evaluation of this experimental regulation will be completed by March 1, 2006. This regulation will be considered successful if the northern pike population maintains a high quality size structure and angling effort increases.

Habitat Management. An inventory of the Lake of the Woods shoal waters will be completed by the summer of 1998.

Leech Lake

Description of the Fishery

Leech Lake is the third largest lake entirely within the boundaries of Minnesota, originally covering 106,000 acres (Figure 1). In 1884, a dam was built that raised the lake two feet and increased the lake to its present size of 111,527 acres. The lake is irregularly shaped with 195 miles of shoreline. Although the maximum depth is 156 feet, about 80 percent of the lake is less than 35 feet deep. Basin types within the lake vary considerably. Bays such as Steamboat and Boy display characteristics similar to lakes with high nutrient

levels (eutrophic) while Walker and Kabekona Bays have basin types similar to Canadian lake trout lakes (oligotrophic). The majority of the lake, like most large Minnesota walleye lakes, falls somewhere in between (mesotrophic). The fish assemblage reflects the diversity of aquatic habitat in Leech Lake. Walleye, northern pike, and muskellunge are the principal predators and are dependent upon the abundant yellow perch and cisco populations for food. Other fish species present include: bowfin, lake whitefish, white sucker, shorthead redhorse, black bullhead, yellow bullhead, brown bullhead, burbot, rock bass, pumpkinseed, bluegill, largemouth bass, and black crappie.

On average, sport anglers spend more than one million hours annually fishing Leech Lake (Haukos 1993). About 10 percent of the total fishing pressure occurs during winter months. Although Leech Lake provides some excellent bluegill, black crappie and largemouth bass fishing, most anglers seek walleye, muskellunge, yellow perch, or northern pike. Anglers harvest approximately 478,700 pounds of fish annually (Table 3). Walleye are the primary component of the harvest, annually averaging 172,500 pounds (Table 8). Other major components include northern pike (128,200 pounds), yellow perch (83,100 pounds) and cisco/lake whitefish (58,000 pounds - includes sport netting). The remainder of the sport harvest (36,700 pounds) consists of muskellunge, rock bass, pumpkinseed, bluegill, largemouth bass, black crappie, burbot, black bullhead, yellow bullhead, and brown bullhead.

Approximately 85 percent of Leech Lake is within the boundaries of the Leech Lake Indian Reservation (LLIR). This reservation was established by the 1855 and 1867 treaties. In 1971, federal district court ruled that the Leech Lake Band had not relinquished their right to hunt, fish and gather and that these were individual property rights of Band members. After this ruling, the state of Minnesota negotiated a settlement with the LLIR. As a result of this settlement, the LLIR created a conservation code. This code allows for subsistence harvest of fish by Band members using methods such as gill nets and spears during a prescribed season. Current annual subsistence harvest is an estimated 10,000 pounds for walleye and 15,000 pounds for northern pike. The code allows for commercialization of only non-game species. Current commercial harvest is an estimated 11,000 pounds for cisco and 9,000 pounds for lake whitefish. Total harvest by Band members accounts for less than 10 percent of the total annual sport harvest.

Leech Lake fish populations have been assessed annually by gill net since 1983 (Figure 10). Gill net catch-per-unit-of-effort (CPUE) indicates stable populations for all species except black bullhead. Black bullhead abundance has declined while average size has increased which indicates poor reproduction or recruitment. Variation in CPUE for walleye and yellow perch are attributed to normal variations of year class strength (Figure 11).

Management History

Until the inception of the LLP in 1983, Leech Lake fish management was primarily reactive to the perceptions of local anglers and businesses. Fish population assessments were done in response to complaints of poor fishing. Walleye stocking was the primary management tool used during this period and occurred intermittently from 1911 through 1987. A locally unpopular commercial walleye fishery was eliminated with the first stocking because a 1909 law prohibited sale of walleye from waters stocked by the Game and Fish Commission. Earlier stockings had no biological basis for improving walleye populations, but were often used to appease anglers during times of poor fishing. The walleye fishery is sustained entirely by natural reproduction.

A muskellunge egg-take operation was established in 1982 for the purpose of establishing brood lakes that could provide a dependable egg source for the statewide muskellunge program. Because of MNDNR policy and the negotiated settlement with the LLIR, 10 percent of muskellunge fingerlings produced during this egg-take were returned to the lake. The LLIR maintains a lake whitefish stocking program that began in 1984. This program has

been difficult to assess for contribution to the fishery.

With the inception of the LLP, management of Leech Lake has become more proactive with emphasis on education, habitat protection and fish population monitoring. Education has been ongoing and focused on a holistic approach to the fishery. Habitat protection has been accomplished primarily through the environmental review process and education. The Tri-County Leech Lake Watershed Project (TCLLWP) was established to bring together government agencies, special interest groups, and citizens to collectively determine best management practices for the Leech Lake watershed. In 1986 a voluntary catch and release program was created in cooperation with many local organizations. These projects were made possible because of the credibility established by the LLP.

Table 8. Historical creel survey estimates by species for Leech Lake.

Winter	1991-92	1990-91	1984-85	-	-	1965-66	-
Summer	1992	1991	1985	1984	1967	1966	1965
Total angler-hours	1,035,748	1,269,520	1,326,555	740,112	839,760	921,439	917,821
Walleye							
Total number harvested	93,297	183,908	162,581	78,273	148,046	162,337	150,145
Total pounds harvested	126,748	191,905	165,092	98,527	201,308	224,611	199,279
Mean weight (pounds)	1.36	1.04	1.02	1.26	1.36	1.38	1.33
Harvest rate (fish/angler hour)	0.090	0.145	0.123	0.106	0.188	0.188	0.174
Yellow Perch							
Total number harvested	297,340	197,100	257,380	173,584	143,050	155,808	161,257
Total pounds harvested	114,027	67,659	94,240	64,415	75,490	82,962	83,215
Mean weight (pounds)	0.38	0.34	0.37	0.37	0.53	0.53	0.52
Harvest rate (fish/angler hour)	0.287	0.155	0.194	0.235	0.170	0.169	0.175
Northern Pike							
Total number harvested	31,015	45,439	81,746	42,836	52,869	57,515	66,974
Total pounds harvested	78,005	103,195	156,191	79,921	143,125	158,670	178,276
Mean weight (pounds)	2.52	2.27	1.91	1.87	2.60	2.65	2.56
Harvest rate (fish/angler hour)	0.030	0.036	0.062	0.058	0.061	0.061	0.071
Black Crappie							
Total number harvested	1,073	1,033	993	4,399			
Total pounds harvested	1,093	1,053	1,013	4,490			
Mean weight (pounds)	1.02	1.02	1.02	1.02			
Harvest rate (fish/angler hour)	0.001	0.001	0.001	0.006			
Cisco							
Total number harvested	2,090	1,761	57	57	930	1,034	1,012
Total pounds harvested	2,575	2,166	70	70	864	725	697
Mean weight (pounds)	1.23	1.23	1.23	1.23			
Harvest rate (fish/angler hour)	0.002	0.001	0.000	0.000			
Rock Bass							
Total number harvested	18,703	30,145	32,866	10,808	9,638	15,351	11,205
Total pounds harvested	12,718	17,183	20,554	6,755	10,602	16,886	12,326
Mean weight (pounds)	0.68	0.57	0.63	0.63	1.10	1.01	1.1
Harvest rate (fish/angler hour)	0.018	0.024	0.025	0.015	0.012	0.018	0.013
Largemouth Bass							
Total number harvested	1,466	1,024	1,166	1,023			
Total pounds harvested	2,844	1,710	2,105	1,847			
Mean weight (pounds)	1.94	1.67	1.81	1.81			
Harvest rate (fish/angler hour)	0.001	0.001	0.001	0.001			

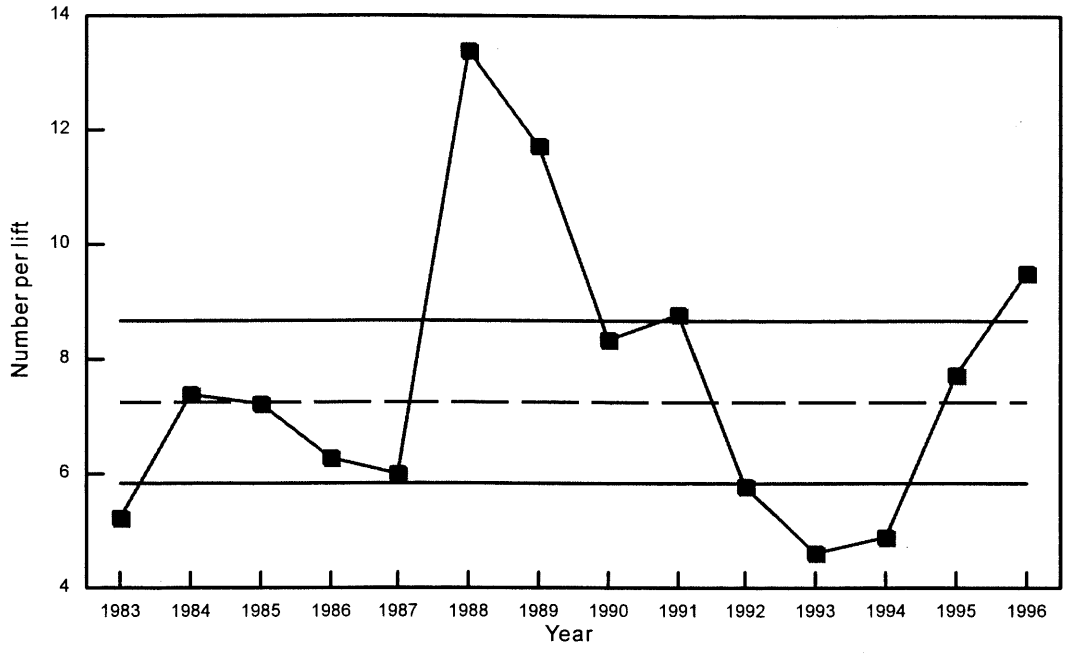

Figure 10. Walleye gill net abundance (1983-1996) for Leech Lake. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

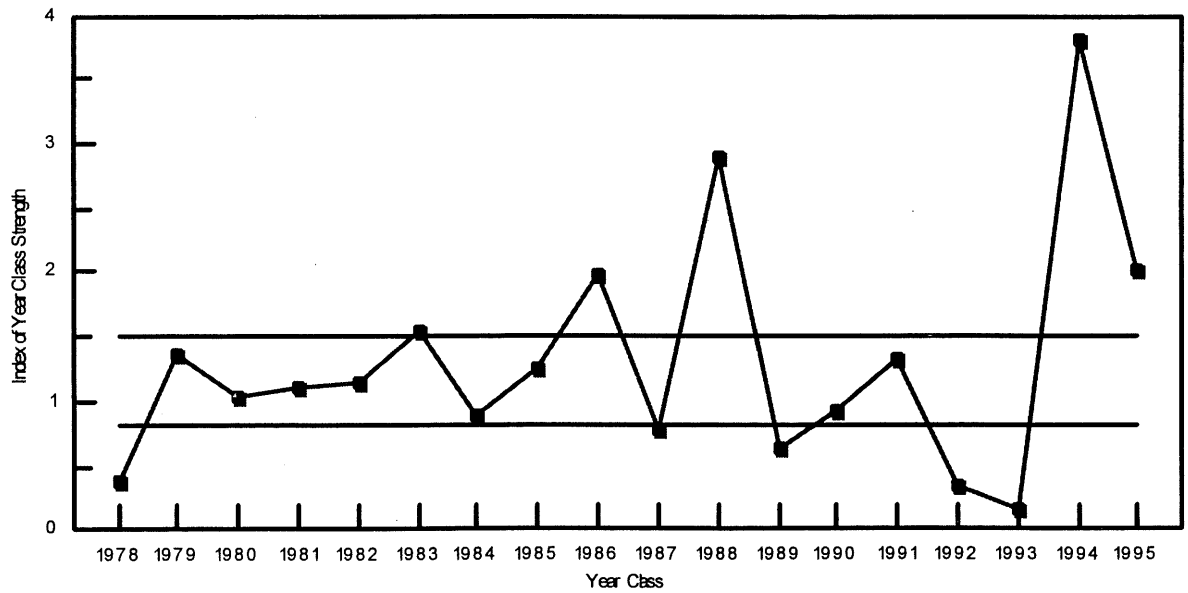

Figure 11. Index of year class strength for walleye from Leech Lake for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

Potential and Target Harvest

After review of available data, the morphoedaphic index (Ryder 1965) was chosen as the first order predictor of potential yields. Because of the diversity of Leech Lake, overall potential yield was derived by determining potential yield for individual areas of the lake and summed. Target yields for all species are the same as potential yields. Current harvest levels for all species are described as the mean harvest for historical creel surveys, adjusted for subsistence harvest by Band members. Methodology used to partition potential yield among species is described in SPOF 12.

The estimated annual potential yield for all species in Leech Lake is 652,000 pounds (Table 3). The current harvest combined for all species is 523,700 pounds, 20 percent below the potential yield. However, it is conceivable certain species in particular areas of Leech Lake are experiencing excessive harvest. It is difficult to determine where and if this is occurring because, recent creel surveys only estimated harvest for the entire lake and not for specific areas.

Walleye. Population assessments indicate the Leech Lake fish community is more complex than most of Minnesota's large lakes. Much of the biomass is made up of species other than walleye. The estimated potential and target yields for walleye were set at 209,000 pounds or 32% of the total predicted yield. Current annual walleye harvest is 182,500 pounds. Ninety-five percent of the harvest is from sport angling (172,500 pounds) and the remaining harvest (10,000 pounds) is a result of subsistence netting by Band members. Of the years creel surveys were conducted, only 1966 (224,611 pounds) exceeded the potential and target yields (Table 8).

Annual assessment of Leech Lake fish stocks has not revealed signs of stress in the walleye population. Growth rates, length at maturity, and age at maturity have not changed. Variation in average weight is more related to year class effects than to exploitation. Compared to other lakes in the LLP, total mortality estimates are low (A = .33) and reproduction and recruitment are stable (Figure 11). Year class failures are not common, but did occur in 1992 and 1993. Cool weather conditions which limited forage production likely contributed to poor recruitment of these year classes. Strong year classes currently contributing to the sport fishery include 1988, 1991, 1994, and 1995.

Yellow Perch. The estimated potential and target yields for yellow perch were set at 98,000 pounds (Table 3). The current annual yellow perch harvest is 83,100 pounds. This is a minimal estimate because additional harvest is occurring during periods not sampled by creel surveys, primarily from the close of the walleye season until ice-out. This period is gaining popularity among anglers. Of the years creel surveys were conducted, only the 1992 harvest (114,027 pounds) exceeded the potential and target yields.

Yellow perch are an important component of the winter and summer sport fishery, and popularity is increasing. Gill net assessments indicate the yellow perch population is doing well (Table 4). The size distribution is good, with 40 percent of the sampled population greater than 8.0 inches. However, the average size of harvested yellow perch has decreased since the mid-1960s and exploitation has increased. Decreased average size is a typical population response to increased exploitation. A minimum of 10 year classes have been represented in each gill net assessment indicating excellent reproduction and recruitment. Angler complaints concerning parasites in yellow perch have increased. Parasites may continue to increase in response to the expanding fish eating bird population on Leech Lake. These birds serve as an intermediate host in the life cycle of many parasites affecting fish.

Northern Pike. Estimated potential and target yields for northern pike were set at 163,000 pounds. The current annual northern pike harvest is 143,200 pounds with 90 percent of this harvest from sport fishing (128,200 pounds). The remaining harvest (15,000 pounds) is a result of subsistence netting by Band members. Of the creel surveys conducted, only 1965 (178,276 pounds) and 1985 (171,191 pounds) exceeded potential and target yields.

Leech Lake gill net assessments indicate a stable northern pike population. Growth rates have not changed, and average length and weight has increased. More anglers are targeting northern pike, especially during midsummer periods when catch rates are low for walleye and high for northern pike. Promotion of the species by Leech Lake resort owners has contributed to the increased angler pressure.

Cisco and Lake Whitefish. The cisco/lake whitefish potential and target yield were set at 130,000 pounds. The current annual cisco/lake whitefish harvest is 78,000 pounds, 60 percent of potential and target yields. Current annual sport harvest of cisco/lake whitefish is 58,000 pounds. The commercial harvest by Band members is 20,000 pounds. Commercial harvest by Band Members is declining, but late-ice angling for cisco/lake whitefish is gaining popularity and harvest is increasing. Potential and target yields have never been exceeded during years creel surveys were conducted.

Leech Lake gill net CPUE for cisco has demonstrated considerable variability. Much of this variation has been attributed to environmental factors instead of population change. Cisco and lake whitefish populations are subject to summerkill. Currently, summerkill may be the biggest limiting factor affecting annual yield of cisco and lake whitefish. Local anglers report that the lake whitefish population has declined since the 1970s. In a survey of commercial netting by Band Members, Strand (1979) estimated the minimal 1978 lake whitefish harvest at 47,000 pounds. In 1996, commercial harvest records indicated only 1,998 pounds were bought through the LLIR's commercial fish processing plant. Commercial harvest records at the LLIR have shown a steady decline since records were first kept (1986). Most of this decline is a result of fewer Band members commercially fishing for lake whitefish. However, the possibility of over harvest does exist. In other inland lakes, lake whitefish have been slow to recover from over harvest (Carlander 1942).

Other species. Other species present or harvested in low numbers include muskellunge, largemouth bass, black crappie, rock bass, bluegill, pumpkinseed, burbot, black bullhead, yellow bullhead, and brown bullhead. Potential and target yields for "other species" were set at 52,000 pounds annually. Current annual harvest is 36,700 pounds and has never exceeded the potential and target yields. However, it is possible individual species within the "other species" category are being harvested at levels detrimental to fishing quality.

Muskellunge. Leech Lake has long been known as one of the premier muskellunge lakes in the country. Muskellunge are located throughout the lake, although some areas such as Steamboat and Boy Bays are primarily spawning and nursery areas. Muskellunge are an important component of the sport fishery; with more than 10 percent of total angling hours targeting muskellunge (Haukos 1993). The current annual harvest is 2,820 pounds. Data from spring egg-take operations indicate good reproduction, growth, and size distribution of muskellunge. Most muskellunge anglers practice catch and release and harvest is directed at trophy size individuals (> 48 inches). Despite the current level of harvest, numbers of trophy muskellunge have not declined.

Largemouth Bass. Until recently, Leech Lake has had a relatively unexploited population of largemouth bass. However, because of media attention, Leech Lake has become a popular largemouth bass lake. This is evidenced by the increase in the number of largemouth bass tournaments and increasing harvest estimates. However, declines in the fishery have not been noted which may be a result of most largemouth bass anglers practicing catch and release. The current annual largemouth bass harvest is 2,280 pounds.

Black Crappie. Black crappie are found in relatively small numbers throughout the lake. However, shortly after ice-out black crappie concentrate in areas that warm rapidly (north bays and harbors) and become vulnerable to anglers. The current annual black crappie harvest is 3,763 pounds. This is likely a minimum estimate because much of the black crappie harvest occurs during periods not sampled by Leech Lake creel surveys. Reports

from anglers and resort owners indicate black crappie average size is declining while angling pressure is increasing. Recent creel surveys also indicate a trend toward increased harvest.

Rock Bass. Rock bass are found throughout Leech lake. The current annual harvest is 13,900 pounds. Although numbers of rock bass harvested appears to be increasing, pounds harvested have remained unchanged. The average size of harvested rock bass has declined from 1.1 pounds (1965-1967) to 0.6 pounds (1991-1992). No angler reports or complaints have affirmed this finding.

Sunfish (bluegill and pumpkinseed). The largest concentrations of bluegill and pumpkinseed are located in Steamboat, Boy, and Shingobee Bays. The current annual sunfish harvest is 7,700 pounds. This harvest appears to be increasing as a result of anglers discovering quality size sunfish in relatively small areas of Leech Lake.

Burbot. The average annual burbot harvest is 3,700 pounds. Since the annual eelpout festival has not been sampled during creel surveys, the average harvest during the festival (2,600 lbs.) was added to the creel estimate. Much of the burbot harvest occurs in Walker, Kabekona, and Agency Bays. Population changes have not been detected.

Bullhead (black bullhead, yellow bullhead and brown bullhead). The current annual bullhead harvest is 2,600 pounds. Some additional harvest occurs as a result of commercial harvest permits issued by the Leech Lake Indian Reservation. Current population assessments indicate a decline in abundance of bullhead species, especially for black bullhead.

Future Management

Stock Assessment. Management of Leech Lake will continue to focus on collecting and analyzing data, education, and habitat protection. Data will be collected and analyzed following the sampling regimes and analysis described by the *Large Lake Sampling Guide*. Additional sampling may be incorporated to address special concerns (e.g., development in known spawning areas). Because of the diversity in Leech Lake, population assessments and creel surveys need to be redesigned to allow for analysis by areas within Leech Lake. Additional effort needs to be given for assessment of muskellunge, bluegill, black crappie, and largemouth bass.

Experimental Regulations. Although no special regulations are currently in place on Leech Lake, they will be explored. If data indicates fish populations are experiencing effects of excessive harvest and special regulations are a viable solution, attempts to gain public support and implementation of regulations will be initiated.

Stocking. Stocking species other than muskellunge will not be done unless it can be determined that stocks are declining and it would be a cost-effective approach to improving those stocks. A muskellunge egg-take will be conducted when additional muskellunge are needed to maintain genetic diversity in brood stock lakes. Ten percent of the fingerling production from these years will be returned into Leech Lake to conform with MNDNR policy and the negotiated settlement with the LLIR.

Education. User involvement is an important component of Leech Lake management. Assessment data and findings from special projects will be made available to constituents. Communication and coordination with constituents, Leech Lake Reservation, and other Federal, State, and Local government agencies will be maintained or improved.

Habitat Management. Protection of fish habitat in Leech Lake will primarily be accomplished through the environmental review process. Division of Waters and Aquatic Plant Management permit processes will be used to protect aquatic habitat whenever feasible. Cumulative impacts will be considered when appropriate. Effects of harbor development on Leech Lake need to be determined. Education will be an important component of the habitat protection efforts. Technical assistance and other support will be given to the TCLLWP and the LLIR in their efforts to protect and maintain Leech Lake habitat. Land exchanges that result in a net loss of publicly

owned shoreline should be opposed. Maintaining public ownership of shoreline should be addressed in Federal, State, and local land use plans.

Geographical information system (GIS) databases should be developed for Leech Lake. Data should include: shoreland development and ownership; identification of sensitive areas within or adjacent to Leech Lake (e.g., wetlands; spawning areas); identification of areas that may benefit from habitat improvement projects; mapping of shoal water substrates and vegetation; and, a current contour map of Leech Lake.

Mille Lacs Lake

Description of the Fishery

Mille Lacs Lake is a 132,516 acre glacial lake located in the east-central Minnesota. Fewer than 20 streams, from a 240,000 acre watershed, flow into the lake. The Rum River is the only outlet. A dam on the Rum River below Lake Ogechie is a water level control structure for Mille Lacs Lake, however, the dam has little impact on the water level. Precipitation and evaporation are the major factors affecting the water level of Mille Lacs Lake. Seventy percent of the 85 miles of shoreline is suitable walleye spawning habitat, which is exposed to wind and waves. The saucer shaped basin of Mille Lacs Lake has a maximum depth of 42 feet and averages 21 feet. Due to wave action and the lake's relatively shallow depth, water mixes freely from top to bottom. There is little thermal stratification and oxygen is available at all depths. Offshore habitats include sand and mud flats, rock reefs, and a few small exposed islands. A few marsh areas exist in the southern part of the lake.

The Mille Lacs Lake game fish community is primarily composed of walleye, yellow perch, northern pike, and muskellunge. These are also the principal species targeted by anglers, in decreasing order of effort. In addition, largemouth and smallmouth bass, black crappie, rock bass, northern cisco (tullibee), burbot, black, yellow, and brown bullheads, bowfin, carp *Cyprinus carpio* and white sucker are also found in Mille Lacs Lake. Other common forage species include spottail *Notropis hudsonius*, mimic *Notropis volucellus* and golden shiners *Notemigonus crysoleucus*, bluntnose minnow *Pimephales notatus*, trout-perch, logperch, and johnny darter *Etheostoma nigrum*.

Based on assessment net catches, the walleye population in Mille Lacs may be the most stable of the large lakes (Figures 12 and 13), however, angling catch rates and harvest fluctuate greatly depending on forage densities and the abundance of walleye in the sizes most readily taken by anglers (14 -17 inches). The primary forage of walleye in Mille Lacs is yellow perch. When yearling perch are at high levels, walleye catch rates are generally low.

Total open water angling effort has more than doubled since the 1960s, with most of the increase directed at walleye (Table 9). Walleye harvest, however, has not increased as dramatically due to more anglers sharing the same number of fish. Most of the walleye harvest occurs in the open water season with more than 50% of the total harvest occurring in the first 6 weeks of the season. Although more than 50% of the angling occurs in winter, only about 12% of the walleye harvest occurs in this season. Much of the winter effort is due to overnight stays in fish houses.

In contrast to the walleye fishery, more than 80% of the yellow perch harvest occurs from December through early April. The yellow perch population appears to have increased in the 1990s, but annual harvest has not changed. A *Columnaris* spp. epizootic in 1992 killed a large portion of the adult perch. This die off of large perch, coupled with a combined walleye harvest of more than 1.5 million pounds in 1992 and 1993, may have reduced the predators of young-of-year perch enough to have increased the survival of the strong 1993 yellow perch year class, which dominates the current population.

Muskellunge are a relative newcomer to Mille Lacs Lake. Stocking efforts since 1984 have established an exceptional fishery, which continues to mature. Some of the fish from the earlier stockings have grown beyond 50 inches. In addition to stocking, natural reproduction has

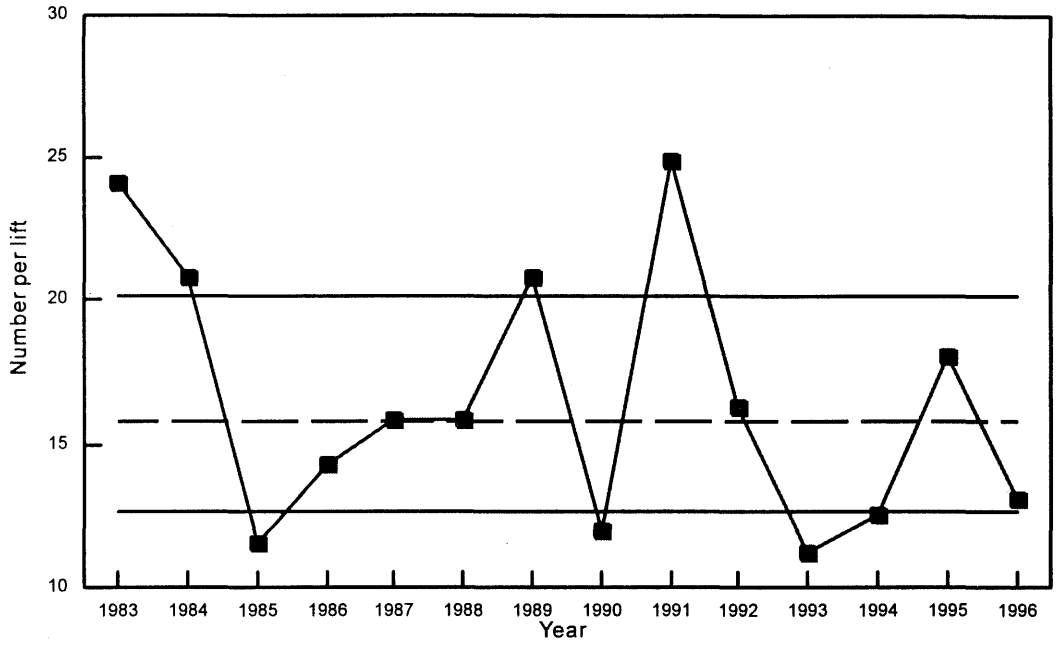

Figure 12. Walleye gill net abundance (1983-1996) for Lake Mille Lacs. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

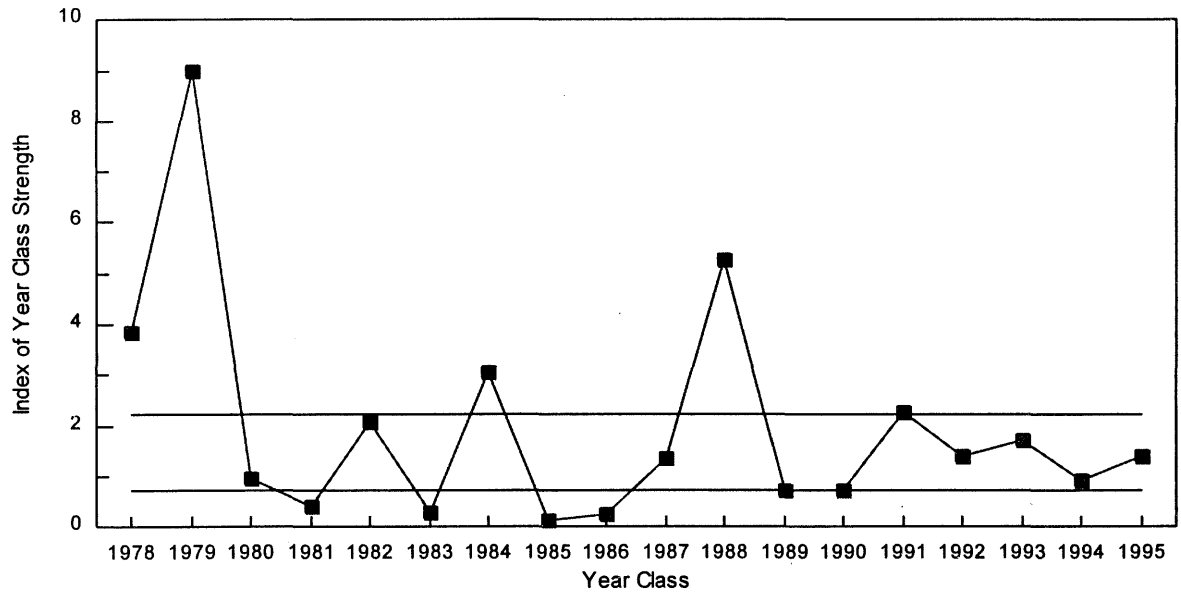

Figure 13. Index of year class strength for walleye from Lake Mille Lacs for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

Table 9. Historical creel survey estimates by species for Mille Lacs Lake.

Winter Summer	1995-96 1996	1994-95 1995	1993-94 1994	1992-93 1993	1991-92 1992	1990-91 1991	1989-90 1990	1988-89 1989	1987-88 1988	1986-86 1987
Total angler-hours	4,253,784	3,379,504	2,766,447	3,871,825	4,851,056	3,797,669	4,493,410	3,628,367	3,163,069	3,170,205
Walleye										
Total number harvested	377,308	229,439	140,208	290,316	681,140	379,562	381,674	271,539	490,820	251,578
Total pounds harvested	617,991	344,841	189,633	501,432	1,078,964	459,765	511,662	430,093	643,499	386,560
Mean weight (pounds)	1.64	1.5	1.35	1.73	1.58	1.21	1.34	1.58	1.31	1.54
Harvest rate (fish/angler hour)	0.089	0.068	0.051	0.075	0.140	0.100	0.085	0.075	0.155	0.079
Yellow Perch										
Total number harvested	413,974	383,970	181,091	89,632	278,480	354,146	470,545	547,849	312,142	354,637
Total pounds harvested	150,138	149,336	71,738	35,263	112,827	124,829	220,765	272,480	154,376	178,230
Mean weight (pounds)	0.36	0.39	0.40	0.39	0.41	0.35	0.47	0.50	0.49	0.50
Harvest rate (fish/angler hour)	0.097	0.114	0.065	0.023	0.057	0.093	0.105	0.151	0.099	0.112
Northern Pike										
Total number harvested	7,595	5,453	3,040	2,406	6,692	4,868	11,940	8,652	5,219	9,303
Total pounds harvested	33,300	21,599	12,667	12,585	28,458	23,360	53,284	43,706	29,668	41,779
Mean weight (pounds)	4.38	3.96	4.17	5.23	4.25	4.80	4.46	5.05	5.68	4.49
Harvest rate (fish/angler hour)	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.002	0.002	0.003
Smallmouth Bass										
Total number harvested	333	403	842	1,073	2,577	1,337	1,050	1,593	850	650
Total pounds harvested	349	403	902	1,180	2,839	1,460	1,050	1,709	1,033	1,174
Mean weight (pounds)	1.05	1.00	1.07	1.10	1.10	1.09	1.00	1.07	1.22	1.81
Harvest rate (fish/angler hour)	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Cisco										
Total number harvested	80,026	56,903	81,068	31,115	10,978	20,548	1,451	6,042	1,814	8,713
Total pounds harvested	53,433	44,893	62,592	21,968	8,581	16,027	1,097	5,439	1,472	7,842
Mean weight (pounds)	0.67	0.79	0.77	0.71	0.78	0.78	0.76	0.90	0.81	0.90
Harvest rate (fish/angler hour)	0.019	0.017	0.029	0.008	0.002	0.005	tr.	0.002	0.001	0.003
Burbot										
Total number harvested	38,734	62,472	24,576	28,278	35,076	13,970	57,824	24,618	23,867	78,735
Total pounds harvested	48,702	75,063	34,033	33,753	45,553	14,846	61,358	29,597	29,126	79,908
Mean weight (pounds)	1.26	1.20	1.38	1.19	1.30	1.06	1.06	1.20	1.22	1.01
Harvest rate (fish/angler hour)	0.009	0.018	0.009	0.007	0.007	0.004	0.013	0.007	0.008	0.025

Table 9. Continued.

Winter	1985-86	1984-85	1983-84	-	1976-77	-	1962-63	1961-62	-
Summer	1986	1985	1984	1983	1977	1976	-	1962	1961
Total angler-hours	3,041,365	2,802,821	2,380,184	945,080	2,835,972	1,005,313	1,098,112	1,135,207	732,685
Walleye									
Total number harvested	177,238	125,740	290,283	251,242	407,312	198,507	125,775	198,237	188,985
Total pounds harvested	309,783	175,885	447,370	285,466	551,094	342,285	233,972	352,291	339,386
Mean weight (pounds)	1.75	1.40	1.54	1.14	1.35	1.72	1.86	1.78	1.80
Harvest rate (fish/angler hour)	0.058	0.045	0.122	0.266	0.144	0.197	0.115	0.175	0.258
Yellow Perch									
Total number harvested	1,058,205	1,132,571	284,153	93,188	297,805	52,704	64,719	215,319	15,749
Total pounds harvested	536,976	572,437	142,448	48,716	156,376	28,375	45,303	21,773	14,644
Mean weight (pounds)	0.51	0.51	0.50	0.52	0.53	.054	0.70	0.86	0.93
Harvest rate (fish/angler hour)	0.348	0.404	0.119	0.099	0.105	0.052	0.059	0.022	0.021
Northern Pike									
Total number harvested	5,411	6,017	10,119	3,363	12,724	3,355	Season	Season	1,017
Total pounds harvested	32,166	26,058	32,485	12,213	57,206	16,350	closed	closed	4,605
Mean weight (pounds)	5.94	4.33	3.21	3.63	4.50	4.87			4.53
Harvest rate (fish/angler hour)	0.002	0.002	0.004	0.004	0.004	0.003			0.001
Smallmouth Bass									
Total number harvested	283	514	62	132					
Total pounds harvested	501	452	93	290					
Mean weight (pounds)	1.77	0.88	1.50	2.20					
Harvest rate (fish/angler hour)	tr.	tr.	tr.	tr.					
Cisco									
Total number harvested	15,762	17,977							
Total pounds harvested	14,186	16,179							
Mean weight (pounds)	0.90	0.90							
Harvest rate (fish/angler hour)	0.005	0.006							
Burbot									
Total number harvested	59,476	20,015	20,583	27					
Total pounds harvested	72,371	26,812	36,389	41					
Mean weight (pounds)	1.22	1.34		1.52					
Harvest rate (fish/angler hour)	0.020	0.007	0.009	tr.					

been evident since 1991. Angling effort directed at muskellunge has increased more than 500% since 1990, but the catch of about 800 fish per year has changed little in the same period. More than 95% of the muskellunge catch is released.

The northern pike population is presently lower than in the 1970s and 1980s. This decline is likely a result of discontinued stocking, loss of spawning habitat, and low water levels in the late 1980s, which limited access of pike to spawning marshes. Current estimates of population size range between 12,000 and 32,000 adults. Most of the pike are harvested by anglers seeking northern pike, but about one third are taken by anglers targeting walleye. When walleye catch rates are high, the incidental catch of northern pike by walleye anglers can account for over 40% of the total harvest. During those years, annual harvest of northern pike was slightly higher than desirable.

Smallmouth bass in summer and cisco in winter are two additional species targeted by anglers. Cisco are also harvested during a fall sport netting season. Burbot in winter and rock bass in summer, although not normally sought by anglers, are common in the catch.

Management History

Fisheries management at Mille Lacs has evolved from water level control, stocking, and rough fish removal to intensive population monitoring, special regulations, habitat protection, and annual estimations of safe harvest levels.

Population assessments were conducted in 1941-43, 1954, 1957-62, and from 1972 through 1996. Qualitative or quantitative creel surveys were conducted in 1958-62, 1975-77, and annually since 1981. In addition, a voluntary creel survey of launches was conducted from 1972 to 1974. Other studies have included an investigation of the relationship between young walleye and yellow perch in 1954 and 1955, an economic survey of the Mille Lacs sport fishery in 1961 and 1962, a study of the daily and seasonal activities of yellow perch in 1969, an evaluation of fish species composition of boat harbors in 1989, an inventory of shoal water substrate types and vegetation complexes 1990-1996, and several other reports written in preparation and as court documents for the 1837 Treaty lawsuit by the Mille Lacs Band of Chippewa. Many other studies including evaluations of regulations, late night creel surveys, late ice creel surveys, and fish tagging studies are reported in the annual large lake assessment and creel survey reports.

Although stocking is limited to muskellunge, a variety of species have been stocked in the past (walleye, crappie, bass, cisco, whitefish, white bass, suckers, northern pike, and muskellunge). Currently, muskellunge are being stocked at a rate of 3,000 fingerlings every other year to maintain the present population. Additionally, some natural reproduction has occurred every year since 1991. In future years, if adequate natural reproduction is sufficient to support the growing fishery, stocking will be discontinued.

Regulations on Mille Lacs Lake have dealt mainly with reducing or redistributing the harvest of walleye or northern pike. These regulations have included closing northern pike fishing in 1962; eliminating northern pike spearing beginning in winter 1983-84; restricting fall cisco netting to two weeks; implementing a night fishing ban in the spring; limiting the harvest of larger walleye to not more than one over 20 inches; and imposing a 15-inch minimum size limit to reduce harvest to a 24% exploitation rate for the 1997 season.

Water levels at Cedar Creek on the southeast shore are managed for northern pike reproduction. Marmon Creek near Malmo is also managed as a northern pike spawning area, although artificial water level manipulations are not needed for reproduction. A barrier at the Rum River outlet was constructed in 1990 to prevent the movement of carp into Lake Ogechie, a major carp spawning area. Other creeks with carp spawning runs are managed with smaller temporary barriers that prevent the carp migrations. Carp and white suckers are harvested in most years by a licensed commercial fisher.

Due to the outcome of the 1837 Treaty lawsuit, the Mille Lacs and seven other Bands

of Chippewa Indians are allowed to net and spear fish in Mille Lacs Lake, regulated by their own Conservation Code (their form of Game and Fish Laws). These intensive harvest methods will be monitored closely by the Great Lakes Indian Fish and Wildlife Commission and the MNDNR. Total maximum allocation has not been decided by the court at this time, however, a five-year Band harvest plan, which was approved by the court, will be in effect. The collective harvest by spearing and netting of walleye in Mille Lacs will be 40,000 pounds in 1997 and will increase by 15,000 pounds each year, to 100,000 pounds in 2001.

The maximum harvest of all other species, except muskellunge, will be 50% of the target harvest level for that year. There is no cap on muskellunge because they are not native to the lake and therefore are not a "conservation concern". The Bands have agreed not to target northern pike or muskellunge in their open water netting and spearing seasons, and have agreed to limit net soak times or change netting locations once their total harvest of muskellunge reaches 5% of the population. They have also implemented a 40-inch minimum size for muskellunge for open water and winter angling and for winter spearing. In addition, once the Band target harvest is reached for any species in Mille Lacs Lake, the gill net fishery will be closed. Target harvest levels at Mille Lacs Lake will be determined by the 1837 Ceded Territory Fisheries Technical Committee, based on protocols established as a result of the lawsuit. This committee comprises fisheries biologists, managers, and other fisheries experts from the State and the Bands.

Potential and Target Harvest

The average values of the creel surveys from 1983 through 1996 were used to describe current harvest levels of all species except cisco and yellow perch. Adjustments were made to account for fall sport netting of cisco and the late ice angling of cisco and yellow perch. Potential yields were derived from the long term average harvests of each species. Estimating production based on historical harvest estimates assumes that the past harvest has been near maximum capacity of the fishery and yet not exceeding it. This is likely a valid assumption for some species at Mille Lacs Lake. If walleye harvest was not near maximum, catch rates would not have decreased with the increase in effort in the 1980s and 1990s. If harvest was much less than maximum, catch rates would have remained stable while harvest increased proportionally to the increase in effort. Conversely, if walleye were being overfished, harvest would have declined as effort increased. This has not occurred.

First order predictors were not used for Mille Lacs Lake because information from the past harvests and assessments suggested that the Mille Lacs Lake fishery was unlike the fisheries used in developing the predictive models. For several of the models, the predictions of potential harvest generally underestimated the yield in lakes that had the higher observed walleye yields. The differences between Mille Lacs Lake and the other lakes are likely due to a less diverse fish community (more production of walleye than other lakes), the more southerly geographic location (longer growing season), and continually mixing nature (continual nutrient cycling and more habitable space) of Mille Lacs Lake. Most of the waters used in developing the models were farther north (reduced growing season), and were thermally stratified; factors that reduce the productivity of the system and limit population size. The less diverse fish community of Mille Lacs Lake is likely due to the low diversity of habitats. Over 70% of the 86-mile shoreline is rocky, providing ample spawning habitat for walleye. Less than 6% of the shoreline is suitable northern pike spawning habitat. Much of the remaining shoreline is unprotected sand that is constantly shifted by wave action, offering little spawning habitat for game fish.

Walleye. Potential yield of walleye is estimated to be 430,000 pounds, the long term average annual harvest. Target harvest for walleye will be set on an annual basis, as per the court order and the current agreements within the 1837 Ceded Territory Fisheries Technical Committee. The target harvest will approximate an exploitation rate of 24% of the walleye vulnerable to harvest (over age 2). This level of

harvest has been determined to be a safe level from current population modeling done on the Mille Lacs Lake walleye fishery. The 24% level is somewhat less than maximum sustained yield (MSY), the point at which an increase in fishing mortality would result in a depletion of the population and its ability to sustain itself. Being conservative is important because gill netting and spearing are intensive harvest methods that are not affected by prey abundance.

To estimate the target harvest level for any given year, the 24% exploitation is applied to population estimates made from the creel survey, assessment gill net, and trawl data. The target harvest level for 1997 is 320,000 pounds. Because the predicted harvest by state anglers for 1997 is 430,000 pounds, and since the bands intend to harvest 40,000 pounds, the harvest by state licensed anglers must be reduced by 150,000 pounds. To accomplish this reduction, the state imposed a 15-inch minimum size limit in addition to the current special regulations. The 15-inch size limit will likely only work for one year due to anticipated changes in the size structure of the population. To meet the court mandated fixed level of 24% maximum harvest, it is probable that regulations will change on an annual basis.

Northern Pike. Potential yield of northern pike was estimated to be 29,000 pounds, the long term average annual harvest. The current population, however, appears to be less than it was in the 1980s. Increased growth rates, cessation of stocking, loss of spawning habitat, and decreased abundance of northern pike since the early 1980s, suggest that the long term harvest may not be sustainable under current conditions. Therefore, the target harvest level was set at 25% of the average adult population size. This level of harvest is considered to be safe, and is just under the average exploitation estimated for 1992-1996 (26%). It is also less than current estimates of natural mortality, a value that is often considered a conservative target for fishing mortality. Population estimates calculated from mark and recapture experiments for 1992 through 1996 indicated an average of 20,300 adult northern pike. At an average weight of 4.5 pounds per harvested northern pike and a 25% exploitation rate, the target harvest for northern pike population would be 23,000 pounds. It is uncertain at what level the Bands will be harvesting northern pike. They have indicated they do not intend to target pike, but there will undoubtably be an incidental catch in nets set for walleye or cisco. The incidental harvest of pike by the Bands is limited to 50% of the target harvest level. If the total harvest by the Bands and by anglers is higher than the target, angling regulations will be implemented to reduce pike harvest.

Yellow Perch/Northern Cisco/Burbot. Estimates of potential and target yields were based on historical median harvests with adjustments made for the late winter/early spring ice angling fishery. An adjustment was also made for the fall cisco sport netting fishery. The following are the potential, target, and current yields for each of these species: yellow perch, 174,000 pounds; cisco, 29,000 pounds; and burbot, 37,000 pounds. More biological information is needed before target harvests can be adjusted for these species. Yellow perch and cisco are vital components of the food base for walleye, northern pike, and muskellunge. Harvest of these species should not jeopardize the food base of these predators.

Future Management

The management plan for Mille Lacs Lake entails seven parts: 1) assess the fishery to estimate abundance or relative abundance of each species; 2) determine a harvest strategy that guides the determinations of target harvest levels; 3) determine regulation options to produce desired harvest (i.e., regulations, seasons, gear, etc.); 4) monitor and enforce the various fisheries; 5) collect and evaluate biological information as benchmarks of the status of the stocks; 6) protect critical habitat and reclaim those lost due to degradation; and 7) annually evaluate the procedure to determine suitable modifications or adjustments.

Stock Assessment. Annual creel surveys and population assessments will be used to monitor harvest and determine population statistics of the Mille Lacs fishery. Chippewa netting and spearing harvests will also be

monitored. Also, because walleye target harvest levels will change annually, it will be important to have adequate public input into potential alternative regulations that may be suitable for regulating harvest in any given year. Species other than walleye (especially perch, cisco, burbot, and smallmouth bass) need to be assessed in more detail. The 1837 Ceded Territory Fisheries Technical Committee will meet twice a year to evaluate the performance of the procedure, discuss the status of the fishery, and to attempt to reach a consensus on target harvests and other biological issues.

Stocking. Muskellunge stocking will continue semiannually until natural reproduction is deemed sufficient to maintain the fishery. The earliest estimates of the contributions of natural reproduction will be in 1999, when the 1991 year class is fully mature. This year class was marked by a fin clip. Therefore, it can be discerned from naturally reproduced fish of the same age.

Habitat Management. Habitat protection, possible habitat restoration, and pollution abatement should ensure the future of the fishery. Harbor and breakwall issues need to be addressed in terms of "cumulative impacts" to the environment because the construction of harbors and breakwalls alters the capacity of the lake to produce world class walleye fishing. The shoal area mapping project was completed in 1996. This data will be integrated to a GIS database so that the information will be easily accessible for investigating permit requests as well as potential violations. It will also provide a base line to measure changes in habitat. Partnerships with citizens, other government agencies, and local units of government should be supported to manage the watershed for sustainable water quality and aquatic habitat.

Lake Pepin

Description of the Fishery

Lake Pepin is a 25,060 acre natural impoundment of the Mississippi River formed at the confluence of the Chippewa and Mississippi Rivers. The lake is considered part of Pool 4, a 43-mile long, 39,255 acre impoundment created by the U.S. Army Corps of Engineers for commercial navigation. Lake Pepin is roughly 21 miles long and averages 1.7 miles in width. The basin has many characteristics of an inland lake, including a fairly regular shoreline with few backwater bays, and shoal water substrates composed mainly of sand, gravel, and rubble. Much of the shoreline is also comprised of artificial bank protection (riprap). Deeper portions of the lake have predominately silt substrates. Maximum depth is 60 feet and mean depth is 21 feet. Transparencies are typically 1.5 feet. However, in the lower portion of the lake secchi depth often exceeds 3.0 feet.

Lake Pepin has a cosmopolitan fish community comprised of at least 85 species (Rasmussen 1979). The lake is hypereutrophic, thus nongame fish and species of commercial importance comprise a significant portion of fish biomass. Species from this group include gizzard shad *Dorosoma cepedianum*, various shiners., common carp, smallmouth buffalo *Ictiobus bubalus,* bigmouth buffalo *Ictiobus cyprinellus*, several redhorses, and freshwater drum *Aplodinotus grunniens*. Dominant game fish species include sauger, white bass *Morone chyrsops*, walleye, and northern pike. Other game fish species include channel catfish *Ictalurus punctatus*, black crappie, white crappie *Pomoxis annularis*, bluegill, and smallmouth bass, and largemouth bass. In contrast to Minnesota's other large lakes, yellow perch are not important as either forage for picivorous fish, or as a sport fish.

Sauger and walleye are targeted by a majority of open-water anglers except during August, when white bass angling usually peaks. Annual yields average 53,000 pounds for sauger (29% of total fish harvest), 50,000 pounds for white bass (28% of total), and 29,000 pounds for walleye (19% of total; Table 3). Sauger are the most abundant species in Lake Pepin's assessment netting, as shown by a median gill net catch of 21.3 fish/net (Figure 14), far exceeding that of white bass (5.3 fish/net) or of walleye (2.8 fish/net). Recent trends in abundance indicate that the sauger stock is improving from a low period during

the early 1990s (Figures 14 and 15). The walleye population is in excellent condition following a series of good year classes (Figures 16 and 17) produced under ideal spawning conditions (i.e., high, sustained spring water levels). For reasons unknown, recruitment of white bass has been sporadic since the early 1980s.

Northern pike are an important component of the fishery, contributing an average of 13,000 pounds or 7% of the total harvest. Although abundance as measured by gill net assessment is not high (0.5 fish/net), average size caught (4.0 pounds) is large enough to generate considerable angler interest. The majority of angling pressure is seasonally directed toward mid-summer, and early and late ice cover.

In the last several years, channel catfish have gained importance in the open water fishery. Record open-water harvests were recorded in 1994 and 1995 angler surveys, comprising 8% of the total harvest. Snagging of catfish during the ice fishing season was popular during the 1960s and 1970s. Catfish snagging is no longer permitted and no harvest was recorded in recent ice-angler surveys. Channel catfish are moderately abundant in gill nets with an average catch of 4.0 fish/net.

Crappie are of limited importance to Lake Pepin's fishery, comprising 1-2% of the open water yield. In some years, a limited winter fishery develops near Lake City. The crappie fishery is largely confined to backwaters. Median catch of crappie in gill net assessments is 0.9 fish/net.

Smallmouth bass are abundant in shoreline electrofishing samples and show consistently good size structure. Electrofishing catch rates average 26.2 fish/hour for fish 7.0 inches and larger. The harvest of smallmouth bass, less than 1,000 fish annually, has always been a relatively minor component of the fishery. A 14-inch minimum length limit has been in effect since 1990. Angler catch rates indicate that a growing catch and release fishery is developing.

Largemouth bass are a minor component of the Lake Pepin fishery, with annual harvests of less than 500 fish (14-inch minimum length limit). Suitable habitat is limiting for largemouth bass in Lake Pepin, making overall abundance relatively low.

Although abundance of bluegill in Lake Pepin has not been quantified, observation of trawl catches and angler surveys suggests bluegill angling is limited, probably due to a lack of vegetated habitat.

Commercial species such as common carp, smallmouth and bigmouth buffalo, freshwater drum, and catfish species are very abundant, and likely comprise a majority of Lake Pepin's fish biomass.

Management History

The first fisheries survey of Lake Pepin, in 1903-04 (Wagner 1908), attempted to develop a fish species list with comments on abundance. Subsequent investigations by federal, state, and university biologists during the 1920s and 1930s were concerned with the effects of pollution and the construction of dams on fish species abundance and distribution. Fish management studies since the 1950s focused on basic life-history information, including data on age, growth, mortality, population abundance, and spawning locations. Most prominent among modern investigations was Thorn's (1984) study on the effects of continuous angling on walleye and sauger populations.

Several organizations have ongoing monitoring programs on Lake Pepin. Northern States Power, Prairie Island Nuclear Generating Plant, conducts fish population surveys near Lock and Dam #3 (annually since 1973). MNDNR has conducted annual monitoring under the auspices of the LLP since 1986. The U.S. Fish and Wildlife Service has operated a Long-Term Resource Monitoring program (LTRM) field station on Pool 4 since 1990.

Twelve quantitative angler surveys of Pool 4 were conducted between 1962 and 1995 (Table 10). The spring open water fishery (March-April) near the Lock and Dam #3 tailwaters was surveyed 24 times from 1968 to 1995. Numerous qualitative angler surveys (usually catch rates and length-frequency data

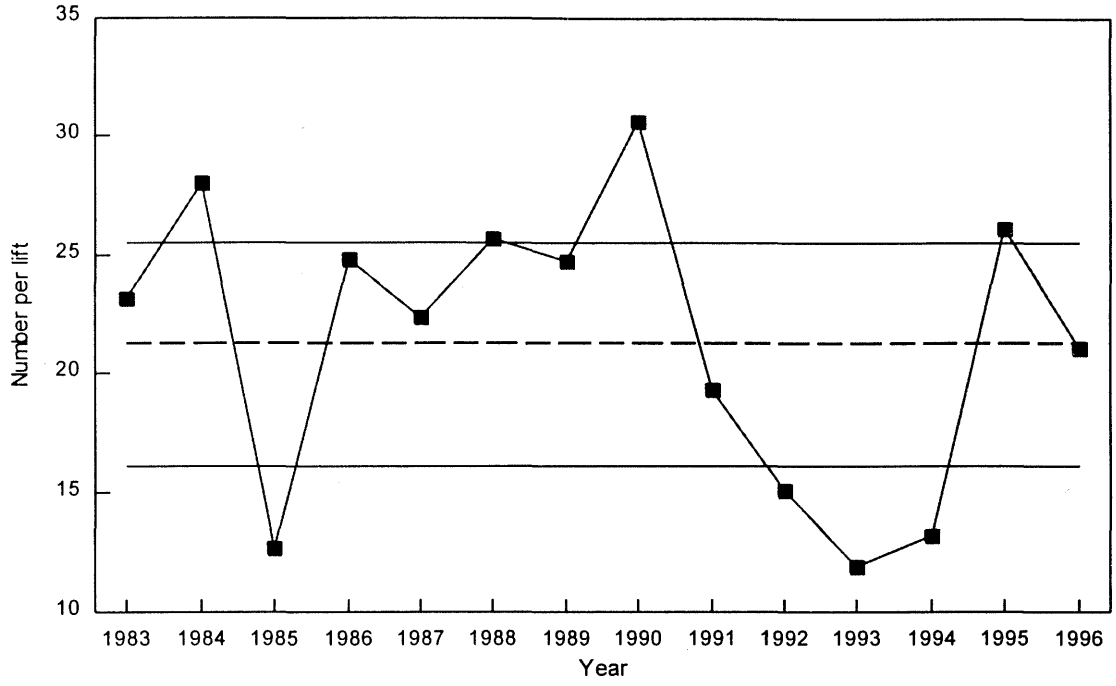

Figure 14. Sauger gill net abundance (1983-1996) for Lake Pepin. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

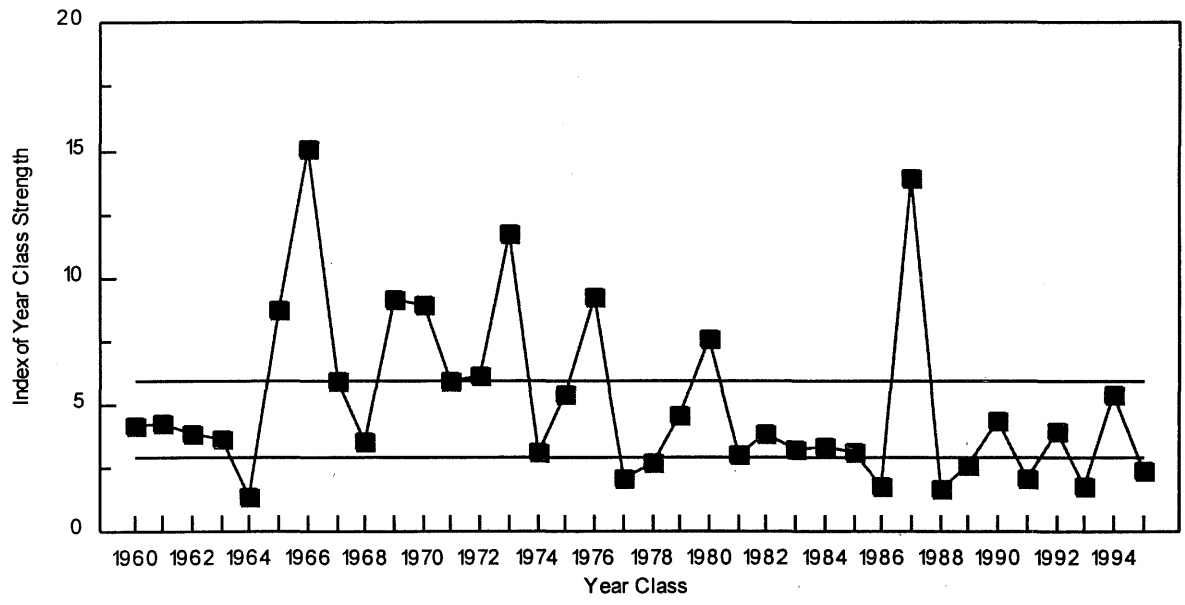

Figure 15. Index of year class strength for sauger from Lake Pepin for the period 1960-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

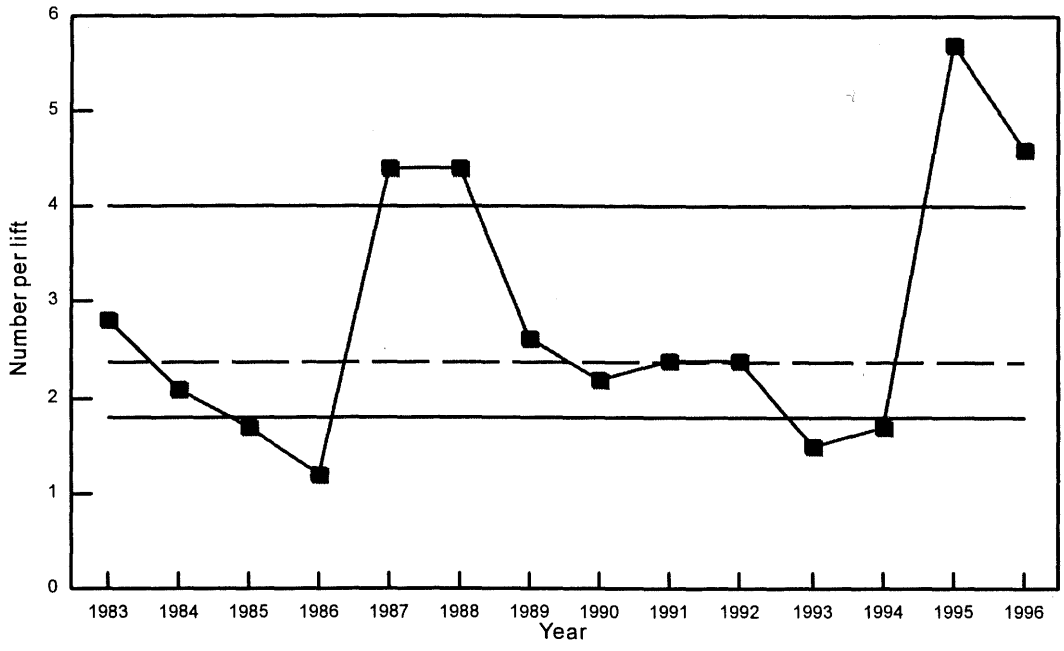

Figure 16. Walleye gill net abundance (1983-1996) for Lake Pepin. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

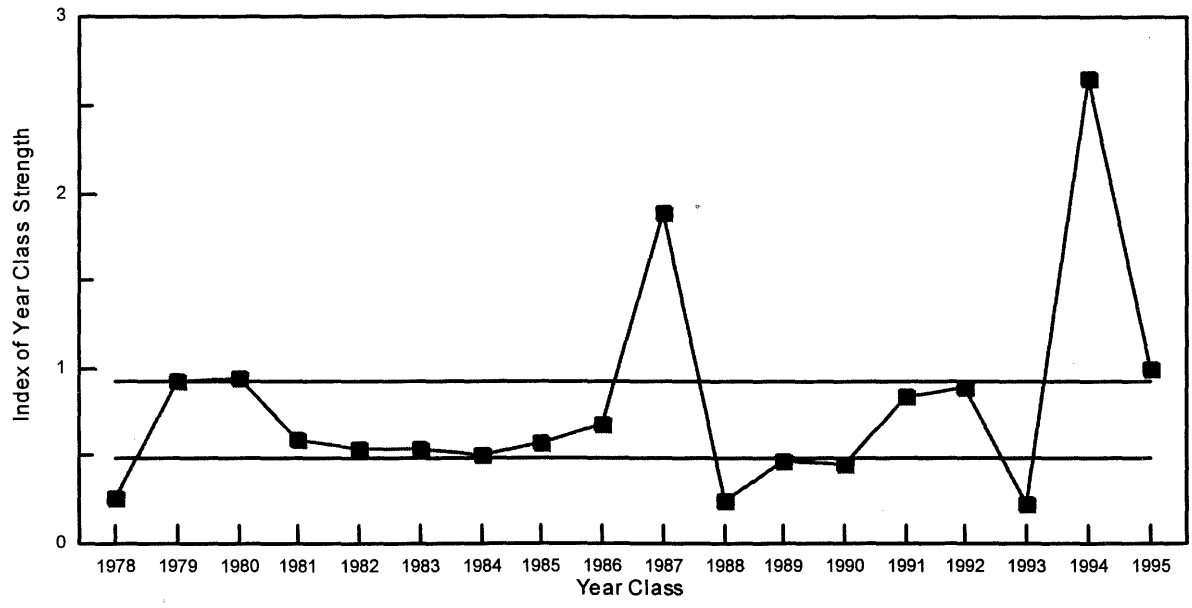

Figure 17. Index of year class strength for walleye from Lake Pepin for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

Table 10. Historical creel survey estimates by species for Lake Pepin.

Winter Summer	1994-95 1995	1993-94 1994	1988-89 1989	1987-88 1988	1972-73 1972	1967-68 1967	1962-63 1962
Total angler-hours	539,223	777,373	449,719	437,462	477,694	575,230	424,243
Walleye							
Total number harvested	8,460	18,124	24,250	24,621	33,362	49,553	19,881
Total pounds harvested	16,074	39,873	29,669	32,253	53,046	87,247	42,745
Mean weight (pounds)	1.9	2.2	1.21	1.31	1.59	1.76	2.15
Harvest rate (fish/angler hour)	0.016	0.023	0.055	0.056	0.07	0.09	0.05
Sauger							
Total number harvested	24,281	46,818	56,020	55,768	129,595	79,403	37,709
Total pounds harvested	29,137	58,782	57,701	68,037	110,156	79,884	39,624
Mean weight (pounds)	1.20	1.26	1.03	1.22	0.85	1.01	1.05
Harvest rate (fish/angler hour)	0.045	0.06	0.125	0.127	0.271	0.14	0.09
Northern Pike							
Total number harvested	733	5,805	2,387	3,311	3,330	9,972	4,104
Total pounds harvested	4,200	24,205	12,771	10,396	9,757	39,100	12,517
Mean weight (pounds)	5.73	4.17	5.35	3.14	2.93	3.92	3.05
Harvest rate (fish/angler hour)	0.001	0.007	0.005	0.008	0.007	0.02	0.01
White Bass							
Total number harvested	59,940	71,092	59,971	53,248	72,816	36,143	78,414
Total pounds harvested	32,971	69,788	47,537	49,521	70,632	31,615	74,499
Mean weight (pounds)	0.55	0.98	0.82	0.93	0.97	0.87	0.95
Harvest rate (fish/angler hour)	0.111	0.091	0.129	0.122	0.152	0.06	0.18
Other							
Total number harvested	27,681	54,404	70,555	85,320	61,264	184,897	171,937
Total pounds harvested	17,993	31,477	35,038	48,152	49,417	123,727	97,709
Mean weight (pounds)	0.65	0.58	0.50	0.56	0.81	0.67	0.57
Harvest rate (fish/angler hour)	0.059	0.084	0.184	0.219	0.128	0.32	0.41

only) for Pool 4 were conducted between 1944 and 1966.

The earliest limnological investigation was conducted in 1921, quantifying plankton and describing water chemistry of Lakes Pepin and Keokuk (Galtsoff 1924). Since that time, a rich collection of studies have been completed describing Lake Pepin's water quality, especially with reference to pollution. Eutrophication has been studied intensively from the 1970s to present, emphasizing phosphorus loadings from point sources originating in the Twin Cities, and non-point loading from the Minnesota River watershed. Accumulation of toxins in the environment and in fish tissue is also a concern, and has been the focus of much work.

Many studies on the river today are initiated by the Army Corps of Engineers in support of their operation of the navigation system. Recent studies have focused on monitoring of corps-financed habitat projects, or have tried to model impacts that might be associated with a potential expansion of the navigation system.

Potential and Target Harvest

Potential and target harvests for all species were set at current harvest levels (the median of values from 1988-95; Table 3). These levels are reflective of current population levels and are sustainable under expected variation of environmental conditions. Several historical harvest values are outliers and could not be used for estimating sustainable yields. Estimates from three earlier surveys (1962, '67, '72) were not considered to be sustainable. A large build up in the walleye and sauger population in the 1960s resulted in harvests of 87,000 pounds of walleye in 1967 and 130,000 pounds of sauger in 1972 (Table 10). This level of harvest is clearly not to be expected under current population levels as indicated by assessment netting (netting began in 1965). Five additional creel surveys conducted from 1977 to 1981 were not used because they lacked data for species other than walleye and sauger.

The mean of the 13 predictive yield models was 159,000 pounds for all species, 21,000 pounds (19%) less than the current (180,000 pounds) yield (Table 3). This residual difference likely results from the large proportion of non-target species in the observed yield, which is relatively large compared to the other large lakes, and is expected of a cosmopolitan, riverine fish community.

Because of fast growth rates, the 15-inch minimum length limit only protects walleye from harvest for about one year. This regulation was developed in conjunction with Wisconsin biologists using GIFSIM (Taylor 1981) modeling with Lake Pepin data. The regulation has been in effect since May 1990. Current harvest data reflects two years of preregulation data and two years following implementation of the regulation.

Sauger population abundance, as measured by assessment netting, has been relatively stable since the late 1970s. Sauger populations are often subject to wide swings in abundance; however, we do not know what conditions control recruitment. The target harvest level for sauger should be monitored and adjusted as the population changes with changes to recruitment.

Target harvests may need to be adjusted more frequently on Lake Pepin than on other large lakes because of its riverine features. Temperature, trophic state, water flow, and other weather-related phenomena (Pereira et al. 1993) may play a larger role in determining species composition and fish production than does angler harvest, especially for Lake Pepin. Changes in the degree of anthropogenic euthrophication of Lake Pepin due to varying land-use policies and practices, and to water treatment practices in the Twin Cities area, will likely influence the Lake Pepin fish community. Setting target yields to track population levels may prevent overexploitation of a fluctuating resource.

Future Management

Stock Assessment. Seining, gill netting, and electrofishing are essential for stock assessment and should be continued. Seining pro-

vides data on fish reproduction and community composition. Gill netting and electrofishing (daytime for adults, night for young-of-the-year) provide data on year-class strength and growth that are essential for management of walleye, sauger, white bass, and smallmouth bass.

Creel surveys provide essential information on fishing pressure, catch, and harvest. Creel surveys should continue to be done two consecutive years out of six. These surveys, along with routine stock assessment, form the backbone of fisheries management. This information is used in environmental review, and to describe year-class fluctuations and angling expectations to area clientele in the form a brochure distributed to the public annually.

Experimental Regulations. Additional angling regulations are not being considered for Lake Pepin at the present time. Minimum size limits for walleye, and smallmouth and largemouth bass were implemented in recent years over concerns about population size structure. The effectiveness of these regulations will be difficult to assess due to natural fluctuations in year-class strength commonly observed on Lake Pepin.

Habitat Management. A study to determine location of sauger and walleye in winter in Lake Pepin using radiotelemetry will be completed from 1997-99. Anglers have complained since the 1980s about poor winter angling for sauger and walleye relative to summer success, raising concern that habitat, possibly thermal habitat, may have changed. Additional information on spawning locations would also be obtained to determine the existence of discrete sub-populations of walleye, as suggested by an analysis of tagging data from the 1970s.

Densities of zebra mussels in Lake Pepin continue to increase, particularly in the lower half of the lake. Monitoring of zebra mussels is provided by MNDNR Section of Ecological Services, who annually sample and report on densities and new areas of colonization. Ongoing fish assessments must be examined with respect to the presence of zebra mussels, which can be expected to change energy pathways, leading to changes in fish species composition and growth of some species. Numerous other exotics (fish, plants, crustaceans) in the Mississippi River system (tributaries) need to be tracked.

Rainy lake

Description of the Fishery

Rainy Lake is located on the international border between Minnesota and Ontario. The lake is a natural reservoir of a drainage system that begins in northeastern Minnesota and ends at Hudson Bay. The surface area of Rainy Lake is 220,800 acres of which 75 percent is in Ontario. Three geographically distinct basins form the lake. The North Arm and Red Gut Bay lie entirely in Ontario and the South Arm is divided by the international border. Minnesota's portion of Rainy Lake covers 54,140 acres. Approximately, 65% (35,142 acres) of the Minnesota waters lie within the boundaries of Voyageurs National Park (VNP). The length of shoreline in Minnesota is 973 miles. The maximum depth is 161 feet, however, 35 percent of the Minnesota waters are less than 15 feet deep. Water levels on Rainy Lake were originally controlled by a rock sill on the Rainy River. Water levels now are controlled by a dam constructed in 1909 at International Falls. Water levels fluctuate an average of 3.6 feet per year, 2.6 feet less than pre-dam conditions (Flug 1986).

Rainy Lake is typical of lakes on the Canadian shield. Waters are soft and infertile, with little aquatic vegetation. Most of the lake basin is composed of bedrock and much of the shoreline is rocky and irregular. The shoreline, and most of the 1,600 islands, is heavily forested. Development is concentrated within areas accessible by road and lying outside the boundaries of VNP.

On average, sport anglers spend 130,000 hours fishing during the open water season on Rainy Lake. Effort has increased over the last several years. Walleye are the primary component of the sport fishery, comprising 58% of the total harvest by number and 47% by weight from U. S. waters (Table 11).

Table 11. Historical creel survey estimates by species for the Minnesota waters of Rainy Lake.

Winter - Summer	1996	1995	1994	1993	1992	1990	1989	1988	1987	1986	1985	1984	1983	1978
Total Angler-hours	171,038	167,964	137,449	111,498	120,834	158,069	137,655	84,662	165,297	112,073	153,618	115,982	117,786	113,694
Walleye														
Total number harvested	35,633	23,199	26,314	14,238	19,461	34,992	22,824	8,217	9,617	18,199	33,369	15,885	18,095	14,405
Total pounds harvested	35,781	24,866	26,047	15,841	25,591	40,454	26,077	6,551	13,249	17,571	37,390	20,968	17,226	16,668
Mean weight (pounds)	1.00	1.07	0.99	1.11	1.31	1.16	1.14	0.80	1.38	0.97	1.12	1.32	0.95	1.16
Harvest rate (fish/angler-hour)	0.208	0.138	0.191	0.128	0.161	0.221	0.166	0.097	0.058	0.162	0.217	0.137	0.154	0.127
Sauger														
Total number harvested	2,965	3,262	3,096	1,229	1,396	5,254	3,680	1,421	1,863	922	936	563		521
Total pounds harvested	1,641	1,543	1,510	831	994	3,158	1,908	737	1,130	509		260		460
Mean weight (pounds)	0.55	0.47	0.49	0.68	0.71	0.60	0.52	0.52	0.61	0.55		0.46		0.88
Harvest rate (fish/angler-hour)	0.017	0.019	0.023	0.011	0.012	0.033	0.027	0.017	0.011	0.008	0.006	0.005		0.005
Yellow Perch														
Total number harvested			702	846	638	1,800	621	664	374	755	1,488	1,906		1,369
Total pounds harvested			463	255	181	604	212	257		373		821		873
Mean weight (pounds)			0.66	0.30	0.28	0.34	0.34	0.39		0.49		0.43		0.64
Harvest rate (fish/angler-hour)			0.005	0.008	0.005	0.011	0.005	0.008	0.002	0.007	0.010	0.016		0.012
Northern Pike														
Total number harvested	5,613	5,047	2,714	2,229	2,599	8,373	9,612	6,044	11,623	15,451	9,840	5,301	2,227	11,625
Total pounds harvested	22,577	20,187	8,885	9,313	9,033	24,456	28,813	16,081	29,866	36,392	24,776	13,517	5,733	27,671
Mean weight (pounds)	4.02	4.00	3.27	4.18	3.48	2.92	3.00	2.66	2.57	2.36	2.52	2.55	2.57	2.38
Harvest rate (fish/angler-hour)	0.033	0.030	0.020	0.020	0.022	0.053	0.070	0.071	0.070	0.138	0.064	0.046	0.019	0.102
Black Crappie														
Total number harvested	491	3,082	6,158	2,629	7,911	4,514	7,506	3,257	4,801	2,489	810	675		556
Total pounds harvested	619	3,111	6,281	2,824	6,185	3,750	1,876	2,617	3,261	1,991		525		556
Mean weight (pounds)	1.26	1.01	1.02	1.07	0.78	0.83	0.25	0.80	0.68	0.80		0.78		1.00
Harvest rate (fish/angler-hour)	0.003	0.018	0.045	0.024	0.065	0.029	0.055	0.038	0.029	0.022	0.005	0.006		0.005
Smallmouth Bass														
Total number harvested	610	1,870	345	457	1,196	2,166	3,023	1,950	3,730	388	6,931	1,686		986
Total pounds harvested	1,385	2,968	359	607	2,032	2,550	6,295	2,403	3,613	291		1,282		1,987
Mean weight (pounds)	2.27	1.159	1.04	1.33	1.70	1.18	2.08	1.23	0.97	0.75		0.76		2.02
Harvest rate (fish/angler-hour)	0.004	0.011	0.003	0.004	0.010	0.014	0.022	0.023	0.023	0.003	0.045	0.015		0.009

Other species reported in the catch include northern pike, sauger, black crappie, smallmouth bass, yellow perch, rock bass and to a lesser extent black bullhead, burbot, white sucker, largemouth bass and lake sturgeon. One commercial fisherman remains on the Minnesota waters and his harvest consists primarily of lake whitefish with lesser amounts of burbot, longnose sucker *Catostomas catostomas*, and cisco.

The walleye population on Rainy Lake is in a state of recovery. Years of overharvest, primarily by commercial netting, and artificial water level management (Cohen et al. 1991) are believed responsible for low overall abundance and poor fishing. Commercial fishing was discontinued in 1985, and an experimental regulation was initiated in 1994 to reduce the sport fishing harvest and aid in the recovery of this stock. Overall gill net catch rates for all walleye and for those over 17 inches have improved in recent years (Figure 18). The catch rate of anglers targeting walleye has also improved. Increases in abundance have been due primarily to the recruitment of several strong year-classes. The 1991 and 1994 year-classes are the strongest recorded on Rainy Lake (Figure 19). Angler catch rates and gill net indices have been strongly influenced by these year-classes. Early indications are that the 1995 year-class is also very strong. The average annual harvest from Minnesota waters since 1984 is 24,200 pounds. The 1996 harvest was 35,800 pounds.

Northern pike are an important component of the sport fishery, comprising 40% of the yield. The average annual harvest of northern pike is 20,300 pounds. Harvest from 1990 to 1996 was considerably less than that recorded during the 1980s. Recruitment during the late 1980s and early 1990s was poor. As a result, abundance declined considerably while mean size and age increased. In 1994, harvest reached its lowest level since 1983. The stock has shown signs of recovery since 1994. Assessment netting has demonstrated improved recruitment and angler catch rates have improved as these fish grow to a catchable size.

Black crappie are also an important component of the fishery and in many years are sought by more anglers than all other species except walleye. The average annual harvest is 3,000 pounds. Stock abundance has varied considerably. Angler harvest reached an historic high in 1994 at 6,300 pounds but by 1996 harvest had dropped to its lowest level since 1984 (600 pounds). Trap net catch rates indicate a similar trend, dropping to an all-time low in 1996. Mean length of angler harvested crappie remained high at 12 inches. Rainy Lake is on the extreme northern end of the crappie range, a point which may explain the wide fluctuations in recruitment.

Smallmouth bass are a minor component of the fishery with an annual harvest of 2,200 pounds. From 1993-96, only 1.2% of the angling parties interviewed were specifically fishing for bass. Smallmouth bass harvest has fluctuated considerably from a low of 300 pounds in 1986 to a high of 6,300 pounds in 1989. Fluctuations appear to be related more to angler behavior than stock abundance. Abundance appears to be stable with a median electrofishing catch rate of 20.9 fish per hour.

Sauger and yellow perch make up minor components of the fishery on Rainy Lake. The combined harvest of these two species since 1984 averaged 1,600 pounds per year. Neither species attain a size large enough to be desirable to anglers.

Management History

Numerous fishery surveys and other investigations have been completed on Rainy Lake. The earliest assessment was conducted in 1955 and used trap nets (Burrows 1955). The first assessment using experimental gill nets was completed in 1959 (Bonde et al. 1961). Several other assessments were completed during the 1960s in response to complaints of poor fishing. These investigations revealed a decline in walleye abundance during the period (Bonde et al. 1961; Bonde et al. 1965; Johnson et al. 1966; Johnson 1967).

In 1969, the International Falls Fisheries Office was established. Annual gill net assessments were completed from 1970 to 1981

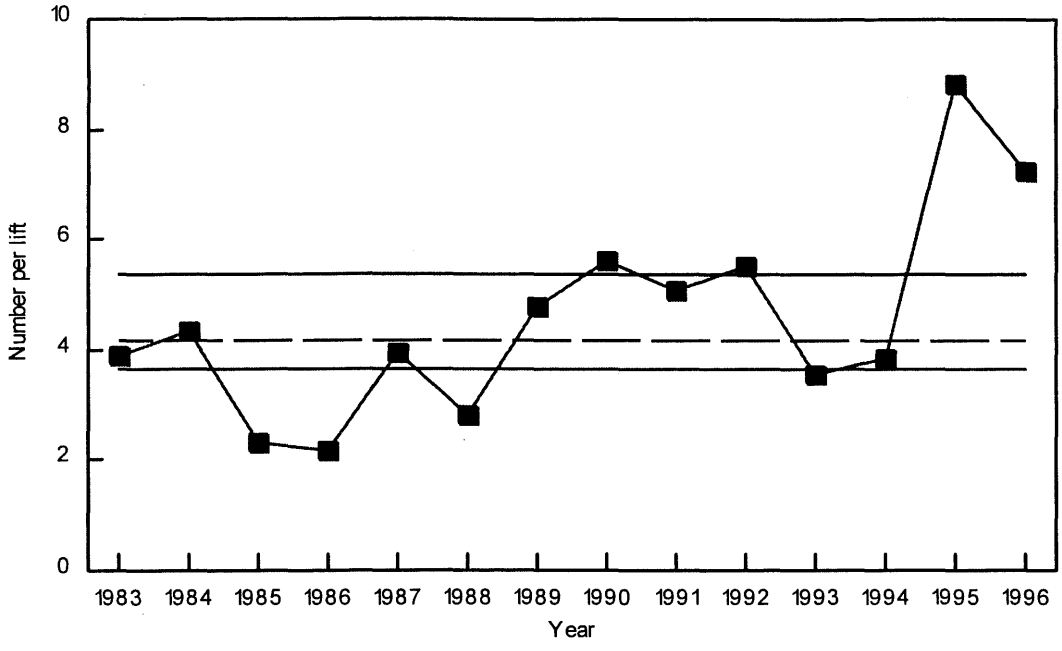

Figure 18. Walleye gill net abundance (1983-1996) for Rainy Lake. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

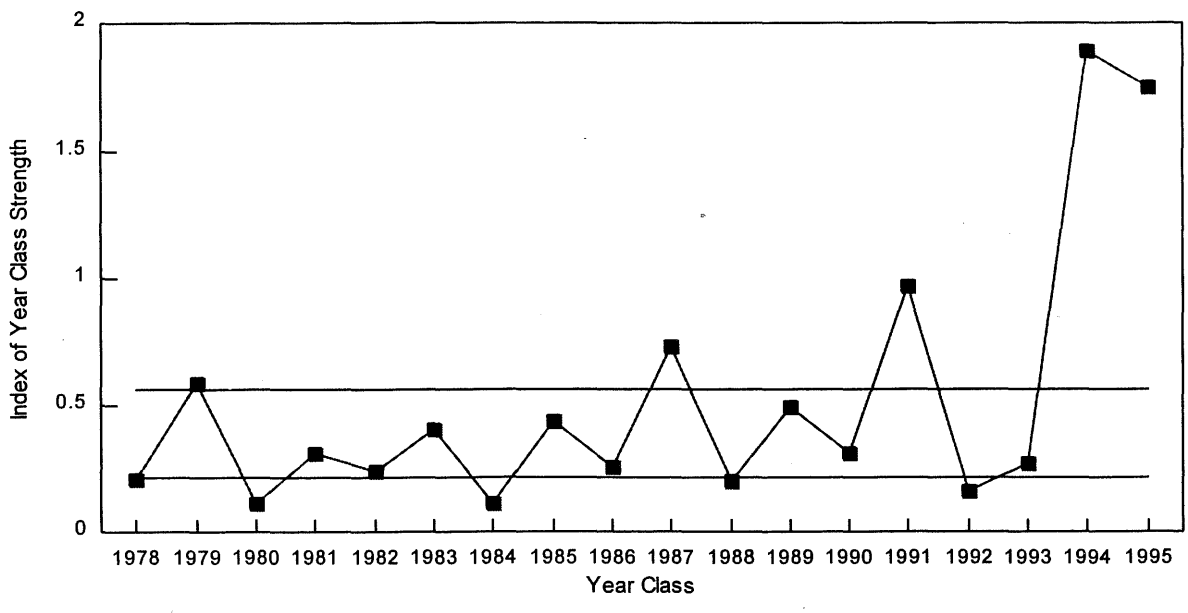

Figure 19. Index of year class strength for walleye from Rainy Lake for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

using 25 standardized net locations. Beginning in 1983, sampling followed the methods described in the *Large Lake Sampling Guide*. Spring trap netting, fall electrofishing and fall small-mesh gill netting have been conducted annually beginning in the early 1990s. The aquatic biology unit at VNP has conducted additional sampling including deep water gill netting, mid-water and bottom trawling and expanded small-mesh gill netting.

With the establishment of VNP in 1974, angling effort was expected to increase on the lakes within the park. As a result, creel surveys were conducted in 1977 and 1978 (Ernst and Osborn 1980) to document "baseline" conditions. Since then, creel surveys have been conducted annually from 1983-90 and 1992-96 (Wingate 1987; Kingsley 1989; Eibler 1990, 1991, 1993, 1994, 1995, 1996, 1997).

Several studies have concluded that artificial water level fluctuations created by the operation of the International Falls dam have had negative impacts on the Rainy Lake aquatic community (Chevalier 1977; Johnson 1967; Johnson, et al., 1966; Osborn, et al. 1981; Cohen et al.1991; Kallemeyn 1987; Kallemeyn and Cole 1990). As a result, a committee composed of private and public representatives was formed to investigate alternative water level management. The committee adopted a compromise rule curve after attempting to incorporate the interests of all user-groups. The International Joint Commission (IJC), the body that governs water levels on this border lake, is currently conducting its own review of the curve before considering implementation.

Commercial fishing has taken place on Rainy Lake for more than 100 years. Catch records date back to 1908. Commercial fishing began in 1885 for lake sturgeon. Gill netting began in 1904, primarily for lake whitefish. Walleye, northern pike, and lake whitefish have been the most important species economically since the 1920s. From 1920 to 1950, the reported annual commercial walleye harvest averaged nearly 50,000 pounds. However, following this period, the commercial fishery was gradually reduced by various means until, in 1985, all remaining commercial fishers accepted terms of a legislated buy-out. One permit is still issued for the harvest of lake whitefish from Minnesota waters.

Rainy Lake has a long history of fish stocking. A walleye spawning site was operated on the Rat Root River in the early part of the century until 1943. Eggs taken were shipped to a hatchery in Ranier which operated up until 1943. Fry hatched in Ranier were stocked throughout northern Minnesota including Rainy Lake. Fry were stocked annually from 1937 through 1943, 1967 through 1985 and again in 1987. Fingerlings were stocked annually from 1981 through 1996. Beginning in 1982, Tilson Pond, a cooperative walleye rearing pond with the Rainy Lake Sportfishing Club, was used to raise fingerlings. Prior to 1950, stocking of other species including lake trout *Salvelinus namaycush*, bass, crappie, catfish, perch, sunfish, and northern pike occurred.

Since 1967, several artificial spawning reefs have been constructed in Black Bay to enhance walleye reproduction. These reef projects were completed in cooperation with the Rainy Lake Sportfishing Club.

The Rainy Lake Sportfishing Club sponsored one of Minnesota's first catch and release programs to help reduce the harvest of walleye and to improve the size structure of northern pike and smallmouth bass. The MNDNR has provided some funding for this project in the past. In 1996, the club applied for and received funding from the Legislative Commission on Minnesota Resources (LCMR) for the continuation of this popular program.

Regulations on Rainy Lake have been altered to improve fish populations. Beginning in 1971, Black Bay was established as a walleye spawning sanctuary and the fishing season was delayed approximately two weeks to reduce exploitation on concentrations of spawning fish. Beginning in 1990, the possession limit of walleye was reduced from 8 to 6 and only one over 19.5 inches in length was allowed. Also, in 1990, the limit of northern pike was reduced to 3, one of which could be over 28 inches in length. In 1984, the first Minnesota-Ontario Boundary Waters Fisheries Atlas (1984) was completed and the walleye

target yield was set at 32,900 pounds. In 1992, the walleye target harvest level was reduced to 20,000 pounds to aide in the recovery of the impaired walleye stock (Minnesota-Ontario Boundary Waters Fisheries Atlas 1992). As a result, an experimental regulation protecting walleye from 17 to 25 inches (with one over 25 inches allowed) in length was implemented on May 14, 1994. The efficacy of this regulation has yet to be determined, however, public opinion has been favorable.

Potential and Target Harvest

Methods used to establish potential and target harvest levels for Rainy Lake may differ from those described for other lakes because the lake is a shared resource and harvest levels are coordinated with the Ontario Ministry of Natural Resources (Minnesota-Ontario Boundary Waters Fisheries Atlas 1992). Current harvest levels were set based on the mean of the six angler creel surveys conducted since 1990 (each year except 1991) for all species except lake whitefish. Estimates for this species were based on the commercial harvests from 1990-96. Potential yields were based on Ryder's Morphoedaphic Index (MEI). Total fish yields predicted by MEI were then partitioned among the species using the approach described in SPOF 12. Potential yield for lake sturgeon was based on the Border Waters Lake Sturgeon Management Committee's recommendation of 0.0357 pounds per acre per year.

Walleye. The potential yield for walleye is 32,900 pounds. Because the walleye stock is in a state of recovery the target yield was reduced by 40% from the potential to 20,000 pounds. The current harvest is approximately 28,100 pounds.

Northern Pike. The potential and target yield for northern pike is 22,000 pounds. The current harvest is 15,700 pounds.

Black Crappie and Smallmouth Bass. SPOF 12 combines black crappie and smallmouth bass in one partition for centrarchids. The potential yield for these two species combined is 18,700 pounds. The black crappie potential yield is 10,900 pounds and the smallmouth bass potential is 7,800 pounds. These potentials were determined by applying the relative proportion of each species in the creel (1984-96 surveys) to the total centrarchid potential. The current black crappie harvest is 3,800 pounds while the smallmouth bass harvest is 1,700 pounds.

Sauger and Yellow Perch. Sauger and yellow perch were not part of the original yield estimates in the Minnesota-Ontario Boundary Waters Fisheries Atlas because they represent a minor component of the fishery. Potential and target harvest yields were set at 2,000 pounds and 1,000 pounds, respectively. The current harvest of sauger is 1,600 pounds and the current harvest of yellow perch is 300 pounds.

Lake Whitefish. The potential and target yields for lake whitefish were set at 26,400 pounds. This is a reduction from the previous target harvest due to unknown impacts from rainbow smelt *Osmerus mordax*, a recent addition to the Rainy Lake fish community. The current mean annual harvest (1990-96) by the lone commercial fisherman remaining on the Minnesota waters of Rainy Lake is 22,500 pounds. Sport gill netting at this time is a minor component of the total whitefish harvest.

Lake Sturgeon. The lake sturgeon potential yield is 1,900 pounds, however, since little is currently known of the stock status of this species, the target has been set at zero. Assessment work for this species has been planned by the MNDNR beginning with the 1998 field season.

Future Management

Stock Assessment. Standard assessment netting based on the *Large Lake Sampling Guide* will be continued. Additional sampling should include periodic spring electrofishing of the Rat Root River to monitor the walleye spawning run, spring trap netting to assess black crappie stocks, fall electrofishing to assess smallmouth bass stocks and age-0 walleye abundance and growth, and fall small-mesh gill netting to assess rainbow smelt stocks. Creel surveys should continue on an annual basis at least until the experimental walleye regulation can be assessed (through 2000). A

winter creel survey should be conducted (preferably in two consecutive years) to quantify effort and harvest during this period.

Experimental Regulations. A protected size limit from 17 to 25 inches, with only one fish over 25 inches, is currently in place for walleye on Rainy Lake. This regulation will be evaluated following the 1999 open water angling season. Because it is a border water, many regulations for Rainy Lake differ from Minnesota's inland lakes. Unlike inland waters, the season is continuous for northern pike and bass. Only one pike over 28 inches is allowed. The walleye/sauger combined limit is 14 provided no more than 6 are walleye, therefore, up to 14 sauger may be taken. The black crappie limit on the main lake is 30, however, in Black Bay the limit is 15. The sturgeon season opens on June 30th and runs until the following May 15th. All other species have continuous seasons and the same inland limits apply.

Regulations designed to improve abundance or size structure of northern pike or smallmouth bass may be considered if support among user groups develops or if target yields are routinely exceeded.

Stocking. No stocking is currently planned for Rainy Lake. Stocking will only be considered as a viable management tool if spawning stock size declines to a point where recruitment is impaired.

Habitat Management. Support should continue for the process that began in the early 1990s to alter the present water level management regime to one that is more favorable for the production of aquatic plants and animals. As part of the IJC's review process two independent fisheries scientists have each concluded separately that the steering committee's proposed rule curve would be beneficial to fisheries resources. Other aspects of the proposed curve are currently under review. This process should be supported and expedited wherever possible.

The shoreline of Rainy Lake is extensively developed from the outflow at Ranier to the boundary of Voyageurs National Park. Heavy development exists both on the mainland and many of the islands. Permit applications for shoreline alterations should be closely scrutinized to preserve aquatic habitat wherever possible. Public education should be used to encourage ecologically sound shoreland management. In addition, present development should be inventoried to better monitor changes that might affect aquatic resources.

A lakewide aquatic vegetation survey should be conducted to inventory present conditions. Such a survey has never been conducted. This inventory would be valuable in locating important spawning habitat and provide baseline data for future assessments.

A local initiative to provide sewer service to lake residents should be supported. Presently, most lake homes utilize septic fields to handle waste loads. Many of these systems are old, located on shallow soils underlain with clay or bedrock and, undoubtedly some are leeching into the lake. Sewer service would be extremely beneficial to the long term protection of water quality.

Upper Red Lake

Description of the Fishery

The fish stocks of Upper and Lower Red Lakes are broadly linked, as are the lakes themselves. Lower Red Lake has a surface area of 167,000 acres and lies entirely within the Red Lake Indian Reservation. Upper Red Lake has a surface area of 108,000 acres, of which 48,000 acres (44%) lies outside of the reservation. Upper Red Lake is a large shallow basin located in the headwaters of the Red River of the North drainage. Upper Red Lake has a uniform shoreline with substrates usually consisting of sand mixed with significant areas of gravel and rubble. Marshy areas exist upstream in tributary rivers and ditches but not on the shoreline proper. The shoreline slope is very gradual along the entire shoreline. Due to the shallow nature of the basin (maximum depth of 18 feet), and near constant wave action, thermal and chemical stratification does not occur. Water temperatures usually track air temperatures closely throughout the open water season. The large fetch has a significant effect on the distribution of substrate particles

of various sizes. Troughs in the sand running parallel to shore are common around much of the lake out to depths of 5-6 feet.

Upper Red Lake has a relatively simple fish community for a lake its size. Walleye and yellow perch have usually been the most abundant species, but freshwater drum have also been abundant, particularly in years when walleye abundance is low. Other species present include lake whitefish, bullhead spp., shorthead redhorse, largemouth bass, rock bass, goldeye *Hiodon alosoides*, and black crappie. Black crappie have increased in abundance the past several years. Nongame species include various shiners and darters, troutperch, and quillback *Carpoides cyprinus*.

Summer angling pressure has fluctuated with abundance of walleye, ranging from 57,295 to 214,515 angler hours per year. Winter angling pressure responds to both walleye abundance and on-ice travel conditions, ranging from less than 1,000 to 220,266 angler hours per year. A commercial fishery for walleye exists on Lower Red Lake and the western half of Upper Red Lake and has had a dramatic effect on the fish community. Other species harvested commercially include yellow perch, freshwater drum, black crappie, northern pike, and lake whitefish.

Walleye is the main component of both the summer and winter sport fisheries, comprising 81-89% by weight of the total sport fishing yield for 1989, 1995, and 1996 (Table 12). The median experimental gill net catch for walleye from 1984-1996 was 12.0 fish/net (Figure 20). Wide variations in year class strength are experienced by this heavily exploited population. The walleye population has been overfished for many years and has collapsed in Upper Red Lake due to recruitment failures in 1987 and 1988 and poor recruitment in most years since 1985 (Figure 21).

Yellow perch can be significant in the sport fishery, but catch and harvest generally are low in comparison to walleye. Yellow perch, are also exploited commercially, like walleye, and experience large variations in recruitment. Northern pike, black crappie, and freshwater drum also contribute small numbers to the sport harvest. Northern pike abundance (experimental gill net catch) has remained fairly stable since 1983. Abundance of black crappie has increased the past several years. The 1994 year class outnumbered walleye almost two to one in the 1996 experimental gill net catch. Freshwater drum have never been abundant in experimental gill nets. Their abundance, as measured by the angler catch rate and commercial harvest, may be more accurate.

Management History

A walleye egg-take site and hatchery were operated on the Tamarac River from 1940-1979. These fish were stocked in many Minnesota waters as well as other states and provinces. Approximately 10 percent of the eggs taken during spawn take each year were returned to Upper Red Lake as fry. Stocking activities for species other than walleye were very limited. Stocking activities by Red Lake Band have included walleye, northern pike, and yellow perch but the extent is unknown.

A survey of the Tamarac River upstream of the hatchery was completed in 1963. Experimental gill netting, beach seining, and electrofishing were conducted on an irregular basis from 1973-1983. The LLP was implemented on Upper Red Lake in 1984, and consists of gill netting (8 sets, 4 stations), seining (15 hauls, 5 stations), electrofishing (6 stations, approximately 3-4 hours), and creel surveys (2 years out of 6). Some spring trap netting and electrofishing has been carried out on an irregular basis since 1984.

Numerous studies of the fisheries of Upper and Lower Red Lake by Dr. Lloyd L. Smith Jr. and students from the University of Minnesota were carried out from the 1940s through the 1970s. Additional work during the 1980s and 1990s has been under the direction of Dr. George Spangler. For a number of years, the Fish and Wildlife Service carried out fish sampling on Upper and Lower Red Lakes. Several years ago, the Corps of Engineers mapped lake contours and completed shoreline habitat sampling. The Red Lake Band of Chippewa has a fisheries monitoring program that utilizes methods comparable to those used

Table 12. Historical creel survey estimates by species for Upper Red Lake.

Winter Summer	1996-97 1996	1995-96 1995	1989-90 1989	- 1980	1977-78 1977	1976-77 1976
Total angler-hours	57,511	91,985	337,824	64,538	205,697	265,046
Walleye						
Total number harvested	10,561	25,305	147,684	28,423	88,625	237,378
Total pounds harvested	12,581	24,079	179,205	28,281	60,961	159,594
Mean weight (pounds)	1.19	0.95	1.21	0.99	0.69	0.67
Harvest rate (fish/angler-hour)	0.18	0.28	0.43	0.44	0.43	0.90
Yellow Perch						
Total number harvested	49	1,481	132,830			23,834
Total pounds harvested	17	323	39,883			
Mean weight (pounds)	0.35	0.22	0.30			
Harvest rate (fish/angler-hour)	<.001	0.02	0.38			0.09
Northern Pike						
Total number harvested	716	1,059	2,537			2,559
Total pounds harvested	1,494	2,247	8,475			
Mean weight (pounds)	2.09	2.12	3.34			
Harvest rate (fish/angler-hour)	0.012	0.012	0.007			0.010
Black Crappie						
Total number harvested	228	194	2,677			285
Total pounds harvested	336	202	2,026			
Mean weight (pounds)	1.47	1.04	0.76			
Harvest rate (fish/angler-hour)	0.004	0.002	0.008			0.001

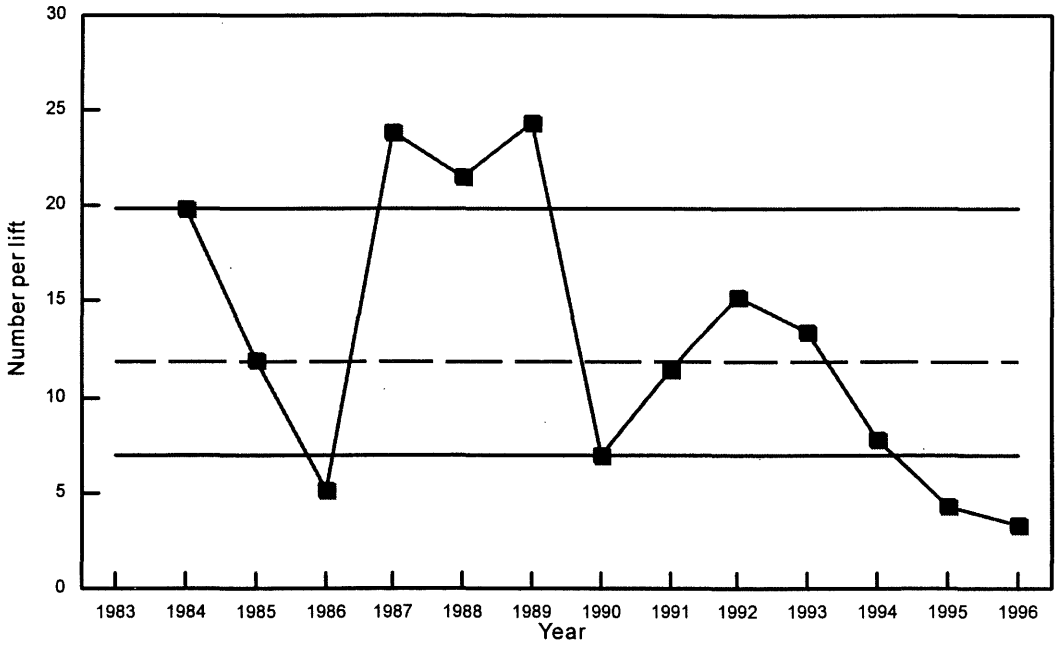

Figure 20. Walleye gill net abundance (1983-1996) for Upper Red Lake. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

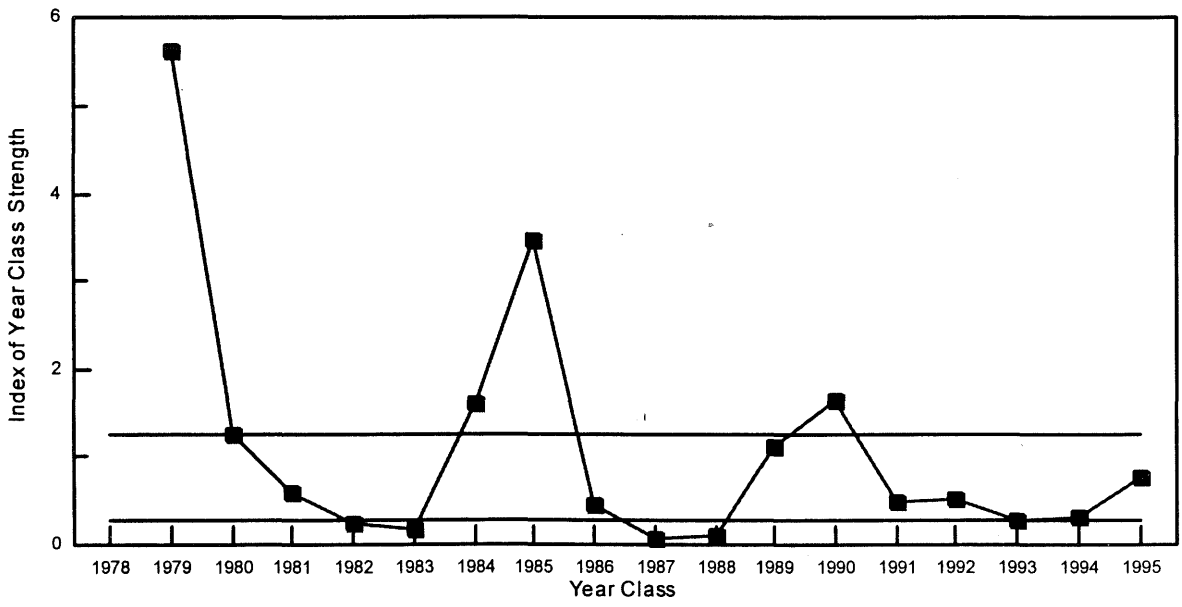

Figure 21. Index of year class strength for walleye from Upper Red Lake for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

by the MNDNR, but using more sets and hauls. Data is also collected from the commercial fishery.

Potential and Target Harvest

Potential yield for the 48,000 acres of Upper Red Lake open to sport angling was estimated by using the median of estimates from the 13 predictive yield models, partitioned using methods described in SPOF 12. Target harvests will not be established until the walleye population has been restored and some semblance of community stability returns. Target harvests will include both sport angling and commercial harvest. Current harvest levels for various species were based on the mean of the 1995 and 1996 summer creel surveys. Because of the large variations in pressure and harvest, means and medians of previous surveys have little value for setting potential or target harvest levels. Using the most recent estimates of pressure and harvest is probably most representative of current conditions. Harvests of species other than walleye are almost entirely incidental, so it is unlikely that actual harvests will ever approach the potential.

Walleye. The potential harvest was estimated at 151,000 pounds, well above the current harvest of 18,300 pounds. It is not likely that the potential harvest will be realized due to the depressed nature of walleye stocks in Upper Red Lake.

Yellow Perch. The potential harvest was set at 64,000 pounds. The current harvest is negligible.

Northern Pike. The potential harvest was set at 32,000 pounds. The current harvest is 1,900 pounds.

Lake Whitefish. The potential harvest was set at 32,000 pounds. Nearly all lake whitefish harvested is by fall gill netting. Few individuals participate in the sport anymore.

Other species. Black crappie and freshwater drum comprise minor portions of the harvest. If recruitment of black crappie continues to increase, angler harvest will likely increase.

Future Management

Stock Assessment. Standard assessment methods described in the *Large Lake Sampling Guide* should be continued. An estimate of spawning stock available and reproductive potential of walleye would be useful in predicting measures needed to rehabilitate the fishery. Additional sampling to evaluate dynamics of black crappie should be investigated. Cooperation and sharing of data between the Red Lake Band and the MNDNR should aid in understanding the fishery and ways to restore it.

Experimental Regulations. No special regulations currently exist for Upper Red Lake. In the spring of 1996, angling was prohibited in the Tamarac River for several days after the walleye opener to protect concentrations of spawning walleye. Restoration efforts may include additional harvest restrictions of longer duration.

Stocking. No stocking of any species is planned at this time.

Habitat Management. The shoreline of Upper Red Lake is relatively undeveloped except for the area in Waskish and along the Tamarac River. Some residences may have inadequate septic systems contributing to localized algae blooms during the summer. Harbor areas often need dredging in low water years, and proper disposal of spoil has been a problem. Encroachment of emergent vegetation into harbors is also an occasional problem. Although development may seem insignificant, permits need to be carefully reviewed and activities monitored to ensure maintenance of adequate spawning and nursery areas.

Operation of the dam on the outlet of Lower Red Lake and maintenance of the current water level regime has been a source of some controversy. There are no plans to alter the current operating schedule.

Lake Vermilion

Description of the Fishery

Lake Vermilion is a large irregularly shaped lake with numerous distinct basins, small bays, and over 350 islands. Geologically,

Lake Vermilion is located at the southwestern edge of the Canadian Shield and has physical characteristics typical of Shield lakes. The shoreline and islands are mostly steep and rocky with only a thin covering of glacial soil. Shoal water substrate is predominantly bedrock, boulder, and rubble. The total surface area of the lake is 40,557 acres and the maximum depth is 76 feet, although most of the lake is less than 40 feet deep. The lake elevation is controlled by a fixed head dam at the outlet to the Vermilion River.

Lake Vermilion has a diverse fish community that is dominated by cisco, northern pike, white sucker, bluegill, smallmouth bass, yellow perch, and walleye. Other species that are present in lesser numbers include whitefish, muskellunge, brown bullhead, burbot, rock bass, largemouth bass, and black crappie. Fishing pressure has increased on Lake Vermilion, from a mean of 9.1 angler hours/acre in 1984-85 to 13.4 angler hours/acre in 1990-91.

Walleye are the primary component of the sport fishery, comprising 54% of the total yield for the four years creel surveys were conducted (Table 13). The estimated annual harvest of walleye is 69,000 pounds. Most of the walleye harvest occurs in the summer, as winter angling on Lake Vermilion is usually insignificant. The median gill net catch for walleye from 1983-1996 was 12.4 fish/net and the population was relatively stable (Figure 22). The walleye age structure is relatively young and the size structure is relatively small. The average age from gill nets is 3.2 years (13.0 inches). Walleye recruitment is moderately variable with occasional strong and poor year classes (Figure 23). Exceptionally strong year classes were produced in 1983 and 1988, while poor year classes were documented in 1985 and 1992. Recruitment appears to be related to first year growth.

Northern pike are a major component of the sport fishery, comprising 20% of the total yield. The estimated annual harvest of northern pike is 26,000 pounds. The median gill net catch from 1983-1996 was 1.0 fish/net and the population is stable. The average length from gill nets is 25.5 inches.

Bluegill and smallmouth bass are also important components of the fishery, comprising 9% and 8% of the total yield respectfully. The estimated annual harvest of these species is 12,000 pounds of bluegill and 10,000 pounds of smallmouth bass. Bluegill were not historically abundant in Lake Vermillion. The population increased during the 1980s, peaked in 1987, and has since declined and stabilized at a moderate level of abundance (median trap net catch = 23.9 fish/net). The average length of bluegill from trap nets is 6.1 inches. The smallmouth bass population appears to be stable with a median electrofishing catch rate of 26.6 fish/hour. The average size of smallmouth bass collected in electrofishing samples is 9.6 inches.

Yellow perch are a minor component of the sport fishery, although they are abundant in the lake. Most perch are not large enough to be acceptable by anglers and there is a high rate of yellow grub infestation. The estimated annual harvest of yellow perch is 2,000 pounds, 2% of the total yield. The median gill net catch from 1983-1996 was 25.8 fish/net. The perch population fluctuated widely during this period, peaking in 1991. A recent increase in the average size of perch in the Big Bay area has the potential to increase fishing pressure directed at perch.

Black crappie and largemouth bass are also minor components of the fishery, comprising 4% and 1% of the total yield respectively. The estimated annual harvest of these species is 5,000 pounds for black crappie and 2,000 pounds for largemouth bass. Population data for largemouth bass is minimal as this species is not readily collected in standard assessment gear. Creel survey data suggests that largemouth bass numbers increased from 1984 to 1991. The median trap net catch of black crappie was 1.4 fish/net. The black crappie population is characterized by highly variable recruitment.

Muskellunge were first introduced in the lake in 1968 and a major stocking program was started in 1987. Spring trap net assessments and angler reports indicate the population is doing well with the larger fish approaching 50 inches.

Table 13. · Historical creel survey estimates by species for Lake Vermilion.

Winter Summer	- 1991	- 1990	1985-86 1985	- 1984
Total angler-hours	567,285	521,106	388,159	378,212
Walleye				
Total number harvested	68,465	78,378	59,254	61,873
Total pounds harvested	68,465	79,162	67,775	57,841
Mean weight (pounds)	1.00	1.01	1.1	0.93
Harvest rate (fish/angler-hour)	0.120	0.150	0.15	0.16
Yellow Perch				
Total number harvested	4,325	3,890	8,545	8,477
Total pounds harvested	1,514	1,478	2,886	2,248
Mean weight (pounds)	0.35	0.38	0.3	0.27
Harvest rate (fish/angler-hour)	0.007	0.007	0.02	0.02
Northern Pike				
Total number harvested	9,153	6,047	9,094	7,153
Total pounds harvested	24,255	16,992	32,001	23,949
Mean weight (pounds)	2.65	2.81	3.5	3.35
Harvest rate (fish/angler-hour)	0.017	0.012	0.02	0.02
Black Crappie				
Total number harvested	15,371	6,663	3,341	3,784
Total pounds harvested	11,375	4,198	1,740	2,533
Mean weight (pounds)	0.74	0.63	0.6	0.67
Harvest rate (fish/angler-hour)	0.026	0.013	0.01	0.01
Smallmouth Bass				
Total number harvested	7,234	6,432	8,233	9,346
Total pounds harvested	8,102	8,426	11,247	11,541
Mean weight (pounds)	1.12	1.31	1.4	1.23
Harvest rate (fish/angler-hour)	0.013	0.012	0.02	0.02
Cisco				
Total number harvested			989	
Total pounds harvested			989	
Mean weight (pounds)			1.0	
Harvest rate (fish/angler-hour)			0.04	
Bluegill				
Total number harvested	60,478	42,213	11,553	13,140
Total pounds harvested	22,982	15,197	3,668	4,481
Mean weight (pounds)	0.038	0.36	0.3	0.37
Harvest rate (fish/angler-hour)	0.110	0.081	0.03	0.03

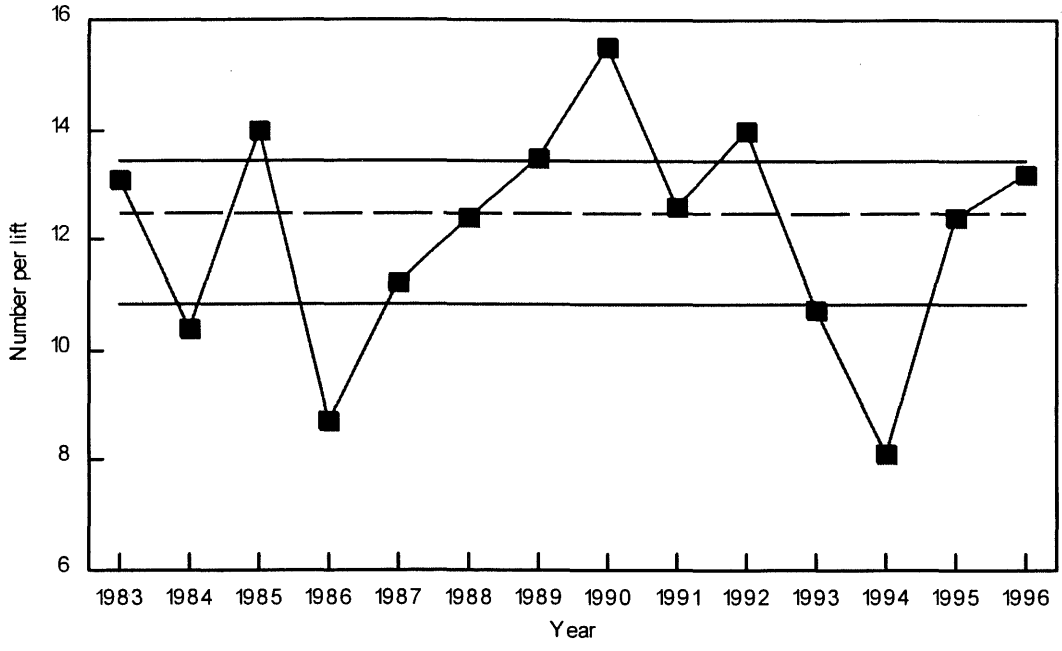

Figure 22. Walleye gill net abundance (1983-1996) for Lake Vermilion. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

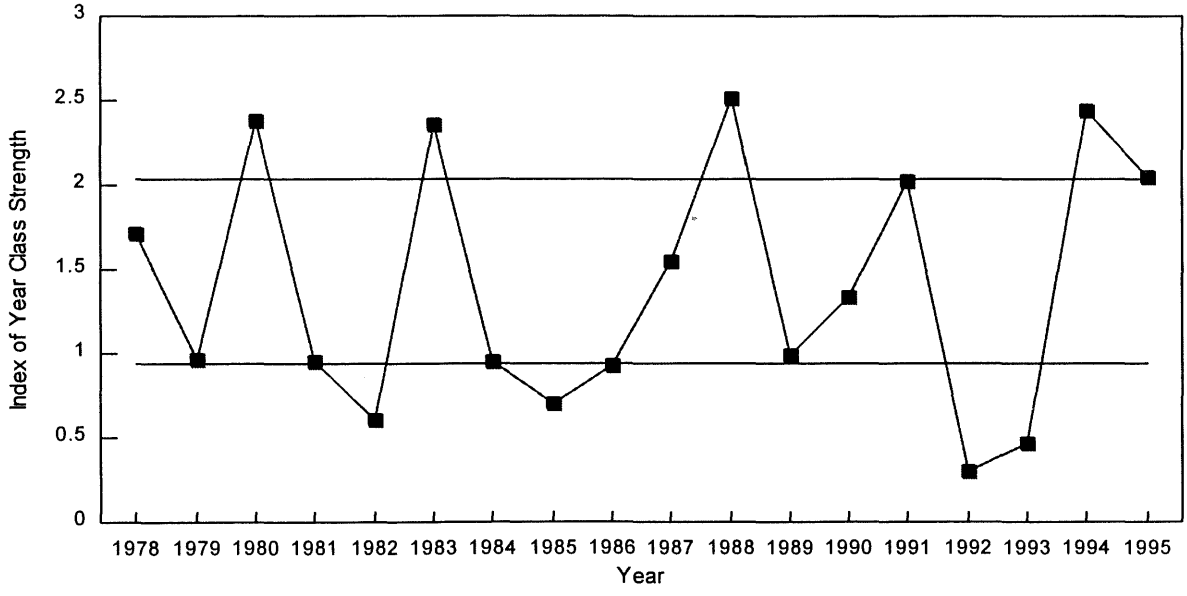

Figure 23. Index of year class strength for walleye from Lake Vermilion for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

Management History

A number of special surveys have been conducted on Lake Vermilion including intensive population assessments in 1940-41 (Carlander and Hiner 1943), 1953 (Johnson and Burrows 1954), and 1968 (Johnson 1968). A detailed study of the interspecific relationship between walleye and cisco was done during the period 1957-1959 (Dobie 1966). Long-term historical data on the walleye spawning run at Pike River was analyzed in 1987 (Heywood and Mix 1987). A creel survey of the 1985 whitefish netting season was conducted to estimate harvest of whitefish, cisco, and by-catch (Mix and Heywood 1986). Whitefish netting assessments were also done during the period 1987-1991 to compile information for setting whitefish netting seasons. A walleye tagging study was conducted at the Pike River spawning run in 1984 (Williams 1989). Near-shore substrates were surveyed in 1990 in the western portion of the lake.

Gill net assessments were conducted biennially from 1973-1983 and annually thereafter as part of the LLP. Gill nets represent the primary sampling gear for monitoring trends in abundance of key sport fish populations, particularly walleye. A trap net assessment was conducted in 1982, and annually since 1987, to evaluate an expanding bluegill population. Beach seining was conducted annually during the period 1972-1983 to evaluate reproduction of walleye and yellow perch. Creel surveys were conducted on Lake Vermilion in 1984, 1985, 1990 and 1991.

A walleye spawn-taking site and hatchery are operated where the Pike River flows into Lake Vermilion. Operation of this site started in 1892 and continued until 1946. Spawn-taking operations resumed in 1971 and continue to present. A new hatchery was built in 1972. Walleye fry have been stocked into Lake Vermilion most years the hatchery was operated, keeping with Section policy to return 10% of the hatchery production to parent waters. Movement of walleye fry from the Pike River Hatchery to other parts of the state has been locally unpopular.

A controlled northern pike spawning area has been operated at Sunset Creek since 1983 as a cooperative project with the Lake Vermilion Sportsmen's Club. Several other minor spawning areas were operated until 1988. Small numbers of Shoepac and Wisconsin strain muskie were stocked in 1968, 1969, 1972, and 1984. Leech Lake strain muskie have been stocked since 1987. Additional species stocked in Lake Vermillion prior to 1970 include cisco, whitefish, Loch Leven strain of brown trout *Salmo trutta*, lake trout, white sucker, smallmouth bass, largemouth bass, and black crappie.

There is no record of any major commercial fishery operated on Lake Vermilion. White sucker have been trapped and removed under permit at various locations since 1968.

Part of the Nett Lake Indian Reservation is located on portions of Big, Everetts, and Pike Bays. Members of the Band have harvested walleye for subsistence purposes for many years. Lake Vermilion is within the 1854 Treaty Area and allocation issues may develop in the future.

Potential and Target Harvest

The general approach used to establish potential yields was based on the median total yield of the 13 predictive models, partitioned among species using the approach described in SPOF 12. For those species not partitioned in SPOF 12, population and harvest data was used to establish target and potential yields. Current harvest levels were described as the mean of the four recent creel surveys (1984, 1985, 1990 and 1991) for all species except cisco and lake whitefish. Harvest estimates for these species were derived from a targeted survey of the 1985 whitefish netting season.

Walleye. The potential yield and target harvest for walleye were set at 76,000 pounds. The current harvest is 70,000 pounds. There is some additional harvest from night dock fishing, late fall fishing, and Native American subsistence netting that has not been quantified. The undocumented harvest probably represents several thousand pounds, which added to the documented level of harvest, would place the

current harvest level near the target harvest. The target harvest was exceeded in 1991, one of four years creel surveys were conducted. Most population parameters indicate the walleye stock is in relatively good condition. There is concern regarding the high total mortality calculated from catch curves (Z = 0.61). Additional analysis of mortality will be done to verify this estimate.

Northern Pike. The potential and target yields for northern pike were set at 34,000 and 29,000 pounds respectively. The current harvest of northern pike is 26,000 pounds. The target harvest was set below the potential yield to compensate for an expanding muskellunge population. The target harvest was exceeded in two of the four years creel surveys were conducted. Intensive stock assessment work has not been done for northern pike, although no obvious indications of stress have been observed.

Bluegill. The potential yield and target harvest for bluegill were both set at 15,000 pounds. The target harvest was exceeded in 1991 as a result of the high abundance of this species observed in the late 1980s. The population has since stabilized at a more sustainable level around the current harvest of 12,000 pounds.

Smallmouth Bass. The potential yield and the target harvest for smallmouth bass were both set at 12,000 pounds. Observed harvests have not exceeded either the potential yield or target harvest. Intensive stock assessment work has not been done for smallmouth bass, although no obvious indications of stress have been observed.

Yellow Perch. The potential yield and target harvest for yellow perch were both set at 10,000 pounds, well above the observed harvest of 2,000 pounds. Yellow perch are a minor component of the sport fishery and the stock is probably not affected by sport angling. A recent increase in the average size of perch in the Big Bay area has generated minor interest by anglers.

Black Crappie. The potential yield and target harvest for black crappie were both set at 11,000 pounds, well above the current harvest of 5,000 pounds. Observed harvests have not exceeded the target harvest. Black crappie are a minor component of the fishery and the population is limited by variable recruitment.

Largemouth Bass. The potential yield and target harvest for largemouth bass were both set at 3,000 pounds, slightly above the current harvest of 2,000 pounds. The target harvest was exceeded in one of the four years (1991) creel surveys were conducted. Largemouth bass are a minor component of the fishery and there is little empirical information about the stock.

Lake Whitefish and Cisco. The potential yield and target harvest for lake whitefish and cisco combined were set at 15,000 pounds. Angler harvest is insignificant although there is a sport gill net fishery. The current harvest is estimated to be around 20,000 pounds.

Future Management

Stock assessment. Standard assessment netting based on the *Large Lake Sampling Guide* should be continued. Additional sampling should include the use of spring trap nets to assess the muskie population, spring electrofishing targeting smallmouth bass, summer trap netting targeting bluegill, and fall electrofishing targeting young-of-the-year walleye. Creel surveys should continue to be done two consecutive years out of six (1996-97, 2002-03 etc.).

Experimental Regulations. No special regulations are currently in place on Lake Vermilion. Regulations designed to improve the size structure of walleye, northern pike, and smallmouth bass populations may be considered if support among user groups develops, or if target harvests are routinely exceeded.

Stocking. Walleye fry will be stocked annually at a rate equivalent to 10% of the walleye egg production at the Pike River Hatchery (annual production varies from 10-20 million). Leech Lake strain muskellunge will be stocked biennially (5,000 fingerlings) to maintain the population. All stocked muskie will be fin-clipped to allow discrimination of stocked fish from those resulting from natural reproduction. If assessment netting indicates sufficient natural reproduction to maintain the

population, stocking will be reduced or eliminated. Operation of the Sunset Creek northern pike spawning area will be continued as a cooperative project with the Sportsmen's Club of Lake Vermilion.

Habitat Management. The shoreline of Lake Vermillion is extensively developed. Preservation of fish habitat and water quality is a priority issue. Permit applications for shoreline alterations should be closely scrutinized to preserve aquatic habitat whenever possible. Public education should be used to encourage ecologically sound shoreland management.

Shoreline currently under public ownership should be maintained. Undeveloped shoreline provides critical habitat for many aquatic species. About 15% of the shoreline around Lake Vermilion is publicly owned under the jurisdiction of various County, State, and Federal agencies. Land exchanges that result in a net loss of publicly owned shoreline should be opposed. Maintaining public ownership of shoreline should be addressed in Federal, State, and local land use plans, including the Superior National Forest Plan.

A detailed inventory of the shoalwater substrates should be done on the portion of the lake not completed in 1990. Work should begin in 1998, after the current creel survey cycle.

Lake Winnibigoshish

Description of the Fishery

Lake Winnibigoshish is a large, shallow, wind swept lake with a sandy shoreline and gently sloping shoal areas. Lake Winnibigoshish has a surface area of 58,544 acres, mean depth of 15.1 feet and maximum depth of 70 feet at average summer elevation. Inlets to Winnibigoshish consist of the Mississippi River, First River Flowage, Third River Flowage, Ravens Flowage, Pigeon River, and several smaller creeks. Water levels are managed by the U.S. Army Corps of Engineers dam at the outlet. The dam, constructed in the 1880s, raised the level of Lake Winnibigoshish approximately 10 feet. Lake Winnibigoshish and Cut Foot Sioux are connected by a navigable channel that is approximately 1/4 mile wide and 6 feet deep at the narrowest point. Cut Foot Sioux Lake has an irregular, rocky shoreline with a surface area of 2,851 acres, and a maximum depth of 78 feet.

Lake Winnibigoshish has a relatively simple fish community dominated by yellow perch, cisco, northern pike, and walleye. Other species present include; largemouth bass, muskellunge, black crappie, rock bass, bluegill and pumpkinseed sunfish, burbot, black, brown and yellow bullhead, various redhorse species, white sucker, bowfin, and minnow species. Lake whitefish were captured in earlier assessment netting, however, none have been captured since 1988. Cut Foot Sioux Lake has a fish community that is similar to Lake Winnibigoshish, however, centrarchid species constitute a larger component of the total fish population.

Between 1939 and 1977, summer sport fishing pressure on Lake Winnibigoshish and the Cut Foot Sioux chain of lakes increased more than seven fold and yield of walleye, northern pike, and yellow perch, more than doubled. Mean weights of walleye and yellow perch decreased by nearly one half during this time period. In the 1980s, summer angling pressure, harvest rates, and mean weight of walleye and northern pike were similar to levels observed in the 1970s (Table 14). Summer angling pressure increased to record high levels in 1994. The observed increase in angling pressure in 1994 occurred despite record low harvest rates and near average yield for walleye. Winter harvest of yellow perch in the 1980s was similar to levels observed in the 1970s, however, pressure, harvest, and yield of yellow perch increased to record high levels during the 1994-95 winter season. Although spearing license sales statewide have decreased nearly 50% since 1982, spearing pressure on Lake Winnibigoshish has remained relatively constant since the 1950s.

Walleye constitute the largest component (49%) of the summer fishery by weight (mean of seven creel surveys between 1975 and 1995). Most of the current harvest of 165,000 pounds of walleye is taken during the open water season. Gill net catch rates have fluctu-

Table 14. Historical creel survey estimates by species for Lake Winnibigoshish.

Winter Summer	1995-96 1995	1994-95 1994	1988-89 1988	1987-88 1987	1977-78 1977	1976-77 1976	1975-76 1975	1958-59 1958	1957-58 1957	- 1939
Total angler-hours	999,750	1,219,080	744,069	756,550	966,596	830,430	703,508	576,480	479,045	91,439
Walleye										
Total number harvested	104,536	78,737	101,261	140,054	198,403	207,788	104,129	135,480	83,344	37,263
Total pounds harvested	165,040	132,285	122,964	148,784	222,212	231,069	137,210	177,000	113,844	81,683
Mean weight (pounds)	1.6	1.68	1.21	1.06	1.12	1.11	1.32	1.3	1.37	2.2
Harvest rate (fish/angler-hour)	0.10	0.065	0.14	0.19	0.21	0.25	0.15	0.24	0.17	0.41
Yellow Perch										
Total number harvested	937,881	1,219,428	168,611	138,092	767,443	204,680	90,130	40,194	30,680	3,085
Total pounds harvested	383,019	638,633	71,237	61,430	330,384	94,562	35,597	22,967	19,310	2,513
Mean weight (pounds)	0.41	0.52	0.42	0.44	0.43	0.46	0.39	0.57	0.62	0.82
Harvest rate (fish/angler-hour)	0.94	1.0	0.23	0.19	0.79	0.25	0.13	0.07	0.04	0.03
Northern Pike										
Total number harvested	30,241	28,006	26,148	37,037	46,966	45,120	32,372	60,874	38,348	37,727
Total pounds harvested	120,840	108,777	87,947	118,174	148,665	121,789	103,561	209,582	113,862	113,134
Mean weight (pounds)	4.0	3.88	3.36	3.19	3.17	2.7	3.2	3.44	2.97	3.0
Harvest rate (fish/angler-hour)	0.03	0.023	0.04	0.05	0.05	0.05	0.05	0.11	0.08	0.41

ated in response to variability in year-class strength (Figure 24). From 1980 through 1986, walleye year-class strength was strong or above average in even numbered years (Figure 25). Between 1988 and 1993, only the 1991 year-class could be considered average, all other year-classes were below average or weak. Currently the 1994 year-class appears strong, and trawl catch rates indicate that the 1995 year-class may be above average.

Northern pike are the second largest component of the summer (26%) and winter (13%) harvest by weight. Northern pike appear to have had more stable recruitment than walleye since 1983, and have shown less variability of test net catch rates.

Yellow perch are currently the third largest component of the summer (21.5%) and largest component of the winter (89%) harvest by weight. Other species harvested at low levels include cisco, black crappie, bullhead sp., burbot, largemouth bass, muskellunge, rock bass, and various sunfish species.

Management History

Comprehensive studies of Lake Winnibigoshish and the Cut Foot Sioux chain of lakes have been conducted since 1939. Angler pressure, harvest, and success were studied by Stoudt (1939), Johnson and Johnson (1971), Osborn and Schupp (1985), and Albert (1996a and b). Walleye egg survival on various bottom substrates was studied by Johnson (1961). Historic data of the walleye spawning run at Little Cut Foot Sioux Lake was evaluated by Johnson (1971). A comprehensive investigation of environmental and species associations of walleye in Winnibigoshish was also completed by Johnson (1969). Routine assessment netting was completed in 1953, 1975, 1977, and 1981. Sampling protocol prescribed in the LLP was initiated in 1983, and has been completed annually since.

A walleye spawn take operation has been conducted annually at the narrows between Cut Foot Sioux and Little Cut Foot Sioux Lakes since approximately 1926. A minimum of 10% of the eggs taken are stocked as fry in Cut Foot Sioux and Little Cut Foot Sioux Lakes, consistent with Section policy. Surplus fry have been stocked occasionally at the mouth of the Third River. Prior to 1996, walleye fry were hatched at the Cut Foot Sioux hatchery. A new hatchery was constructed at the Grand Rapids DNR complex in 1995, which now serves as the hatchery for walleye eggs taken at the Cut Foot Sioux spawn take site.

Shoreline erosion control projects have been constructed on Lake Winnibigoshish by the U.S. Forest Service, U.S. Army Corps of Engineers, Leech Lake Indian Reservation (LLIR), and the MNDNR. Most of the east shoreline from the Birches boat access to the south end of the High Banks summer homes, along with scattered areas throughout the lake have been stabilized. Spawning areas that had been covered with sand in the Little Stony Point and High Banks areas have been reestablished in conjunction with these erosion control efforts.

Rough fish removal was first recorded on Lake Winnibigoshish in 1940. Fish species removed included; bullhead spp., bowfin, burbot, yellow perch, white sucker, shorthead redhorse, cisco, and lake whitefish. Rough fish removal was conducted by state crews and contract fishermen from 1940 thru 1972. Rough fish have been harvested in very low numbers by the LLIR since 1973.

Potential and Target Harvest

Thirteen predictive yield models were examined in an initial effort to estimate the total yield for Lake Winnibigoshish. Of these models, only one (chlorophyl a) was similar to observed mean yields for the 1975 to 1995 time period. Because historic creel data did not conform to the partitioning suggested in the SPOF-12, population and harvest data were used to establish target and potential yields for all species. Current harvest levels for walleye and northern pike were described as the mean of harvest data collected between 1975 and 1995. Current harvest levels for yellow perch were described as the mean of harvest data

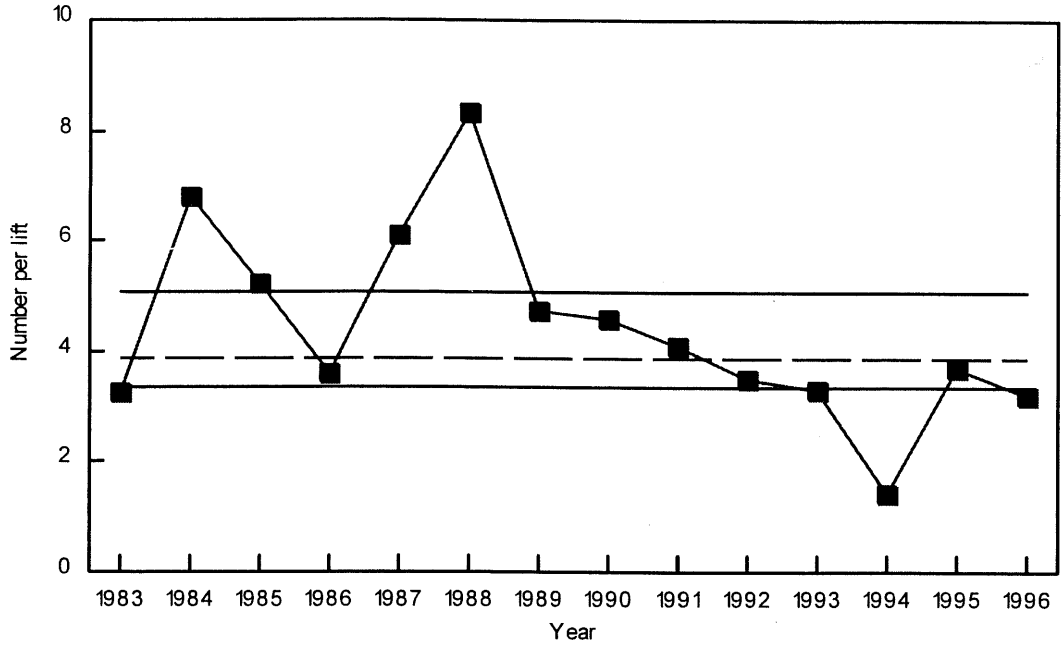

Figure 24. Walleye gill net abundance (1983-1996) for Lake Winnibigoshish. The dashed line represents the historical median; solid lines represent the 25th and 75th quartiles.

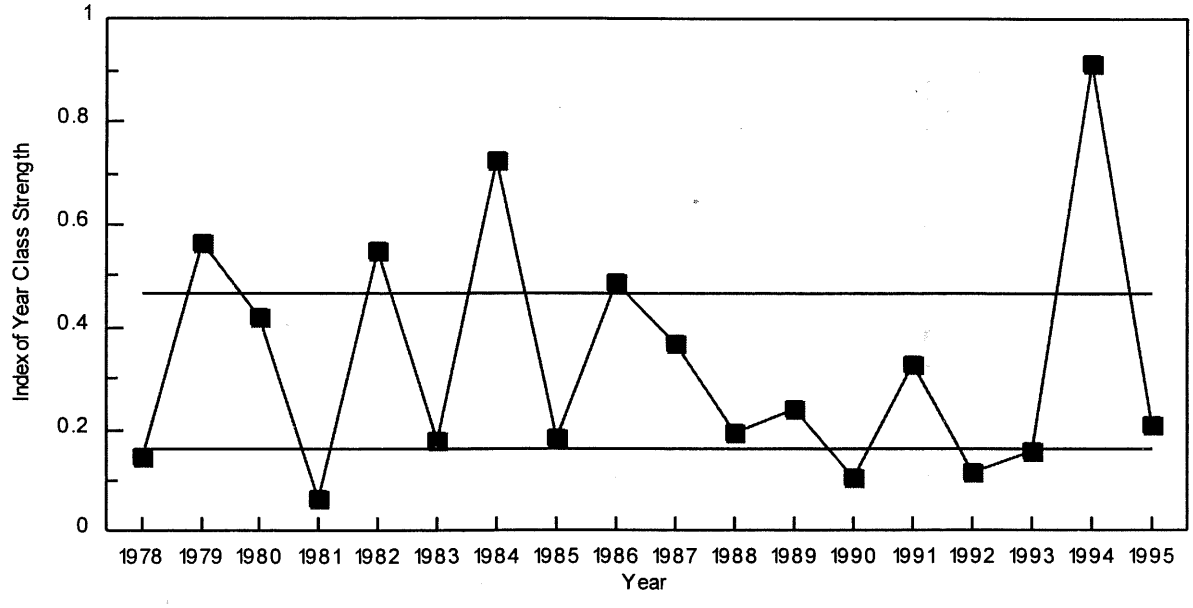

Figure 25. Index of year class strength for walleye from Lake Winnibigoshish for the period 1978-1995. Values above and below the lines (75th and 25th quartiles) can be considered strong and weak year-classes respectively.

between 1977 and 1995 since no late winter creel data was collected prior to 1977.

Walleye. The potential yield for walleye was set at 180,000 pounds based on historic creel survey data. The target harvest was set below the potential yield, at 168,000 pounds, because the population, as indicated by assessment netting, is lower than average. The current harvest of 165,000 pounds is very close to the established target. Some additional harvest is present in the form of night fishing and subsistence netting by members of the Leech Lake Indian Reservation, however, this harvest is believed to comprise a small component of the total yield.

Northern Pike. The potential harvest and target yields for northern pike were set at 140,000 pounds. The current harvest of northern pike is 114,000 pounds. The highest harvest recorded since 1975 was 148,664 pounds in 1977. The highest historical harvest was recorded in 1958 when 209,582 pounds were taken. Assessment netting indicates that the northern pike population is strong with good recruitment and size structure.

Yellow perch. The potential and target yields for yellow perch were set at 400,000 pounds. Based on population modeling using the Management Simulation (MANSIM) model this level of harvest would appear to be sustainable. The current harvest of yellow perch is 383,000 pounds. The highest recorded harvest since 1977 was 638,633 pounds in 1994-95. This level of harvest is most likely not sustainable.

Cisco. Cisco are essentially an unharvested species in Lake Winnibigoshish due to the presence of parasites. The potential and target harvest were set at 164,000 pounds based on assessment netting.

Other species. Other species sampled in low numbers in recent creel surveys include black crappie, bullhead sp., burbot, largemouth bass, muskellunge, rock bass, and various sunfish species. The majority of harvest for these fish species is in Cut Foot Sioux and Little Cut Foot Sioux Lakes. Target and potential harvest levels for this group of species were set at 8,000 pounds.

Future Management

Stock Assessment. Population monitoring as prescribed in the *Large Lake Sampling Guide* should be conducted annually. Additional sampling should include: transferring the eight gillnet sets from Cut Foot Sioux to mid-lake areas of Lake Winnibigoshish; fall electrofishing to verify changes in walleye abundance and growth as determined from trawling; and collect and analyze water samples on a biweekly basis from early June through mid September. Creel surveys should continue to be conducted two consecutive years out of six.

Experimental Regulations. An experimental regulation for walleye is currently being proposed for Lake Winnibigoshish. The objectives of the regulation are to increase angler catch rates, increase the average size of fish harvested, and increase the abundance of walleye greater than 19 inches.

Stocking. Walleye fry will be stocked in Cut Foot Sioux and Little Cut Foot Sioux Lakes as the percentage return from the walleye spawn take operation. A minimum of 10 percent of the eggs taken will be returned to the lake system as fry. The number of fry stocked will be determined by averaging the previous three years egg take and multiplying by 0.1. In addition to the percent return of fry, surplus fry produced at the Grand Rapids walleye hatchery may be stocked in the Winnibigoshish system.

Habitat Management. Lake Winnibigoshish is entirely within the Chippewa National Forest, and nearly all shoreline is in federal or state ownership. Lake Winnibigoshish and its watershed are relatively lightly impacted by humans, however, Lake Winnibigoshish is a large open system that is vulnerable to shoreline erosion during high wind events. Between 1938 and 1961 some areas have eroded in excess of 1,000 feet inland. Presently much of the east shore from Tamarack Point to Musky Bay has been stabilized, however the highly erodible south shore from Lake Harry to the Richards Townsite access is in need of stabilization.

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Acknowledgments

The Section of Fisheries thanks the employees that contributed to the development of this publication. Members include Gerry Albert, Steve Boe, Rick Bruesewitz, Melissa Drake, Henry Drewes, Jeff Eibler, Norm Haukos, Tom Heinrich, Don Pereira, Al Stevens, and Duane Williams. Thanks also to Vicky Schiller for her work with tables and figures, and final copy setting and proofing.

Edited by:

C. S. Anderson, Fisheries Research Supervisor
P. J. Wingate, Fisheries Research Manager
H. G. Drewes, Fisheries Survey/Systems Coordinator
S. A. Hirsch, Fisheries Program Manager
D. H. Schupp, Fisheries Research Supervisor

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