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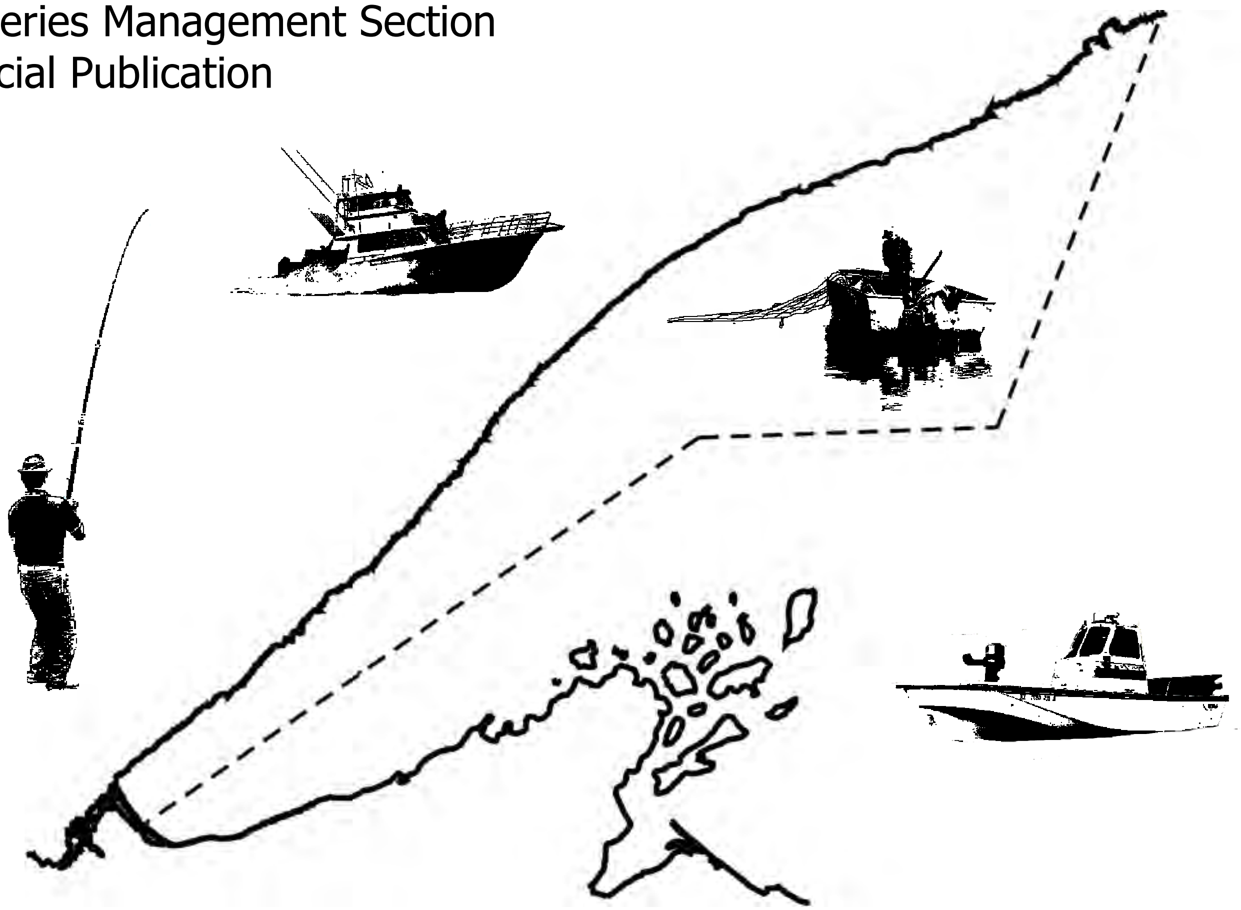
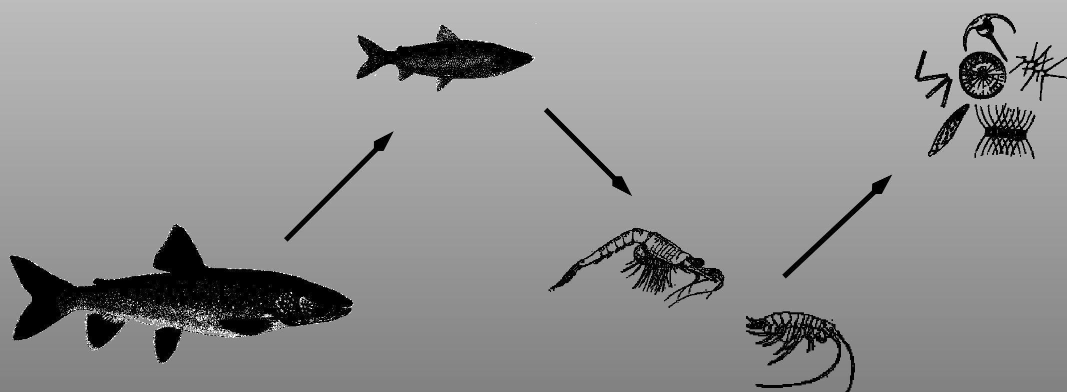


No. 163

Fisheries Management Plan for the Minnesota Waters of Lake Superior

September 2006



Minnesota Department of Natural Resources

Division of Fish and Wildlife

Minnesota Department of Natural Resources
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FISHERIES MANAGEMENT PLAN FOR THE MINNESOTA WATERS OF LAKE SUPERIOR

Prepared by

Donald R. Schreiner
Joseph J. Ostazeski
Theodore N. Halpern
Steven A. Geving

Minnesota Department of Natural Resources
Lake Superior Fisheries Area
5351 North Shore Drive
Duluth, MN 55804

in cooperation with the
MNDNR North Shore Management Group
and the
Lake Superior Advisory Group

2006

Minnesota Department of Natural Resources
Division of Fish and Wildlife
Fisheries Management Section

North Shore Management Group
Minnesota Department of Natural Resources
Fisheries Management Section

Alan Anderson, Duluth Area Fisheries, French River
Darryl Bathel, Cold Water Hatchery Coordinator, French River
Mark Ebbers, Cold Water Program Coordinator, St. Paul
Steve Geving, Lake Superior Area Fisheries, French River
Tim Goeman, Northeast Regional Fisheries Manager, Grand Rapids
Theodore Halpern, Lake Superior Area Fisheries, French River
Deserae Hendrickson, Duluth Area Fisheries, French River
John Lindgren, Duluth Area Fisheries, French River
Mary Negus, Research Biologist, French River
Joe Ostazeski, Lake Superior Area Fisheries, French River
Steve Persons, Grand Marais Area Fisheries, Grand Marais
Donald Schreiner, Lake Superior Area Fisheries, French River
Fred Tureson, French River Hatchery, French River

Lake Superior Advisory Group

Organization	Representative
1854 Authority	Andrew Edwards
Arrowhead Fly Fishers	Doug Mroz
Cook County Tourism	George Wilkes
Duluth Charter Fishing Guides	Peter Dahl
Fish Producers and Processors	Stewart Siverson
Fond du Lac Band of Chippewa	Brian Borkholder
Grand Portage Band of Chippewa	Seth Moore
Independent Angler	John Eaton
Izaak Walton League	Bill Miner
Kamloops Advocates	Ross Pearson
Lake County Recreation Association	Lino Rauzi
Lake Superior Steelhead Association	Kevin Bovee
North Shore Commercial Fishers	Steve Dahl
North Shore Charter Captains Association	Barry Le Blanc
North Shore Processors	Harley Toftey
Save Lake Superior Association	LeRoger Lind
Saint Louis River Citizens Action Committee	J. Howard McCormick
Trout Unlimited	John Lenczewski
Two Harbors Catch and Donate	Forest Johnson
United Northern Sportsmen	Chuck Cieluch
Western Lake Superior Trollers	Dave Koneczny

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EXECUTIVE SUMMARY

The Lake Superior fish community has undergone dramatic changes since the mid-1900s due to over-fishing, introduction of non-native species, pollution, and land use changes in the watershed. Since the 1950s, the Lake Superior fish community has become much more complex, and is now composed of both native and non-native species. The most devastating introduction to the Lake Superior community has been the sea lamprey, which virtually eliminated the lake trout in all but a few isolated areas of Lake Superior. Since the 1960s, rehabilitation efforts, including sea lamprey control, harvest regulations and stocking programs, along with stricter pollution standards and best management practices for land use, have led to restoration of healthy fish stocks throughout much of Lake Superior.

This plan is a comprehensive guide on how to best manage Minnesota's portion of the Lake Superior fishery. The plan is written for use by both the Minnesota Department of Natural Resources (MNDNR) Fisheries Management Section and citizens interested in the management of Minnesota's Lake Superior fishery resource. The plan is based on a fish community approach to fisheries management. The strategies and actions in this plan will focus on the work of the MNDNR Fisheries Management Section over the next decade. The goals and objectives are expected to remain relevant for 10 years, but the plan is written to be flexible, and modifications are expected to occur during that time period.

Citizen participation was a critical aspect in the planning process. An advisory group that represented fishing clubs, environmental groups, Indian bands, commercial fishing interests, county organizations, and individual anglers was formed at the beginning of the planning process. This group was involved with initial discussion on all issues, solicited input from their organizations, and reviewed and commented on the draft plan. In addition, three "Open House" meetings were held to get feedback on the draft plan from citizens not associated with a representative on the advisory group. All comments were summarized, reviewed, and considered for inclusion in the final draft. The final draft was thoroughly discussed within the Fisheries Management Section and represents the Department's position on how to best manage the Lake Superior fishery.

GENERAL PLAN OVERVIEW

Fisheries management in Minnesota is the responsibility of the Minnesota Department of Natural Resources (MNDNR), Fisheries Management Section. The long-term goal for fisheries management in the Minnesota waters of Lake Superior is:

> **To protect the Lake Superior ecosystem, restore its watershed, and manage for a diverse, stable, self-sustaining fish community that provides recreational, commercial and tribal fishing opportunities.**

The MNDNR uses an ecosystem-based management approach. In its mission to protect the Lake Superior ecosystem and manage the fishery based on ecological principals, the plan recognizes that:

- Fish production in Lake Superior is finite, and although users may desire more fish from its waters, the lake simply may not have the capacity to produce higher levels. Additional stocking of trout and salmon cannot take place without considering impacts on the forage base.

- Lake Superior is the least productive but most pristine of the Great Lakes, and has demonstrated the capacity to support self-sustaining fish populations through natural reproduction. The plan emphasizes the continued need for habitat protection, and the desire for managing self-sustaining fish populations that are best suited to the lake's environment.

- User groups on Lake Superior have diverse interests, and the Lake Superior Management Plan (LSMP) attempts to balance resource protection, recreational opportunities, cultural beliefs and economic development for the benefit of both present and future generations. Citizen participation was the cornerstone of the planning process, and will be an ongoing process once implementation begins.

- Lake Superior fishery management is an expensive program when compared to other fisheries in the state, consuming approximately 4.5% of the total fisheries budget. Although Lake Superior is a unique resource and offers diverse recreational opportunities, user groups must recognize that increased expenditures for Lake Superior fishery programs will be difficult to justify when viewed from a statewide perspective.

- The effectiveness of Lake Superior management programs must be continually evaluated. If established criteria indicate program changes are required, interested citizens will be consulted and the necessary action will be taken.

- Only 7% of Lake Superior falls within the state of Minnesota. The Great Lakes Fishery Commission provides the structure for cooperative management among the various jurisdictions around the lake, and continued involvement with the Commission is required to address the ever-increasing complexity of issues that arise.

As we begin to implement this plan, citizen participation will be crucial, and we expect the plan will focus and stimulate ongoing conversations about future fisheries management for the Minnesota waters of Lake Superior. It is our belief that this plan is required for sound management of the Lake Superior fishery, and its success will ultimately be determined by citizen support and the long-term benefits to the resource and its users.

BODY OF THE PLAN

HABITAT

Background: Lake Superior is the most pristine of all of the Great Lakes, and habitat protection is a high priority. Unimpaired habitat is critical for a productive, self-sustaining fish community. Throughout the Lake Superior basin, point source pollution has been greatly reduced in the last 20 years, but nonpoint and atmospheric pollution continues to cause problems with bioaccumulation of mercury, PCBs and other toxins in fish and wildlife. The St. Louis River is classified as an area of concern by the U.S. Environmental Protection Agency, and its cleanup is now being addressed through the St. Louis River Remedial Action Plan. The Minnesota Pollution Control Agency (MPCA) has developed the Lake Superior Basin Plan, a watershed approach to managing the Lake Superior Basin, while the Bi-national Plan for Lake Superior is focused on the Lake Superior ecosystem including water quality, pollution, and habitat concerns.

Goal: Protect, restore and enhance the quantity and quality of fisheries habitat in the Minnesota waters of Lake Superior.

Objectives:

1. Identify and prioritize areas of degraded habitat in Lake Superior tributary watersheds, and work with appropriate agencies and citizens to restore its capacity to produce fish.

2. Increase the awareness of the importance of habitat to Lake Superior fisheries and work with MNDNR Division of Waters (DOW), MPCA, and other agencies and citizen groups to reduce habitat degradation in the Lake Superior watershed through the regulatory process.

3. Work with MPCA, Minnesota Department of Health (MDH) and other agencies to establish a consistent sampling protocol to monitor contaminant levels in Lake Superior and St. Louis River fish species.

4. Protect, restore, and enhance riparian areas in the Lake Superior Basin (Minnesota Chapter of the American Fisheries Society 2004).

5. Monitor movement and location of different fish species to determine what specific habitats are used by different species.

6. Identify and quantify potential spawning areas and other critical habitats in Lake Superior and tributary streams so these areas can be monitored and protected.

PREY

Background: Forage includes organisms from several trophic levels, but this plan addresses forage fish most commonly used by salmonines in Lake Superior. In Minnesota waters of Lake Superior, lake herring were the major forage and commercial species until rainbow smelt became established in the late 1950s. From 1940 to 1985, abundance of lake herring declined, and beginning in the 1950s, rainbow smelt abundance increased. In the 1980s, this trend reversed, and lake herring abundance has increased while rainbow smelt have declined. Despite the low level of abundance, rainbow smelt are still commonly used by salmonine predators in Minnesota's portion of Lake Superior, but more recently lake herring have again become a dominant component of predator diets. Both lake herring and rainbow smelt support commercial fisheries in the Minnesota waters of Lake Superior. Deepwater chubs serve as forage and have also supported a small commercial fishery.

Goals: Rehabilitate and protect self-sustaining Coregonine stocks (predominately lake herring) to support a stable production of predators and a limited commercial fishery. Provide a nearshore prey base of smelt sustained by natural reproduction that supports spring dip net and limited commercial fisheries.

Objectives:

1. Use hydroacoustic sampling and trawl surveys to monitor year-class strength, and determine the biomass of lake herring and smelt in Minnesota waters of Lake Superior at least once every three years through 2015.

2. Annually, investigate the age structure, catch per effort, and yield from the commercial fishery for lake herring and smelt in the Minnesota waters of Lake Superior.

3. Use results of acoustic surveys, commercial harvest, and bioenergetics modeling to determine the allocation of lake herring and smelt biomass and production among lake trout, other predators, and commercial harvest.

4. Initially determine a TAC for lake herring using hydroacoustic estimates, and explore the use of a population model to compliment the use of an acoustics-based model.

5. Work with commercial operators to implement a TAC-based lake herring commercial fishery that allocates harvest equitably among participants.

6. Limit the number of commercial operators along the Minnesota shoreline to 25.

7. Conduct predator diet surveys once every five years to determine the contribution of lake herring and rainbow smelt as prey in the Lake Superior fish community.

8. Do not expand the commercial fishery for rainbow smelt at this time, and limit the present commercial fishery to a level that has minimal impact on the rainbow smelt population.

LAKE TROUT

Background: Lake trout have historically been the top predator in the Lake Superior fish community, and were historically represented by different stocks. Following the invasion of the sea lamprey, many of these stocks were reduced or eliminated. Through natural reproduction by remnant stocks and management efforts by agencies around Lake

Superior, most areas of the lake are dominated by wild lake trout populations. In 2004, over 70% of the lake trout caught in the Minnesota summer sport fishery were wild. From 1995 through 2004, the lake trout population has supported a major sport fishery with an average annual catch of approximately 19,000 fish. Lake trout have consistently been the primary species caught by anglers.

Goal: Rehabilitate and maintain self-sustaining lake trout stocks capable of supporting a productive sport fishery.

Objectives:

1. Increase proportion of wild lake trout in the May assessment to 90% by 2015.

2. Use a Statistical Catch-at-Age (SCAA) model to determine the harvestable surplus for each management zone every five years.

3. Maintain lake trout total annual mortality rates below 45% to achieve the desired level of rehabilitation.

4. Reduce adult sea lamprey populations, in cooperation with the Great Lakes Fishery Commission and the U.S. Fish and Wildlife Service, until annual lamprey-induced adult lake trout mortality is less than 5%.

5. Reduce exploitation of spawning-size lake trout in the sport fishery by promoting voluntary release of fish greater than 25 inches.

6. Locate and protect areas where lake trout successfully spawn.

7. Monitor forage biomass so it can be effectively managed to maintain lake trout yield.

CHINOOK SALMON

Background: Minnesota introduced spring-run Chinook salmon in 1974 and converted to fall-run Chinook in 1979 because growth rates were better, and because disease-free spring run eggs were not available. Chinook salmon catch in the summer fishery has averaged 4,052 from 1995-2004. The number of adult Chinook salmon returning to the French River trap peaked in 1986, and has decreased since 1990, averaging less than 100 since 2000. In 1987, a lake-wide stocking evaluation was conducted to determine the extent of natural reproduction, and to document the movement of stocked fish throughout the lake. Returns to the summer sport fishery in Minnesota from 1990 to 1994 indicated that natural reproduction accounted for 43% of the Chinook salmon caught. Stocked fish contributed 57% to the Minnesota summer harvest, with 31% of the stocked fish originating from Minnesota. The percent contribution of Minnesota stocked Chinook salmon to the summer sport fishery has declined since the lake-wide study to under 5% in recent years, with approximately 95% being naturally reproduced fish. Despite poor survival of stocked fish, harvest and catch rates for all Chinook salmon in the summer creel have generally increased. Chinook salmon abundance is now largely dependent on natural reproduction from other jurisdictions in Lake Superior.

Goal: Provide a diverse summer sport fishery, sustained by natural reproduction that allows anglers the opportunity to harvest Chinook salmon.

Objectives:

1. Discontinue the Chinook salmon stocking program

2. Sustain an average annual catch of 2,500 Chinook salmon from the summer boat fishery, understanding there will be large annual fluctuations.

3. Coordinate with other jurisdictions involved in wild Chinook salmon management since very little natural reproduction takes place in Minnesota waters.

COHO SALMON

Background: Coho salmon were stocked in the Minnesota waters of Lake Superior from 1969 through 1972. Because management goals for coho salmon were not met, the program was abandoned in favor of the Chinook salmon program in 1972. Coho salmon have since become naturalized throughout Lake Superior, and are normally second only to lake trout in frequency of catch by Minnesota anglers. Natural reproduction in other areas of the lake support most of the coho salmon fishery in Minnesota waters. The average summer harvest of coho salmon in Minnesota waters from 1995 to 2004 was 3,261. The location of the coho salmon catch changes seasonally in Minnesota waters.

Goal: Provide a diverse sport fishery sustained by natural reproduction that allows anglers the opportunity to harvest coho salmon.

Objectives:

1. Sustain an average annual catch of 3,000 coho salmon from the summer fishery based on natural reproduction, understanding there will be large annual fluctuations.

2. Coordinate closely with neighboring jurisdictions on wild coho salmon management since very little production of coho salmon occurs in Minnesota tributaries.

PINK SALMON

Background: Pink salmon were accidentally introduced into Lake Superior in 1957. In Minnesota, the first pink salmon were caught in 1959. In Lake Superior, pink salmon abundance increased from the 1960s through the 1970s, declined during the late 1980s, but increased again since the mid-1990s. Given that pink salmon normally live for only two years, harvest of pink salmon is extremely variable because anglers are fishing only one year-class. There is no targeted management program for pink salmon; however, they are included in the combined Pacific salmon harvest limit.

Goal: Maintain the opportunity to harvest naturalized pink salmon that originate from tributaries in Minnesota and other states.

Objective:

1. Allow angler harvest of pink salmon in Lake Superior and tributary streams.

RAINBOW TROUT

Background: Anadromous rainbow trout from the west coast of North America were first introduced into the Minnesota waters of Lake Superior in 1895. The species has become naturalized and supports an important recreational fishery. During the 1970s and 1980s, fishing pressure increased and anglers perceived that the number of steelhead were declining. In response, the MNDNR initiated a number of steelhead enhancement programs. However, despite these enhancement programs, the number of wild steelhead declined through the late 1980s. To address the decline of wild steelhead, the *1992 North Shore Steelhead Plan* was developed and implemented. In 2003, the *Rainbow Trout Management Plan for the Minnesota Waters of Lake Superior* was developed to update and replace the *North Shore Steelhead Plan*. The *Rainbow Trout Management Plan for the Minnesota Waters of Lake Superior* forms the basis of the rainbow trout chapter in this plan.

Goal: Rehabilitate steelhead stocks using Minnesota strain fish to achieve a level that will allow limited angler harvest largely supported by naturally reproducing populations.

Objectives:

1. Protect or improve steelhead habitat in North Shore watersheds by maintaining suitable stream flows, water temperatures, water quality, and access to spawning and nursery areas.

2. Continue to investigate the factors limiting sustained production of naturalized steelhead in the Minnesota waters of Lake Superior by monitoring the fishery and conducting research.

3. Implement management strategies to rehabilitate naturalized steelhead popula-

tions in the Knife River with a target of 1,000 spawning fish by 2010.

4. While the rehabilitation plan is in progress, continue to provide a rainbow trout fishery that utilizes Kamloops rainbow trout, while attempting to minimize any negative impacts on naturalized steelhead populations.

5. Coordinate with MNDNR Ecological Services Division, U.S. Department of Agriculture, and interested citizens to monitor the cormorant population on Knife Island and if necessary, reduce their potential impact on emigrating Knife River steelhead.

6. Increase efforts to locate and contact willing landowners to acquire easements and angler access to North Shore streams with the assistance of angling organizations, and develop a map depicting locations where angler access is currently available along North Shore streams.

BROOK TROUT

Background: Brook trout are native to Lake Superior and its tributaries below the first barrier. Reports from the mid-1800s through the 1920s indicate that "coasters", a brook trout strain that spends a portion of its life in Lake Superior, supported a popular fishery. Management agencies on Lake Superior have been working to protect the remaining brook trout stocks, gather critical biological information for coaster rehabilitation, and implement projects to address problems facing brook trout rehabilitation. All agencies understand that brook trout rehabilitation in Lake Superior will be a long-term process, and that cooperation among conservation groups, fishing clubs and management agencies will be required.

Goal: Protect and maintain self-sustaining coaster brook trout stocks in the Minnesota waters of Lake Superior in original locations where practical.

Objectives:

1. Identify and protect remnant coaster brook trout populations, and prioritize suitable streams for rehabilitation projects.

2. Protect and rehabilitate essential in-stream habitat through watershed management, focusing on high priority streams for coaster brook trout rehabilitation.

3. Support research directed at answering questions on basic brook trout biology.

4. Coordinate with other agencies on coaster brook trout management and apply successful techniques.

5. Work cooperatively with the Grand Portage Band of Chippewa to monitor the results of the various coaster brook trout stocking strategies being implemented by the Band.

BROWN TROUT

Background: Brown trout are not native to Lake Superior, but have established anadromous runs in a number of tributaries in other states. In Minnesota, attempts to establish anadromous populations in streams has met with limited success. Brown trout are rarely caught in tributary streams below the barrier, but are caught occasionally during the summer boat fishery.

Goal: Maintain the opportunity to harvest naturalized brown trout that originate from tributaries in Minnesota and other states.

Objective:

1. Allow angler harvest of brown trout in Lake Superior and tributary streams with minimal management activities.

WALLEYE

Background: Most walleye found in the Minnesota waters of Lake Superior originate from the St. Louis estuary; however, a small population is present in the Pigeon River that forms part of the Minnesota-Ontario boundary. The St. Louis River population is presently in good condition, but there are some concerns about the potential impact of invasive species such as ruffe on the population. Efforts by the Grand Portage Band of Chippewa to rehabilitate walleye in the Pigeon River are being implemented

Goal: Maintain, enhance, and rehabilitate walleye populations that spawn in the St. Louis River estuary and Pigeon rivers.

Objectives:

1. Manage walleye populations in cooperation with the Wisconsin Department of Natural Resources (WIDNR), Ontario Ministry of Natural Resources (OMNR) and Grand Portage Band since both populations are a shared resource.

2. Maintain high catch rate and quality size structure of St. Louis River walleye through harvest regulations.

3. Monitor walleye population dynamics through assessments in the St. Louis River estuary.

4. Protect walleye spawning and nursery habitat below the Fond du Lac Dam.

5. Coordinate management and rehabilitation of the Pigeon River walleye population with the Grand Portage Band and OMNR.

LAKE STURGEON

Background: The lake sturgeon is native to the Minnesota waters of Lake Superior. Two river systems in Minnesota - the St. Louis and the Pigeon - once supported lake sturgeon populations below the upstream barrier. The St. Louis River population was extirpated due to poor water quality, degraded habitat, and overfishing. Water quality within the St. Louis River estuary has dramatically improved since the Western Lake Superior Sanitary District began operation in 1978. In 1984, a program to rehabilitate lake sturgeon in the St. Louis River estuary focused on stocking fingerling sturgeon, and evaluating the success of stocking with annual summer gill net assessments. The Pigeon River forms the border between Ontario and Minnesota and is located on the Grand Portage Indian Reservation. The Pigeon River historically had a small lake sturgeon population that is no longer present in any significant abundance. Recently the Grand Portage Band has expressed interest in rehabilitating this population through a stocking program.

Goal: Reestablish a self-sustaining population of lake sturgeon in western Lake Superior.

Objectives:

1. Monitor juvenile and sub-adult lake sturgeon population dynamics cooperatively with WIDNR in the St. Louis River estuary and Lake Superior.

2. Annually monitor lake sturgeon spawning activity, flow, and daily spring water temperatures below Fond du Lac Dam in historical spawning areas.

3. Complete a habitat enhancement project that creates three spawning riffles below Fond du Lac Dam in a historical sturgeon spawning area.

4. Cooperate with the Grand Portage Band and OMNR on the management and rehabilitation of the Pigeon River sturgeon population.

5. Continue to participate in the lake sturgeon workgroup of the Lake Sturgeon sub-committee of the Lake Superior Technical Committee.

PREFACE

The purpose of this plan is to guide fisheries management in the Minnesota waters of Lake Superior. It is written for use by both the Minnesota Department of Natural Resources (MNDNR) Fisheries Management Section, and citizens that are interested in the management of Minnesota's Lake Superior fishery resource. This plan is based on a fish community approach to fisheries management and highlights why this approach is necessary. The plan begins with an introduction, a fish community chapter, and a chapter that discusses the combined aspects of habitat, water quality and contaminants. These are followed by chapters that discuss the management of individual species, but reiterate the community approach and the interdependence of one species on the others.

This plan is designed to guide effective and efficient allocation of time and money to protect the Lake Superior fish community and provide for its sustained use. It is one of many management plans being developed by the MNDNR Fisheries Management Section to guide fisheries management throughout the state. Long range plans for many fish species have been developed, and individual lake management plans are being compiled for all managed bodies of water in the state. The strategies and actions listed in this plan will focus the work of the MNDNR Fisheries Management Section over the next decade, as will the strategies and actions listed in other management plans.

This plan proposes both short and long-term changes in present management strategies for some species. It is anticipated that short-term changes will be made in 1-3 years and long-term strategies will be carried out over a 3-10 year period. The goals and objectives of this plan are expected to remain relevant for 10 years, but it is written to be flexible, and deviations are expected to occur over that time period. Citizen participation has been a major component in the development of this plan and will be critical for its implementation. The plan's usefulness will ultimately be determined by its benefits to the resource and its users.

CHAPTER 1: INTRODUCTION

The Lake Superior fish community has undergone dramatic changes since the mid-1900s due to overfishing, introduction of non-native species, pollution, and land use changes in the watershed. Before 1950, the community was a relatively simple one with lake trout *Salvelinus namaycush namaycush*, siscowet *Salvelinus namaycush siscowet*, lake whitefish *Coregonus clupeaformis,* brook trout *Salvelinus fontinalis*, lake sturgeon *Acipenser fulvescens* and walleye *Sander vitreum* as the top native predators. Rainbow trout *Oncorhynchus mykiss* had been intentionally introduced in the late 1800s, and quickly established self-reproducing populations throughout the lake. The major prey fish species were lake herring *Coregonus artedi*, chubs *Coregonus hoyi* and *C. kiyi* and sculpins Cottidae.

Since the 1950s, the Lake Superior fish community has become much more complex, and is now composed of both native and non-native species. Introductions of non-native species were both intentional and unintentional. Introduced game fish species include Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *Oncorhynchus kisutch*, pink salmon *Oncorhynchus gorbuscha*, Atlantic salmon *Salmo salar*, brown trout *Salmo trutta*, and a variety of rainbow trout strains (Kamloops, Madison, Donaldson, etc). The non-native rainbow smelt *Osmerus mordax* was heavily preyed upon by most game fish species, and also became an important commercial species. The most devastating introduction to the Lake Superior community has been the sea lamprey *Petromyzon marinus*, which virtually eliminated the lake trout through predation in all but a few isolated areas of Lake Superior. During the 1980s there was a large increase in the number of invasive species from Europe that include ruffe *Gymnocephalus cernuus*, zebra mussel *Dreissena polymorpha* and the spiny water flea *Bythotrephes longimanus*.

Since the 1960s, rehabilitation efforts including sea lamprey control, restrictive harvest regulations, and stocking programs, along with stricter pollution standards and best management practices for land use, have led to increased rehabilitation of healthy fish stocks. In 1995, the MNDNR with assistance from a group of interested citizens developed the first *Fisheries Management Plan for the Minnesota Waters of Lake Superior* (LSMP). The 1995 LSMP was a comprehensive guide on how to best manage Minnesota's portion of the Lake Superior fishery. The 1995 LSMP was written for use by both the Minnesota Department of Natural Resources (MNDNR) Fisheries Management Section and citizens interested in the management of Minnesota's Lake Superior fishery resource. The plan was based on a community approach to fisheries management, and since 1995 rehabilitation of the fishery has progressed rapidly as the plan has been implemented. The goals and objectives described in the 1995 LSMP were expected to remain relevant for approximately 10 years, and implementation of all the recommendations is essentially complete. It was expected that the LSMP would be revised after 10 years and a new version published.

Goals and Guiding Principals

Fisheries management in the Minnesota waters of Lake Superior is the responsibility of the Minnesota Department of Natural Resources, Fisheries Management Section. The MNDNR mission as stated in *A Strategic Conservation Agenda 2003 – 2007* (MNDNR 2005) is "to work with citizens to conserve and manage the state's natural resources, to provide outdoor recreation opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life." This mission complements the MNDNR Fisheries Management Section mission which is "to protect and manage Minnesota's aquatic resources and associated fish communities for their intrinsic values and long-term ecological, commercial, and recreational benefits to the people of Minnesota." In the context of the LSMP, "aquatic resources" are defined as the Lake Superior ecosystem and its watershed, which includes water quality, habitat, and the natural communities present within.

The long-term goal for fisheries management in the Minnesota waters of Lake Superior is:

To protect the Lake Superior ecosystem, restore its watershed, and manage for a diverse, stable, self-sustaining fish community that provides recreational, commercial and tribal fishing opportunities.

For our purposes, the definitions of terms used in this goal statement are as follows: a "diverse" fish community is one that includes different strains of native and introduced species that have established themselves through natural reproduction and are presently found in Minnesota waters. "Stable" means that although the abundance of various populations may fluctuate, they do so within a limited range. A "self-sustaining" community is one in which the fish species can sustain themselves largely through natural reproduction, but at times may require assistance through management actions such as stocking.

The mission of the MNDNR, the Fisheries Management Section, and the Lake Superior Management Plan all stress the need to protect the resource (ecosystem), and provide for resource use. There are times when these two responsibilities conflict. When such conflicts occur, the long-term protection of the resource must take precedence, because without a resource to use there can be no sustained public benefit.

The MNDNR uses an ecosystem-based management approach. In its mission to protect the Lake Superior ecosystem and manage the fishery based on ecological principals, the plan recognizes that:

- Fish production in Lake Superior is finite, and although users may desire more fish from its waters, the lake simply may not have the capacity to produce at higher levels. Additional stocking of trout and salmon cannot take place without considering impacts on the forage base.

- Lake Superior is the least productive, but most pristine of the Great Lakes and has demonstrated the capacity to support self-sustaining fish populations through natural reproduction. The plan emphasizes the continued need for habitat protection, and the desire for managing self-sustaining fish populations that are best suited to the lake's environment.

- User groups on Lake Superior have diverse interests, and the LSMP attempts to balance resource protection, recreational opportunities, cultural beliefs and economic development for the benefit of both present and future generations. Citizen participation was the cornerstone of the planning process, and will be an ongoing process, once implementation begins.

- Lake Superior fishery management is an expensive program when compared to other fisheries in the state, consuming approximately 4.5% of the total fisheries budget. Although Lake Superior is a unique resource and offers diverse recreational opportunities, user groups must recognize that increased expenditures for Lake Superior fishery programs will be difficult to justify when viewed from a statewide perspective.

- The effectiveness of Lake Superior management programs must continually be evaluated. If established criteria indicate program changes are required, interested citizens will be consulted and the necessary action will be taken.

- Only 7% of Lake Superior falls within the state of Minnesota. The Great Lakes Fishery Commission provides the structure for cooperative management among the various jurisdictions around the lake, and continued involvement with the Commission is required to address the ever-increasing complexity of issues that arise.

As we begin to implement this plan, citizen participation will be crucial, and we expect the plan will focus and stimulate ongoing conversations about future fisheries management for the Minnesota waters of Lake Superior. It is our belief that this plan is a requirement for sound management of the Lake Superior fishery, and its success will ultimately be determined by citizen support and the long-term benefits to the resource and its users.

Financial Resources of the Department

The MNDNR requires financial resources to carry out its responsibility for natural resource protection and management. The Fisheries Management Section budget comes from the sale of fishing licenses, trout stamps, and federal aid reimbursement through an excise tax on fishing equipment. Over the last 5 years an average of 1.6 million fishing licenses and 96,000 trout stamps have been sold annually. Trout and salmon anglers constitute 6% of the total licensed anglers in Minnesota. Financial resources are limited and must be used efficiently to manage the vast array of lakes and streams in Minnesota. The Minnesota portion of Lake Superior is only one part of the state's fishery resource, and managers must decide how to best allocate limited funds.

Decisions regarding financial and resource concerns are usually initiated at the field level. On Lake Superior, this usually involves collaboration between the Lake Superior Area and the three other areas along the shore: Duluth, Finland and Grand Marais. If resolution cannot be reached, the decision is passed to the regional level, and if there continues to be disagreement, the St. Paul staff becomes involved. The ultimate decision on both resource and financial issues rests with the Commissioner of Natural Resources. Citizen input is encouraged at all levels, but is most useful when initiated at the field level.

Allocation of Funds to Lake Superior

The overall annual operating budget for the Fisheries Management Section in fiscal year (FY) 2005 (July 1, 2004 - June 30, 2005) was about $30,600,000. The major source of this funding is from the sale of fishing licenses. Approximately $6,400,000 of the overall section budget, or 21% was spent on the coldwater program. Trout stamp sales accounted for $1,114,850, which is 3.6% of the overall fisheries budget and 17.5% of the coldwater budget. Major expenditures in the coldwater program include fish culture and stocking, habitat improvement, research, and special management projects on Lake Superior and the anadromous portions of its tributaries.

Approximately 4.5% of the total statewide fisheries budget and 22.0% of the coldwater budget is allocated to the Lake Superior program. We estimate that an average of approximately $1,398,000 was spent on Lake Superior fisheries management annually in FY 2003-2005. Of the $1,398,000 spent on Lake Superior, approximately $584,000 (42%) was spent on fish culture, $564,000 (40%) on management activities, $125,000 (9%) on research, and $125,000 (9%) on administration.

In a study on the benefits of coldwater angling in Minnesota, it was estimated that approximately 1.2% of all licensed anglers and 20% of all anglers that purchased trout stamps participated in the Lake Superior and anadromous stream fishery (Gartner et al. 2002). The average annual angling pressure estimated from MNDNR creel surveys from 2000 to 2004 was 219,500 hours. This includes the average annual pressure from both the summer and spring fishery, the annualized averages from the 1998 and 2003 fall creel surveys, and 1997 and 2001 winter creel surveys. The estimated management cost per angler hour on Lake Superior averaged approximately $6.37 from 2000 through 2004. The cost per angler hour is high when compared to estimated costs from other large lakes in Minnesota over the same time period.

The estimated average hatchery cost per fish stocked in Lake Superior ranged from $0.30 for Chinook salmon fingerlings to $2.85 for steelhead yearlings. The estimated cost per hatchery fish caught in Lake Superior ranged from $25.00 for Kamloops to $360.00 for Chinook salmon (Table 1.1). As management strategies are reviewed in times of shrinking budgets, the financial realities must be considered along with the biological and social concerns.

Fish culture is the most expensive portion of the Lake Superior program. During the 5-year period from FY 1999 through FY 2003, an average of 37% of the statewide coldwater hatchery expenditures went toward Lake Superior stocking programs. During this period, the state produced lake trout, steelhead and Kamloops yearlings, Chinook salmon fingerlings,

Table 1.1. Average estimated production cost per fish stocked and average cost per stocked fish caught by angling from 2000-2004.

Species	Production cost/fish stocked	Size	Cost/angler caught fish
Lake trout	$0.45	Yrl	$34.00
Chinook salmon	$0.30	Fgl	$360.00
Kamloops	$1.45	Yrl	$25.00
Steelhead	$2.85	Yrl	$347.00

and steelhead fry for Lake Superior. As state budgets continue to tighten and the sale of angling licenses remains flat or decreases, the potential for expanded coldwater culture programs for Lake Superior appears remote.

Relationships to Other Agencies

Lake Superior is bordered by several political jurisdictions, which share fisheries management responsibilities for the lake. Approximately 7% of Lake Superior's surface area lies within Minnesota state boundaries. Fisheries management is coordinated among the various agencies in each jurisdiction under the auspices of the Great Lakes Fishery Commission (GLFC). The GLFC is an international commission established by the U.S. and Canada in 1956 to control sea lamprey, coordinate fisheries management, and direct fisheries research on the Great Lakes. States bordering the Great Lakes, the province of Ontario, and a number of Indian Bands are partners in the GLFC. Minnesota, as a partner in the GLFC, is represented on the Lake Superior Committee, which is comprised of policy level decision makers, and the Lake Superior Technical Committee, which is comprised of fishery biologists from the various management agencies. These committees are established to coordinate fisheries management throughout the Great Lakes, and specifically on Lake Superior.

The GLFC has produced two major documents, *A Joint Strategic Plan for Management of Great Lakes Fisheries* (SGLFMP) (GLFC 1997) and the *Strategic Vision of the Great Lakes Fishery Commission for the First Decade of the New Millennium* (2001), which set the overall direction for fisheries management in the Great Lakes. Following the direction of SGLFMP and the Vision, *Fish Community Objectives for Lake Superior* (Horns et al. 2003) was drafted and adopted by all management agencies on Lake Superior. It describes the goals and objectives for fisheries management on Lake Superior and, along with its companion documents, establishes the framework for fisheries management by participating agencies. The goals and objectives for fisheries management in the Minnesota waters of Lake Superior fall within the framework proposed in the *Fish Community Objectives for Lake Superior* (Horns et al. 2003).

The Binational Plan for Lake Superior is another international initiative on Lake Superior that has the potential to affect fisheries management and the Lake Superior fish community. Participants in the Binational Plan include the states bordering Lake Superior, the province of Ontario, a number of Indian bands, Environment Canada, and the U.S. Environmental Protection Agency (USEPA). The Binational Plan promotes the goal of zero discharge of nine persistent toxic substances, and outlined a comprehensive ecosystem management plan (LaMP) for Lake Superior (Lake Superior Binational Program 2004).

Citizen Participation

The cornerstone of the Lake Superior planning process has been citizen participation. When the 1995 LSMP was developed, a group of interested citizens, the Lake Superior Advisory Group (LSAG), was formed and was instrumental in developing the plan. That group was reassembled in late 2004 to assist with drafting the 2005 LSMP. In 2005 there were 21 members that formed the LSAG. Members of the LSAG represent fishing organizations, environmental groups, Indian bands, commercial fishing interests, local governments, and individual anglers interested in fisheries management in Minnesota's portion of Lake Superior.

In discussions with members of the LSAG, a conference was planned to begin revision of the LSMP. The *Lake Superior Fisheries Conference* was open to all citizens interested in Lake Superior fisheries management and held on December 4, 2004. The goal of the conference was to provide information on Lake Superior fisheries management to interested citizens, and to identify major issues for the MNDNR and the LSAG to address in the revised LSMP. During the conference, MNDNR biologists and invited scientists addressed various aspects of fisheries management in Lake Superior through a variety of brief presentations. Citizens engaged in two one-hour breakout sessions where they discussed and identified important issues they felt the MNDNR and the LSAG should address in the revised plan. After the conference, issues identified by the participants were summarized and prioritized based on topic areas. The LSAG was assembled and biological information on management issues were provided by MNDNR biologists and a variety of invited scientists from outside the agency. Six meetings were held over a six-month period with the LSAG where brief presentations were made, and discussions took place among the members that focused on the major issues identified by citizens at the *Lake Superior Fisheries Conference*. Each member of the LSAG was asked to provide written input from their organizations on the various issues discussed, and share that input with the LSAG. All input on each issue was compiled and distributed to all groups involved, including personnel in the Fisheries Management Section.

Comments and input from the LSAG varied, with some areas of common agreement and other areas where little or no agreement was apparent. After all the issues had been discussed by the LSAG, each organization's comments were recorded and summarized. The comment summaries were used by a group of MNDNR fishery managers and biologists that met to compile a set of recommendations to address the various issues raised by the citizens and discussed by the LSAG. These recommendations were crafted into a revised draft LSMP and reviewed by regional and central office fisheries staff. The draft LSMP was distributed to the LSAG for comment and discussion. Comments received from the LSAG were reviewed and modifications to the draft LSMP were made. The draft LSMP was then distributed to the general public by mail and web posting for comment and review. Three "Open House" meetings were also held to distribute, discuss, and get feedback on the draft LSMP from the general public interested in the Lake Superior fishery. The "Open House" meetings were held in St. Paul, Schroeder, and Duluth.

Public comments that were received from the open house meetings, submitted by mail, or collected over the internet were compiled, summarized and distributed to the Lake Superior Advisory Group as well as posted on the MNDNR website for public review. The North Shore Management Group met to discuss all of the comments, and determine what sections of the plan should be modified and what sections should remain unchanged. Controversial parts of the plan were thoroughly discussed within the Department of Natural Resources. After approval by the Division Management Team and Commissioner's office, the final plan was developed. Significant changes that were made in the final plan were summarized and distributed to the Lake Superior Advisory Group, and were also posted on the MNDNR website for public review.

The completed plan was distributed to all interested citizens and posted on the MNDNR website. As this plan is implemented, citizens may inquire at the Lake Superior Area Office to receive information on its progress. The LSMP process was a group effort that involved many hours of work by many people. As among any diverse group, there are areas of disagreement, but there are also many areas of agreement. The LSMP is expected to focus and stimulate ongoing conversations about future fisheries management for the Minnesota waters of Lake Superior. The plan needs to be followed to be effective; however, the plan is also flexible and may be modified based on: 1) major changes in the fish community; 2) the necessity to protect the resource if it is being compromised; or 3) shifts in societal values placed on the Lake Superior fisheries resource. We believe the LSMP is a requirement for sound management of the Lake Superior fishery, and will ultimately move us closer to the goals we have identified.

References

Gartner, W. C., L. L. Love, D. Erkkila, and D. C. Fulton. 2002. Economic impact and social benefits study of coldwater angling in Minnesota. Minnesota Department of Natural Resources, Section of Fisheries, St. Paul.

Great Lakes Fishery Commission. 1997. A joint strategic plan for management of Great Lakes fisheries. Great Lakes Fishery Commission, Ann Arbor, Michigan.

Great Lakes Fishery Commission. 2001. Strategic vision of the Great Lakes Fishery Commission for the first decade of the new millennium. Great Lakes Fishery Commission, Ann Arbor, Michigan.

Horns, W. H., C. R. Bronte, T. R. Busiahn, M. P. Ebener, R. L. Eshenroder, T. Gorenflo, N. Kmiecik, W. Mattes, J. W. Peck, M. Petzold, and D. R. Schreiner. 2003. Fish community objectives for Lake Superior - 2000. Great Lakes Fishery Commission, Special Publication 03-01, Ann Arbor, Michigan.

Lake Superior Binational Program. 2004. Lake Superior lakewide management plan (LaMP) 2004. Available: http://www.epa.gov/glnpo/lakesuperior/2004 (July 2006).

Minnesota Department of Natural Resources. 2005. A strategic conservation agenda 2003 – 2007. Minnesota Department of Natural Resources, St. Paul.

CHAPTER 2: FISH COMMUNITY INTERACTIONS

Over the last 15 years, most organizations involved in fisheries management have made the transition from an individual species-based approach to a community-based approach. A community approach is one that considers information about a wide variety of species from different trophic levels (e.g., plankton, invertebrates, vertebrates) and environmental factors (e.g., weather, water temperature, contaminants) in the context of their interactions. The community approach requires managers to integrate and synthesize information from many sources to predict the effects of management actions on species assemblages or aquatic communities (Christie et al. 1987).

The MNDNR Fisheries Management Section is committed to the concept of watershed, ecosystem, and biological community management (MNDNR 1994). These concepts recognize that a variety of physical, biological, chemical, and human-induced factors affect fisheries. Fisheries management that focuses primarily on the species approach is more subject to inaccurate or incomplete analysis of problems, and more prone to failure as a result of taking inappropriate actions. Although this issue has long been recognized, fisheries management techniques have historically emphasized the species approach because effective techniques for assessing and managing aquatic communities have not been readily available.

The biological community consists of all the plants and animals within an ecosystem. Healthy ecosystems rely on native and naturalized species that are self-sustaining and relatively stable. Many fishery management activities, such as stocking programs and the introduction of non-native species, have the potential to disrupt the interrelationships among species in an established community, and therefore must be explored thoroughly before action is taken. In the Great Lakes, popular recreational fisheries are often in conflict with the integrity of the natural community, and may contribute to instability in the aquatic community. Throughout the Great Lakes, many anglers still strongly support management for a favorite species, which is often introduced, and can only be sustained through heavy stocking. Management agencies are often pressured by anglers to deliver their favorite species at larger sizes and in greater numbers on a continual basis. In many areas, the situation is compounded because of angler demands for several favorite species. Introductions of non-native species by management agencies does not promote biological diversity, rather it is a prime example of the species approach and demonstrates a disregard for the overall effects on the integrity of the established fish community.

In the 1995 LSMP (Schreiner 1995), the community-based approach was discussed, and the plan was structured to use this approach in managing the Lake Superior fishery in Minnesota. Much progress has been made over the last 10 years in the formulation of community-based management strategies, and in the public's understanding of how the fish community functions. Although anglers still promote their favorite species, many recognize the need to consider the entire ecosystem, and the constraints that Lake Superior poses for assemblages of certain fish species. By gaining a better understanding of the community dynamics in Lake Superior, many anglers have also recognized that their expectations for the Lake Superior fishery far exceeded the productive capacity of the fish community on a sustainable level. By using a community-based approach, fish management agencies may reduce the potential for the boom-or-bust fisheries that anglers have experienced in the other Great Lakes. Management emphasis on self-sustaining native and naturalized species assemblages, an understanding of their prey base, and adequate protection of habitat will ensure a healthy, sustainable fishery into the future.

The MNDNR will continue to manage for a stable, diverse, self-sustaining sport fishery in Lake Superior. Most species that have been introduced into Lake Superior have become naturalized and are now permanent components of the fish community. Future management strategies and goals cannot ignore the established sport fishery and economic impacts that have developed because of these introduced species. The MNDNR strives to attain a balance between a sustainable Lake Superior fish community, the economics of the fisheries, and angler expectations.

A general approach to ecosystem and community management from a fisheries perspective involves the following (MNDNR 1994):

- Examination of the physical characteristics and human activities, including fishing, in the watershed to determine possible effects on the fishery.
- Survey and classification of the water body according to its physical, chemical, and morphological characteristics.
- Survey of the biological community, focusing primarily on the fish assemblages.
- Determination of whether the numbers and varieties of fish species in the community, and their yield to the fishery, conform to regional or theoretical norms for the particular water body.
- Formulation of management plans to maintain or improve the fishery based on the above evaluations.
- Implementation of management activities.
- Evaluation of the success of management activities, and cessation or modification of activities as warranted by the evaluation.

A community approach to fisheries management improves the chances for success, and the information collected in the process leads to improved techniques. Since implementation of the 1995 LSMP, public acceptance of fish management activities has been enhanced by this approach to community-based management, particularly when MNDNR staff communicate frequently and work closely with concerned citizens.

Present Status of the Lake Superior Fish Community

Many changes have occurred in the Lake Superior fish community since 1970, and the positive trends identified in the 1995 LSMP have continued. Wild lake trout abundance has increased and may be approaching fully rehabilitated levels (Corradin 2004; Wilberg et al. 2003). Lake herring stocks have also rebounded in much of the lake, but continue to exhibit sporadic recruitment. The deep-water fish community composed mainly of siscowet, burbot *Lota lota*, deep-water chubs and sculpin, remains relatively undisturbed. Pacific salmon have become naturalized and are largely supported by reproducing populations, which makes continued stocking ineffective. Prey biomass has largely shifted from non-native rainbow smelt to native species, and high predation rates may limit any future recovery of rainbow smelt to historical levels. Managers have little influence on prey abundance, as predatory impact is the driving force, and control of predator abundance is limited because most species are now self-sustaining (Bronte et al. 2003). A potential threat to the recovering fish community remains the adverse affects of new and unwanted introductions of invasive species.

The introduction and widespread naturalization of Pacific salmon in Lake Superior over the last 30 years is significant to the Lake Superior fish community. On an individual basis, Chinook salmon exhibit a higher rate of predation than any other salmonine species in Lake Superior and, therefore, could theoretically have the greatest impact on forage abundance over the shortest period of time (Negus 1995). Recent information suggests that survival of stocked Chinook salmon has decreased dramatically in Lake Superior, and the population is now dominated by naturalized Chinook salmon (Peck et al. 1999). On a lake-wide basis, community-based models predict that Chinook salmon impact lake trout far less than lake trout impact Chinook salmon (Kitchell et al. 2000). Bioenergetics simulations also suggest that the Chinook salmon population has a relatively low impact on the forage base compared to the impact exerted by the abundant and long-lived lake trout. The naturalization of both Chinook and coho salmon throughout much of Lake Superior leaves management agencies with limited control over abundance, movement, and community impact of these introduced species. However, some anglers prefer salmon to lake trout, and despite high levels of natural reproduction and poor survival of stocked fish, continue to request increased stocking programs.

A number of trends continue in the Lake Superior fish community and appear to be interrelated. In Minnesota, the abundance of wild lake trout and naturalized Chinook salmon has increased. In contrast, survival of stocked lake trout and stocked Chinook salmon has decreased, while stocking levels have been stable or have expanded (Hansen et al. 1994; Hansen 1994; Peck et al. 1999). A major shift in the forage base from rainbow smelt to lake herring (Bronte et al. 2003) may have greatly influenced the community dynamics in Lake Superior. This shift could explain the increased mortality of stocked juvenile fish, changes in the spatial distribution of predators, and decreasing growth rates of Pacific salmon (Schreiner and Halpern 2005; Negus et al. *in preparation*). In Minnesota waters, there is evidence that some yearling lake trout are consumed soon after they are stocked (Ostazeski et al. 1999). Both stocked and naturally produced juveniles of all salmonines may be subject to similar predation. Predator avoidance, and competition for forage among juvenile fish may cause them to disperse over wider areas and become more pelagic than in the past. Catchability of a dispersed stock usually decreases, whether the gear used is hook-and-line or gill net. Predators that expend more energy seeking and processing pelagic food items over a wide area may exhibit slower growth rates. A signal that a population has reached carrying capacity is the increase of older fish, with a stable or declining rate of recruitment. Many of these trends are evident throughout Lake Superior (Hansen 1994; Richards et al. 2005; Corradin 2004).

The management of a fish community approaching carrying capacity involves different considerations than rehabilitating a depleted stock, which has been the focus of past management activities. For example, stocking large numbers of yearling lake trout may slow rehabilitation of native lake trout if stocked fish are in competition with their native counterparts for scarce resources (Evans and Willox 1991; Corradin 2004). If survival of stocked fish is declining, as it is in Minnesota, stocking more fish may not have the desired results of increasing abundance, and may even be counterproductive.

Use of Community-Based Models and New Technologies

Initial bioenergetics modeling of the fish community in the Minnesota waters of Lake Superior identified critical information needs to adequately understand the dynamics of the Lake Superior fish community (Negus 1995). This modeling effort identified a need for more detailed information on prey biomass, predator abundance, predator diets, and predator growth (Ebener 2003). Major efforts to collect this information have occurred since 1995. In 1996 and 1997, a pilot study to estimate the biomass of prey species in the western arm of Lake Superior was conducted using hydroacoustics (Mason et al. 2005). From 2003 – 2005 a collaborative effort between the MNDNR and the University of Minnesota-Duluth involved designing a hydroacoustics survey that could efficiently estimate prey biomass and aid in developing sustainable harvest targets for prey species (Hrabik et al. 2005).

A Statistical-Catch-At-Age (SCAA) model (Bence and Ebener 2002) was developed to better estimate lake trout abundance and mortality rates in Lake Superior. Abundance of other predators in Minnesota waters was determined from returns to creels, traps, and applying mortality rate estimates to stocked fish abundance (Negus et al. in preparation). Aging techniques were refined using otoliths, and standards for determining age and growth were recommended for use by all fish management agencies working on Lake Superior (Schreiner and Schram 2001). All agencies increased diet collections from predators (Ebener 2003), and all data from agency collections were combined into a centralized database for future use on Lake Superior (Ray 2004).

Determining the link between fish and the lower aquatic trophic levels is recognized as a critical need to better understanding the Lake Superior food web. The relationship between forage fish biomass and their prey abundance (zooplankton) was explored in the 1996-1997 pilot study of Lake Superior's western arm (Johnson et al. 2004). Diets of lake herring, deepwater coregonines, and rainbow smelt were compared to the composition of organisms taken simultaneously in plankton tows. Foraging behavior by lake trout on rainbow smelt and lake herring in western Lake Superior has also been investigated to determine if changes have occurred as prey abundance has changed (Mason et al. 1998). In 2004, initial discussions began on a lakewide project to address the relationships between all trophic levels in Lake Superior, with the ultimate goal of determining the productive potential of the lake in terms of prey fish and predator abundance. This project is a collaborative effort between the Department of Fisheries and Oceans, Canada; the US Geological Survey, Ashland Biological Station; the USEPA Mid-Continent Research Lab in Duluth; a number of scientists from surrounding universities; and most of the fish management agencies on Lake Superior. The field portion of this project began in 2005 and requires the use of three large vessels and a number of smaller vessels to collect temporal and spatial information over a two-year period. Information gained from this project will be the first all-encompassing study that examines the entire aquatic community and the interactions between trophic levels in Lake Superior. This study will create a baseline for monitoring production of the Lake Superior fish community well into the future.

The continued use of new technologies and community-based models proposed in this plan will enable us to better estimate, predict, and understand the dynamics of the fish community. As described above, models that help to explain the processes affecting fish communities have been developed, and will evolve to serve as useful tools in the future management of the Lake Superior fishery. The application of bioenergetics models (Negus 1995; Negus et al. *in preparation*), ecosystem models such as Ecopath-Ecosim (Kitchell et al. 2000), and Statistical-Catch-At-Age models (Bence and Ebener 2002) will allow managers to examine different scenarios at no cost to the resource and at minimal cost to the management agency or angler. The results of different management strategies can be analyzed and demonstrated to other biologists, administrators, legislators, and the public (Jones et al. 1993). As we gain a better understanding of the Lake Superior fish community, we must remember that the overall productivity of the lake will remain essentially unchanged, and the production of a species will largely depend on the critical habitat available and how well it has adapted to the Lake Superior ecosystem.

Genetic Aspects and Management of the Lake Superior Fish Community

The genetics of fish, combined with their environment, determine the quality and sustainability of the fish community. Historically, managers have attempted to manipulate fish populations through harvest regulations, stocking, habitat improvement, etc., with little regard to the genetic makeup of fish stocks. This may have been shortsighted as relatively minor changes in management strategies may alter the genetic integrity of a stock (Kapuscinski and Miller 2003). Maintaining genetic variation is important to fish stocks. Genetic variation gives fish populations the ability to adapt to changing environments. The genetic diversity in a fish population is finite and can be lost. The results of losing genetic variability may be the creation of a fish population that lacks the ability to adapt to short-term stressors and long-term environmental change.

To create a sustainable fish community, the consequences of management actions on the genetic structure of native or naturalized stocks must be considered. A number of studies have described the potential conflict between wild trout management and stocking. Much has been published over the last two decades on the use of stocking to rehabilitate depleted fish stocks (Krueger and May 1991; Stroud 1986; Hallerman 2003). Significant genetic problems can occur when high numbers of hatchery fish are stocked into waters with remnant wild populations (Ferguson 1990; Evans and Willox 1991; Utter 2003). More recently, specific research targeting restoration of native species by stocking has been conducted on a variety of species (Krueger and Ihssen 1995; Hallerman 2003; Nickum et al. 2004).

Lake trout populations in Lake Superior were historically subdivided into discrete spawning stocks. These stocks used different spawning habitats and displayed different behavioral traits (Ihssen 1984). With the invasion of the sea lamprey, many of these stocks were lost and the genetic diversity of lake trout was reduced (Meffe 1995). Fortunately, a few remnant lake trout stocks remained which continued to reproduce, and were eventually used as an egg source for hatchery production. Sea lamprey predation and extensive stocking programs undoubtedly reduced the genetic diversity of lake trout in Lake Superior. However, local adaptation through natural selection should occur, and with proper management, genetic diversity should slowly increase (Krueger and Ihssen 1995). Initial strain selection, hatchery breeding techniques, stocking locations, stocking rates, and fishing pressure will all influence the rate of genetic differentiation in the future (Burnham-Curtis et al. 1995).

Detailed genetic studies by a number of research scientists discuss the potential consequences of stocking on coaster brook trout rehabilitation in Lake Superior (Burnham-Curtis 1996, 2001; Wilson et al. *in press*). Few wild coaster brook trout populations are sufficiently large to be used as a source population for gametes. Development of locally adapted brood stock strains from wild populations, and comparative studies of these strains are recommended (Wilson et al. *in press*). To increase the probability that stocked fish will successfully contribute to rehabilitation efforts, strategies should include maintaining genetic variability, and using best management practices for creating brood stock in all hatcheries (Allendorf and Ryman 1987; Miller and Kapuscinski 2003; Cooper 2004).

Many studies on West Coast steelhead and salmon have described the negative impacts that domesticated hatchery fish have on wild stocks. Based on studies conducted by MNDNR research biologists and university scientists, hybridization between Kamloops and wild steelhead is a risk in Lake Superior, and would likely be detrimental to wild steelhead rehabilitation efforts through dilution of the steelhead gene pool. A study by researchers at the University of Minnesota indicated lower survival of fry produced from hatchery-reared steelhead than steelhead fry produced by wild Knife River steelhead (Caroffino et al. *in review*). This study also suggested that there might be a loss of genetic variability in hatchery-reared steelhead when compared to wild Knife River steelhead, potentially reducing the long-term fitness of the population. Additional genetic information on rainbow trout can be found in the *Rainbow Trout Management Plan for the Minnesota Waters of Lake Superior* (Schreiner 2003).

Global Climate Change

Global climate models have been used to predict the effects of climate warming on annual water temperature and precipitation in the Great Lakes region. A number of studies have been conducted on the potential effects of global climate change on the Lake Superior fish community (Magnuson et al. 1997; Hill and Magnuson 1990; Jones et al. 2004). Summer and winter air temperatures have increased in the Great Lakes region during the 1990s and early 2000s, however no significant changes in the Lake Superior fish community have been attributed to this warming (Bronte et al. 2003).

It is predicted that the long-term consequences of climate warming will impact the Lake Superior fishery by affecting both the lake and stream communities. Precipitation in the Lake Superior basin is predicted to decrease by 5% in the summer and increase by up to 20% in the winter. Summer air temperatures are predicted to increase by 5º C and winter air temperatures by 7º C (Magnuson et al. 1997). Extrapolations indicate this could warm the epilimnion waters from July-September by 1.8 – 5.7º C. These changes would decrease ice cover and increase the thermal habitat volume for many fish species. Increased volume of thermal habitat may enhance production of most Lake Superior fish species. However, abundance of invasive species such as white perch *Morone americana*, ruffe and alewife, which are all rare in the main basin of Lake Superior, may increase because of increased water temperatures. It is projected that the annual fish production in Lake Superior would increase along with the diversity and biomass (Magnuson et al. 1997). Primary production could increase by 1.6 to 2.7 times, and fish yield 1.4 to 2.1 times present levels (Regier et al. 1990).

Fish communities that use tributary streams would also be affected by climate warming. Stream temperatures in Minnesota are projected to increase by 2.4 – 4.7º C. Summer stream flows are predicted to decrease and sand bars may form more frequently at stream mouths impeding movement of migratory fish. Habitat available to cold-water species such as brook trout, rainbow trout, and pacific salmon may decrease dramatically during peak summer temperatures, decreasing the overall production of these game fish in Lake Superior. In Minnesota during the 1990s and early 2000s, summer die-offs of rainbow trout in the Lester, Knife and a number of other rivers with limited ground water have been common and appear to be increasing in occurrence and intensity. This indicates that many of Minnesota's most productive streams for migratory fish species are vulnerable to climate warming.

Although increased productivity in Lake Superior may initially sound positive to resource users, there is great risk that the system will not act as predicted, and the establishment and increased productivity of invasive species may offset any increase in production of desirable species. There is much uncertainty with global climate forecasts, and their potential effects on the fish community. Most models have emphasized the effects on temperature alone. To make more realistic predictions habitat change must be linked to fish population dynamics (Jones et al 2004). Work is just beginning to develop such models for the Great Lakes.

Invasive Species

The ecological and economic impacts of invasive species in the Great Lakes and their effect on the native fish community have been well documented (USEPA 2005). This section briefly summarizes some of the major impacts invasive species have had on the Lake Superior fish community, and what steps must be taken to minimize future introductions. Since the 1980s, at least 139 non-indigenous aquatic organisms, including 25 fish species have become established in the Great Lakes (Mills et al. 1993), and since 1970, 39 new non-indigenous aquatic organisms have entered Lake Superior. Of these new invasive species, nine are fish, seven are aquatic invertebrates, eight are fish disease causing organisms and parasites, and those remaining are composed of various aquatic plant species (Bronte et al. 2003). Over 66% of all unintentional introductions have occurred since 1970, averaging 1.4 new introductions per year. Lake Superior has had the least introductions of non-indigenous species when compared to the other Great Lakes (Mills et al. 1993).

Sea lamprey, which invaded Lake Superior in the early 1930s is the most well known and detrimental of all invasive species in Lake Superior. Destruction of fish stocks by sea lamprey has cost hundreds of millions of dollars in losses to the fisheries and costs for control. Fortunately, many invasive fish species cannot tolerate the low annual temperature and reduced productivity of Lake Superior, and have largely been confined to estuaries, bays and tributaries. Ruffe, zebra mussel , white perch, and round goby *(Neogobius melanostomus)* are all examples of such species and all have become established in the St Louis River Estuary. The spiny water flea is a predacious zooplankter, and unlike the invasive species described above is found throughout Lake Superior in the pelagic zone. The potential long-term effects of these recent introductions on the ecological relationships and economics on the Lake Superior fish community are still unknown, but in other locations, invasive species have competed with, and in some instances replaced, significant portions of the native fish community.

Major pathways for new introductions are mostly human related and include ballast water transport (24%), cultivation of aquatic and terrestrial plants (24%), release of parasites and pathogens carried by hatchery fish (19%), newly connected waterways and unintentional stocking (2%), and a large variety of other known (aquarium releases, bait buckets, angler live-wells, etc.) (15%) and unknown mechanisms (15%). Since 1970, all of the introduced fish and three of the four introduced aquatic invertebrates in Lake Superior were attributed to inter-lake movement of foreign cargo ships (Bronte et al. 2003). Many of the initial discoveries occurred in the St. Louis Harbor, which is the busiest inland port in the United States with over 1,000 vessel trips annually.

Strategies to prevent or reduce future introductions of invasive species are some of the most important management actions we can make to protect the long-term health of Lake Superior. The effective treatment and management of ballast water from international and inter-lake vessels is critical if new introductions are to be curtailed. The development and continued implementation of public education programs to promote greater awareness of invasive species from all sources, and the general public's role in the introduction and movement of invasive species will also help minimize future introductions. Agencies responsible for environmental protection and maritime commerce must collaborate to develop and implement a surveillance program, along with a rapid response strategy that will increase the ability to predict, prevent and contain the introduction of new non-indigenous species (Ebener et al. *in review*).

Summary

The premise of this plan is that the Lake Superior fishery is a complex, interrelated community. Throughout this plan, the idea of community is reinforced, and management strategies are suggested that have their foundation in the community approach, as we understand it today. If management strategies ignore the interrelationship of species within the community, the stability of the system and the future of the resource may be at risk.

References

Allendorf, F. W., and N. Ryman. 1987. Genetic management of hatchery stocks. Pages 141-159 *in* N. Ryman and F. Utter, editors. Population genetics and fishery management. University of Washington Press, Seattle.

Bence, J. R., and M. P. Ebener, editors. 2002. Summary status of lake trout and lake whitefish populations in the 1836 treaty-ceded waters of lakes Superior, Huron and Michigan in 2000, with recommended yield and effort levels for 2001. Technical Fisheries Committee, 1836 treaty-ceded waters of Lakes Superior, Huron and Michigan, Ann Arbor.

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 60:1552-1574.

Burnham-Curtis, M. K. 1996. Mitochondrial DNA variation among Lake Superior brook trout populations: summary of genetic analyses. U.S. Fish and Wildlife Service, Ashland Fisheries Resource Office, Research Completion Report, Ashland, Wisconsin.

Burnham-Curtis, M. K. 2001. Genetic profiles of selected brook trout *Salvelinus fontinalis* populations from Lake Superior. U.S. Geological Survey, Great Lakes Science Center, Research Completion Report, Ann Arbor, Michigan.

Burnham-Curtis, M. K., C. C. Krueger, D. R. Schreiner, J. E. Johnson, T. J. Stewart, R. M. Horrall, W. R. MacCallum, R. Kenyon, and R. E. Lange. 1995. Genetic strategies for lake trout rehabilitation: a synthesis. Journal of Great Lakes Research 21(Supplement 1):477-486.

Caroffino, D. C., L. M. Miller, A. R. Kapucsinski, and J. J. Ostazeski. *In review*. One year of parental hatchery experience reduces success of steelhead fry stocked into their naturalized environment. Canadian Journal of Fisheries and Aquatic Sciences.

Christie, W. J., J. J. Collins, G. W. Eck, C. I. Goddard, J. M. Hoenig, M. Holey, L. D. Jacobson, W. MacCallum, S. J. Nepszy, R. O'Gorman, and J. Selgeby. 1987. Meeting future information needs for Great Lakes fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2):439-447.

Cooper, A. 2004. Microsatellite-based genetic monitoring in Lake Superior brook trout *Salvelinus fontinalis* hatchery strains: implications for broodstock management and rehabilitation efforts. Master's thesis. University of Minnesota, St. Paul.

Corradin, L.M. 2004. Recruitment and growth dynamics of lake trout in western Lake Superior. Master's thesis. University of Wisconsin-Stevens Point, Stevens Point.

Ebener, M. P. (editor). *In review*. The state of Lake Superior in 2000. Great Lakes Fishery Commission Special Publication, Ann Arbor, Michigan**.**

Ebener, M. P., (editor). 2003. Sampling and reporting protocols of the Lake Superior Technical Committee. Lake Superior Technical Committee, Ann Arbor, Michigan.

Evans, D. O., and C. C. Willox. 1991. Loss of exploited indigenous populations of lake trout, *Salvelinus namaycush*, by stocking of non-native stocks. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1):134-147.

Ferguson, M. M. 1990. The genetic impact of introduced fishes on native species. Canadian Journal of Zoology 68:1053-1057.

Hallerman, E. M., editor. 2003. Population genetics: principles and applications for fisheries scientists. American Fisheries Society, Bethesda, Maryland.

Hansen, M. J., editor. 1994. The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1, Ann Arbor, Michigan.

Hansen, M. J., M. P. Ebener, R. G. Schorfhaar, S. T. Schram, D. R. Schreiner, and J. H. Selgeby. 1994. Declining survival of lake trout stocked during 1963-1986 in U.S. waters of Lake Superior. North American Journal of Fisheries Management 14:395-402.

Hill, D. K., and J. J. Magnuson. 1990. Potential effects of global climate warming on the growth and prey consumption of Great Lakes fishes. Transactions of the American Fisheries Society 119:265-275.

Hrabik, T., D. R. Schreiner, M. Balge, and S. A. Geving. 2005. Development of a hydroacoustic design to quantify prey fish abundance in the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Investigational Report 530, St. Paul.

Ihssen, P. E. 1984. Genetics. Pages 15-21 *in* R. Eschenroder, C. H. Olver, and T. P. Poe, editors. Strategies for rehabilitation of lake trout in the Great Lakes: proceedings of a conference on lake trout research, August 1983. Great Lakes Fishery Commission Technical Report 40. Ann Arbor, Michigan.

Johnson, T. B., M. H. Hoff, A. S. Trebitz, C. R. Bronte, T. D. Corry, J. F. Kitchell, S. T. Lozano, D. M. Mason, J. V. Scharold, S. T. Schram, and D. R. Schreiner. 2004. Spatial patterns in assemblage structures of pelagic forage fish and zooplankton in western Lake Superior. Journal of Great Lakes Research 30(supplement 1):395-406.

Jones, M. L., J. F. Koonce, and R. O'Gorman. 1993. Sustainability of hatchery-dependent salmonine fisheries in Lake Ontario: the conflict between predator demand and prey supply. Transactions of the American Fisheries Society 122:1002-1018.

Jones, M. L., B. J. Shuter, Y. Zhao, and J. D. Stockwell. 2004. The challenge of inferring possible effects of climate change on Great Lakes fisheries: models that link habitat supply to population dynamics can help. Great

Lakes Fishery Commission Completion Report, Ann Arbor, Michigan.

Kapuscinski, A. R., and L. M. Miller. 2003. Genetic guidelines for fisheries management. Minnesota Sea Grant, University of Minnesota, Duluth.

Kitchell, J. F., S. P. Cox, C. J. Harvey, T. B. Johnson, D. M. Mason, K. K. Schoen, K. Aydin, C. Bronte, M. Ebener, M. Hansen, M. Hoff, S. Schram, D. Schreiner, and C. J. Walters. 2000. Sustainability of the Lake Superior fish community: interactions in a food web context. Ecosystems 3:545-560.

Krueger, C. C., and P. E. Ihssen. 1995. Review of genetics of lake trout in the Great Lakes: history, molecular genetics, physiology, strain comparisons and restoration management. Journal of Great Lakes Research 21(Supplement1):348-363.

Krueger, C. C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1):66-77.

Magnuson, J. J., K. E. Webster, R. A. Assel, C. J. Bowser, P. J. Dillon, J. G. Eaton, H. E. Evans, E. J. Fee, R. I. Hall, L. R. Mortsch, D. W. Schindler, and F. H. Quinn. 1997. Potential effects of climate changes on aquatic systems: Laurentian Great Lakes and Precambrian shield region. Hydrological Processes 2:825-871.

Mason, D. M., T. B. Johnson, and J. F. Kitchell. 1998. Consequences of prey fish community dynamics on lake trout (*Salvelinus namaycush*) foraging efficiency in Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 55:1273-1284.

Mason, D. M., T. B. Johnson, C. J. Harvey, J. F. Kitchell, S. T. Schram, C. R. Bronte, M. H. Hoff, S. T. Lozano, A. S. Trebitz, D. R. Schreiner, E. C. Lamon, and T. Hrabik. 2005. Hydroacoustic estimates of abundance and spatial distribution of pelagic fishes in western Lake Superior. Journal of Great Lakes Research 31:426-438.

Meffe, G. K. 1995. Genetic and ecological guidelines for species reintroduction programs: application to Great Lakes fishes. Journal of Great Lakes Research 21(Supplement1):3-9.

Miller, L. M., and A. R. Kapuscinski. 2003. Genetic guidelines for hatchery supplementation programs. Pages 329-355 *in* E. Hallerman, editor. Population genetics: principles and practices for fisheries scientists. American Fisheries Society, Bethesda, Maryland.

Mills, E. L., J. H. Leach, J. T. Carlton, and C. L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crisis and anthropogenic introductions. Journal of Great Lakes Research 19:1-54.

Minnesota Department of Natural Resources. 1994. Fisheries management operational guidelines. Minnesota Department of Natural Resources, Section of Fisheries, St. Paul, Minnesota.

Negus, M. T. 1995. Bioenergetics modeling as a salmonine management tool applied to Minnesota waters of Lake Superior. North American Journal of Fisheries Management 15:60-78.

Negus, M. T., D. R. Schreiner, T. Halpern, S. T. Schram, and D. Pratt. *In preparation*. Bioenergetics evaluation of prey consumption by predator fish in the western arm of Lake Superior in 2000 and 2004.

Nickum, M. J., P. M. Mazik, J. G. Nickum, and D. D. MacKinlay, editors. 2004. Propagated fish in resource management. American Fisheries Society Symposium 44, American Fisheries Society, Bethesda, Maryland.

Ostazeski, J. J., S. A. Geving, T. N. Halpern, and D. R. Schreiner. 1999. Predator diets in the Minnesota waters of Lake Superior, 1997-98. Minnesota Department of Natural Resources Lake Superior Area, Duluth.

Peck, J. W., T. S. Jones, W. R. MacCallum, and S. T. Schram. 1999. Contribution of hatchery-reared fish to Chinook salmon populations and sport fisheries in Lake Superior. North American Journal of Fisheries Management 19:155-164.

Ray, B. A. 2004. Spatial and temporal variability in prey fish composition and predator diet characteristics in Lake Superior from 1986-2001. Master's thesis. University of Minnesota-Duluth, Duluth.

Regier, H. A., J. A. Holmes, and D. Pauly. 1990. Influence of temperature changes on aquatic ecosystems: an interpretation of empirical data. Transactions of the American Fisheries Society 119:374-389.

Richards, J.M., M. J. Hansen, C. R. Bronte, and S. P. Sitar. 2004. Recruitment dynamics of the 1971-1991 year-classes of lake trout in Michigan waters of Lake Superior. North American Journal of Fisheries Management 24:475-489.

Schreiner, D. R., and S. Schram, editors. 2001. Lake Superior fish aging manual. Great Lakes Fishery Commission, Miscellaneous Publication, Ann Arbor, Michigan.

Schreiner, D. R., and T. N. Halpern. 2003. Report to Lake Superior Committee, Great Lakes Fishery Commission, 2003 Annual Meeting, Milwaukee, Wisconsin.

Schreiner, D. R., editor. 1995. Fisheries management plan for the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Section of Fisheries Special Publication 149, St. Paul.

Schreiner, D. R., editor. 2003. Rainbow trout management plan for the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Section of Fisheries Special Publication 157, St. Paul.

Stroud, R. H., editor. 1986. Fish culture in fisheries management. American Fisheries Society, Fish Culture Section and Fisheries Management Section, Bethesda, Maryland.

Utter, F. M. 2003. Genetic impacts of fish introductions. Pages 357-378 *in* E. Hallerman, editor. Population genetics: principles and practices for fisheries scientists. American Fisheries Society, Bethesda, Maryland.

USEPA. 2005. Great Lakes Regional Collaboration Strategy. Available: http://www.glrc.us/ (July 2006).

Wilberg, M. J., M. J. Hansen, and C. R. Bronte. 2003. Historic and modern abundance of wild lean lake trout in Michigan waters of Lake Superior: implications for restoration goals. North American Journal of Fisheries Management 23:100-108.

Wilson, C., W. L. Stott, L. M. Miller, A. Cooper, S. D'Amelio, and M. Jennings. *In press*. Conservation genetics of Lake Superior brook trout: issues, questions and directions. North American Journal of Fisheries Management.

CHAPTER 3: HABITAT

I. History

Habitat is the area or type of environment where an organism lives. It includes areas used by all stages in the life history of the organism. For Lake Superior fish species, habitats may include areas in streams as well as certain parts of the lake. In Lake Superior, fish habitat is primarily influenced by the physical properties of the lake basin and its watershed. These properties determine aspects of the water quality of the lake such as temperature, nutrient levels, and suspended sediments. Much of the Lake Superior basin is composed of bedrock, so the runoff is very low in nutrients. The temperature of the lake water remains low, which affects the growth of organisms at all trophic levels. Factors such as these limit the productivity of Lake Superior and the fisheries that it can support. Activities within the basin, as well as contaminants from point and non-point sources can affect the habitat in the lake and its tributaries. Protecting the quantity and quality of habitat is the basis for sustainable fisheries management. Although Lake Superior has suffered the least amount of habitat degradation of the Great Lakes, future protection of habitat is critical in the face of increasing use and development of areas within the basin.

Lake-wide habitat in Lake Superior can be classified into four zones, each of which has a characteristic fish community. About 77% of the surface area in Lake Superior is offshore habitat, which are waters >240 ft deep. The nearshore zone, waters <240 ft deep, comprise about 23% of the lake's surface area. The major sport and commercial fisheries in Lake Superior are located in the nearshore zone. In Minnesota's portion of Lake Superior the nearshore zone comprises approximately 10% of the total surface area, while the offshore zone makes up about 90%. The third zone consists of embayments, which are harbors, estuaries, and bays subject to seiches. In Minnesota, the St. Louis Bay and estuary is the most significant habitat in this category. Lastly, the fourth zone is composed of tributary reaches not subject to seiches. In Minnesota there are approximately 65 tributaries that fall into this category. Much of the habitat degradation in the Lake Superior basin has been in the tributaries, embayments, and nearshore waters. Landuse practices such as logging, mining, and shoreline development have altered fish habitat. Timber harvest has caused streams to warm, stream hydrology to change, and soil erosion and sedimentation to increase. Effluents discharged by the taconite mining industry have increased sedimentation in nearshore areas of the lake. Development of roads, homes, and businesses along the coastal areas of Lake Superior has also increased erosion and sedimentation.

In Minnesota, major habitat damage has occurred in the St. Louis River because of industrial discharge, sewage effluent, urban development, and sedimentation. The river is classified as an area of concern by the USEPA, and its cleanup is now being addressed through the St. Louis River Remedial Action Plan (RAP). The Lower St. Louis River Habitat Plan gives conservation goals to facilitate the protection of the ecological diversity of the river (SLRCAC 2002).

Throughout the Lake Superior basin, point source pollution has been greatly reduced in the last 30 years. Atmospheric and other non-point sources of pollution continue to cause problems of bioaccumulation of mercury, PCBs, and other toxicants in fish and wildlife. The MNDNR, Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Health (MDH) monitor contaminant levels of most Lake Superior fish species. Polychlorinated biphenyls (PCBs) and mercury (Figure 3.1) concentrations in lake trout from Lake Superior have been monitored routinely, and in general, have decreased over the last 20 years (Ebener *in review*), but health consumption advisories still remain.

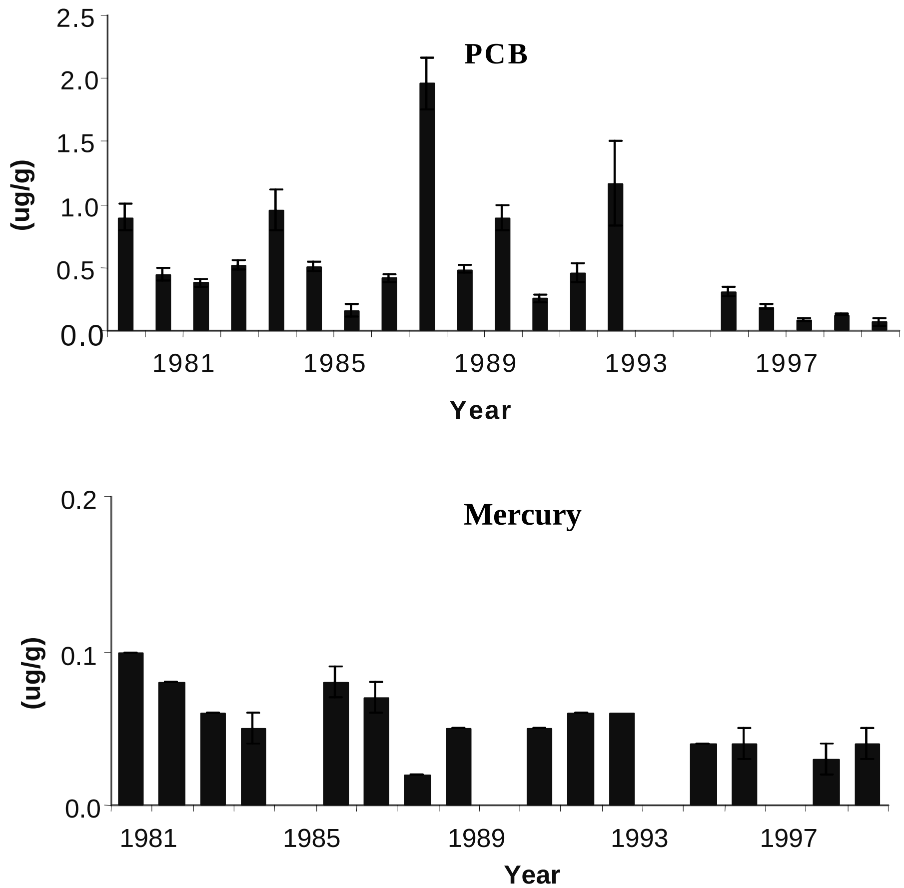

Figure 3.1. Mean concentration of total polychlorinated biphenyls (PCB) and total mercury in 4-year whole old lake trout from Lake Superior, 1980-2000 (Ebener in review).

Concern has emerged statewide about lead contamination from lost fishing tackle in aquatic environments (Radomski et al. 2006). This may be a potential problem in the lower reaches of North Shore streams and near river mouths as tackle loss by anglers fishing for migratory species such as rainbow trout, pacific salmon, and brook trout are concentrated in these areas. We will attempt to investigate tackle loss in these specific areas and keep apprised of any developments on this issue that may affect Lake Superior.

The Lake Superior Binational Program focuses on habitat, water quality, and pollution in the Lake Superior ecosystem (Lake Superior Binational Program 2004). The program identifies problems and sets goals and targets for achieving a vision for the future. One aspect of the program is a zero discharge demonstration project, which is a model to eliminate toxic chemicals and end the discharge of toxic, persistent, and bioaccumulative chemicals in Lake Superior. Another aspect of the program coordinates agencies within the Lake Superior basin to address other issues regarding habitat such as forests and wetlands, surface and groundwater, and fish and wildlife. Support for, and cooperation in this initiative should help preserve habitat, improve water quality, and reduce contaminant levels in Lake Superior.

The MPCA has developed the Lake Superior Basin Plan (MPCA 2004), a watershed approach to managing the Lake Superior Basin. The plan is an extension of local initiatives and plans that already exist, and was developed because water quality problems of today are more complex. The Lake Superior

Basin Plan attempts to define strategies, priorities, and goals for management of water resources in the Minnesota portion of Lake Superior. The Lake Superior Basin Plan sets guidelines and recommendations to restore degraded resources, and protect the high quality of water in the basin.

Recently, the MPCA has listed impaired waters throughout the state, including the Lake Superior Basin. The Federal Clean Water Act requires MPCA to conduct a Total Maximum Daily Load (TMDL) study for each pollutant that causes a water body to fail to meet water quality standards. The study identifies the source(s) of the pollutant and determines how much each source must reduce its contribution to assure water quality standards are met. At present, 15 rivers and creeks in the Lake Superior watershed are listed as impaired waters for a variety of reasons, including impaired biota, turbidity, high temperature, low dissolved oxygen, and contamination by various pollutants. Several TMDL projects on Lake Superior Basin streams are currently underway. Where feasible, the MNDNR will partner with MPCA to help address these concerns. Specifically, the list of impaired waters will be useful in prioritizing fisheries habitat projects, with the goal of increasing fish productivity.

II. Goals and Objectives

Goal: Protect, restore, and enhance the quantity and quality of fisheries habitat in the Minnesota waters of Lake Superior.

Objectives:

1. Identify and prioritize areas of degraded habitat in Lake Superior tributary watersheds, and work with appropriate agencies and citizens to restore its capacity to produce fish.

2. Increase the awareness of the importance of habitat to Lake Superior fisheries, and work with MNDNR Division of Waters (DOW), MPCA and other agencies and citizen groups to reduce habitat degradation in the Lake Superior watershed through the regulatory process.

3. Work with MPCA, MDH, and other agencies to establish a consistent sampling protocol to monitor contaminant levels in Lake Superior and St. Louis River fish species.

4. Protect, restore, and enhance riparian areas in the Lake Superior Basin (Minnesota Chapter of the American Fisheries Society 2004).

5. Monitor movement and location of different fish species to determine what specific habitats are used by different species.

6. Identify and quantify potential spawning areas and other critical habitats in Lake Superior and tributary streams so these areas can be monitored, and protected.

7. Work with federal, state and local governments, along with citizens to prevent the introduction and spread of unwanted invasive species.

III. Recommendations:

1. Complete the substrate mapping of near-shore waters of Lake Superior in Minnesota initiated by Richards et al. (1999) to identify and quantify fish spawning areas in Lake Superior, and identify critical stream habitat for anadromous species so it can be monitored and protected against potential long-term changes.

2. Continue to evaluate and comment on permits issued by various agencies (DOW, U.S. Army Corps of Engineers, etc.) so that fishery habitat is not degraded, and is enhanced where possible by appropriate project design.

3. Work with DOW, local units of government, the North Shore Management Board, and other agencies to ensure criteria that protect fishery habitat are included in policy guidelines for zoning and development within the Lake Superior watershed.

4. Continue to work with forest managers to ensure that best management practices are understood and implemented, and protection of the riparian areas near streams and wetlands is adequate (Minnesota Chapter of the American Fisheries Society 2004).

5. Increase productive capacity of streams for fish in the Lake Superior watershed by working to minimize erosion, beaver damage, high flows, groundwater degradation, and poor land-use practices in the watersheds. Work with agencies and citizens to restore or improve degraded habitat. Some examples may include: planting coniferous trees in riparian areas, using rip rap to prevent erosion, modifying road crossings and culverts to improve fish passage, and investigate the use of gravel to enhance fish spawning areas in low to moderate gradient stream reaches. Implement habitat improvement recommendations found in MNDNR fisheries stream management plans.

6. Work to increase the awareness among environmental agencies, local governments and citizens of the effects of contaminants on Lake Superior fisheries. Work in cooperation with, and encourage to the extent possible, the Lake Superior Binational Program, St. Louis River Citizens Action Committee, MPCA, USEPA and other agencies to reduce contaminant input to Lake Superior from all sources and to continue implementation of the St. Louis River RAP.

7. Encourage the use of lead-free fishing tackle, especially in tributary streams, at river mouths and along the shore of Lake Superior, as proposed in the MNDNR's "Get Out the Lead" program. Monitor loss of fishing tackle by asking specific questions when conducting angler surveys.

8. Work with land managers to consider the consequences of cumulative impacts on fisheries habitat when significant land-use changes are proposed within a watershed (American Fisheries Society 1991).

9. Continue to support all agencies working on watershed projects by requesting them to make use of Forest Stewardship Plans for private landowners in the watershed. Work with MNDNR Forestry, and the Soil and Water Conservation Districts in Cook, Lake and St. Louis counties to develop an aquatic habitat section in Forest Stewardship Plans for private landowners. Assist with funding for Forest Stewardship Plans by partnering with various agencies to secure grants (USFWS, USEPA, MPCA, Minnesota Coastal Program, etc).

10. Contract with an appropriate expert or synthesize existing information to develop a manual for private landowners that describes forestry practices on small land tracts that would positively influence water quality in North Shore streams. Make manual available to all interested landowners along North Shore streams, especially those where watershed projects are being conducted and include as part of all Forest Stewardship Plans where significant aquatic resources exist.

11. As funding becomes available, partner with MPCA to restore fisheries habitat in streams listed on the impaired waters list. The list is a good starting point for prioritizing habitat work in streams when funding becomes available. If opportunities or critical habitat needs in non-listed streams arise, they will also be pursued.

IV. Justification

Unimpaired habitat is critical for a productive, diverse, self-sustaining fish community. When habitat for a species is degraded or destroyed, the species will be affected and local populations may disappear. The loss of a species can affect the integrity of the entire community. Protection of fish habitat is necessary to ensure the persistence of the fish community in Lake Superior for present and future generations.

The status of habitat within the lake is largely determined by the health of the tributary waters that enter the lake. Land use planning should avoid practices that degrade these waters, and should be regulated to ensure a healthy Lake Superior ecosystem. The long-term consequences of incremental changes in land use practices should be considered during planning, and habitat destruction in the watershed should be avoided.

An important and controversial result of the contamination of waters in the Lake Superior basin by persistent toxic chemicals is the limitation it imposes on the use of fish by humans. Current health advisories suggest that humans limit their consumption of most game fish in Lake Superior because of contaminants. Older and larger individuals of a species tend to accumulate more contaminants and usually have more restrictive advisories. Current advisories suggest that lake trout < 23 inches can be safely eaten once per week, while lake trout from 23-34 inches should only be eaten once per month. Lake trout > 34 inches should not be eaten more than once every two months (MDH 2005). Although lake trout and siscowet in Lake Superior accumulate higher contaminant loads than other predators, they are the best-adapted top predators in the Lake Superior ecosystem. Trying to replace them with shorter-lived species with lower contaminant loads would only address a symptom of the problem and, as demonstrated, management efforts have had limited success. Rather, efforts to reduce the input of contaminants into the lake should be expanded.

This document does not attempt to address the many issues that surround contaminants in the Lake Superior Basin. Many contaminants found in the Lake Superior Basin are deposited through atmospheric deposition. Atmospheric deposition of contaminants is a broad-scale regional issue that must be addressed at both the Federal and state levels. There are many documents and ongoing efforts by various organizations that specifically address these concerns. Our major objective with respect to contaminants is to point out that if the important issues that surround contaminants are not addressed soon, citizens that now enjoy the opportunity to catch and consume Lake Superior fish, may no longer be able to do so in the future.

V. Information Needs/Community Interaction

The quality and quantity of habitat determine which species are productive, and affects the structure of the fish community. More information is needed on the habitat requirements of the various life history stages of all species in the Lake Superior fish community, and the extent of this habitat should be quantified. The linkage between habitat and fish production is being addressed by the Lake Superior Technical Committee as part of the *Ecosystem Objectives for Lake Superior* (in preparation). Ecosystem objectives are being developed by the GLFC for each of the Great Lakes. This knowledge would enable predictions of the possible productivity and composition of the fish community, and is critical for the efficient management of the fish community in the Lake Superior ecosystem. Identification of critical habitat and stresses to that habitat is important if protection of that habitat is to occur. New techniques are being developed for fisheries science, and as they prove effective they should be applied to the management of the Lake Superior ecosystem.

References

American Fisheries Society. 1991. Cumulative effects of small modifications to habitat (revised). Fisheries 16:12-14, 16-17.

Ebener, M. P., editor. *In review*. The state of Lake Superior in 2000. Great Lakes Fishery Commission, Special Publication.

Lake Superior Binational Program. 2004. Lake Superior Lakewide Management Plan (LaMP) 2004. Available: http://www.epa.gov/glnpo/lakesuperior/2004 (July 2006).

Minnesota Chapter of the American Fisheries Society. 2004. Position statement of the Minnesota Chapter of the American Fisheries Society (MNAFS) regarding forest harvest. Available: http://www.mnafs.org/forestharvest.pdf (July 2006).

Minnesota Department of Health. 2005. Fish consumption advice. Available: http://www.health.state.mn.us/divs/eh/fish/index.html. (July 2006)

Minnesota Pollution Control Agency. 2004. Lake Superior Basin Plan 2004. Available: http://www.pca.state.mn.us/publications/reports/lakesuperior-basinplan.pdf (July 2006).

Radomski , P., T. Heinrich, T. S. Jones, P. Rivers, and P. Talmage. 2006. Estimates of tackle loss for five Minnesota walleye fisheries. North American Journal of Fisheries Management 26:206-212.

Richards, C., J. Bonde, D. Schreiner, J. Selgeby, G. Cholwek, and K. K. Yin. 1999. Mapping lake trout spawning habitat along Minnesota's North Shore. Natural Resources Research Instituite Technical Report NRRI/TR-99-01, Duluth, Minnesota.

St. Louis River Citizens Action Committee. 2002. Lower St. Louis River habitat plan. St. Louis River Citizens Action Committee, Duluth, Minnesota.

CHAPTER 4: PREY

Prey in Lake Superior includes organisms from a variety of trophic levels, such as zooplankton, microcrustacea, aquatic and terrestrial insects, larval fish, and various prey fish species. In this plan, the term "prey" refers to the prey fish used by trout and salmon in Lake Superior. The species of prey fish most common in Lake Superior are lake herring *Coregonus artedi*, deepwater chubs *C. hoyi* and *C. kiyi,* and rainbow smelt *Osmerus mordax*. Less common species include members of the sucker family Catostomidae, minnows in the family Cyprinidae, and four species of sculpin *Cottus bairdi*, *C. cognatus*, *C. ricei and Myoxocephalus thompsoni*. In this plan, only Coregonines (lake herring and deepwater chubs) and rainbow smelt will be discussed in detail since they are the major fish species consumed by predators (Conner et al. 1993; Ray 2004), support a commercial fishery and are managed by the MNDNR.

Coregonines

I. History

In this section, we focus on lake herring, and to a lesser extent on deepwater chubs. Minnesota has very few lake whitefish *C. clupeaformis*, but populations of round whitefish *Prosopium cylindraceum* are present nearshore. Therefore, we will also briefly address the management implications for whitefish in this section.

Lake Herring

In Minnesota waters of Lake Superior, lake herring were the major diet item for lake trout (Dryer and Biel 1964), and the major commercial species until rainbow smelt became established in the late 1950s (Baldwin and Saalfeld 1962). The commercial lake herring fishery in Minnesota began around 1875. Harvest increased until the 1920s, then stabilized at over 6 million pounds annually until 1940 (Figure 4.1). From 1940 to 1985, harvest of lake herring declined. Starting in 1985, harvest increased each year until reaching a peak in 2000 of approximately 450,000 pounds, and then declined gradually to approximately 240,000 lbs in 2004. Lake herring have increased as a diet item in nearshore predator species such as lake trout and salmon. In certain seasons, they likely make up a majority of the prey biomass consumed. Although abundance of lake herring has rebounded from the lows recorded in 1985, conservative management is still warranted as the fishery is still in a rehabilitation phase.

Lake herring recruitment has been extremely variable since the major declines starting in the late 1940s. Strong year-classes were produced in three consecutive years from 1988-1990, and moderately strong year-classes were recorded in 1998, 2002 and 2003 (Figure 4.2) (Stockwell et al. 2005). These year-classes account for the major increase in lake herring abundance since 1985. Lake herring are pelagic and are well adapted to utilize the productivity found in Lake Superior. Because they are adapted to use much of Lake Superior and their habitat overlaps with lean lake trout, lake herring are the most appropriate prey for maximizing lake trout restoration. It is encouraging that since the mid-1980s lake herring have increased significantly. Conservative management of the stocks is critical to sustain the population, and to the stability of the predator populations and the commercial fishery.

Starting in the early 1970s, major efforts to rehabilitate lake herring stocks included: a reduction in the number of commercial operators through attrition and limited entry; an inshore refuge enacted in 1971, which prohibited harvest within 0.25 mile from shore; a closure of the fishing season in November since 1973 to protect spawning adults; and a stocking program in the Duluth area from 1975 to 1986. Since the early 1970s, the commercial fishery for lake herring has mainly supplied fish for local restaurants, grocery stores, and smoked fish shops. During the spawning season from October through mid-December, a lucrative market develops for lake herring roe (eggs). Minnesota operators have had limited access to this market because of the November closure imposed in an attempt to rehabilitate

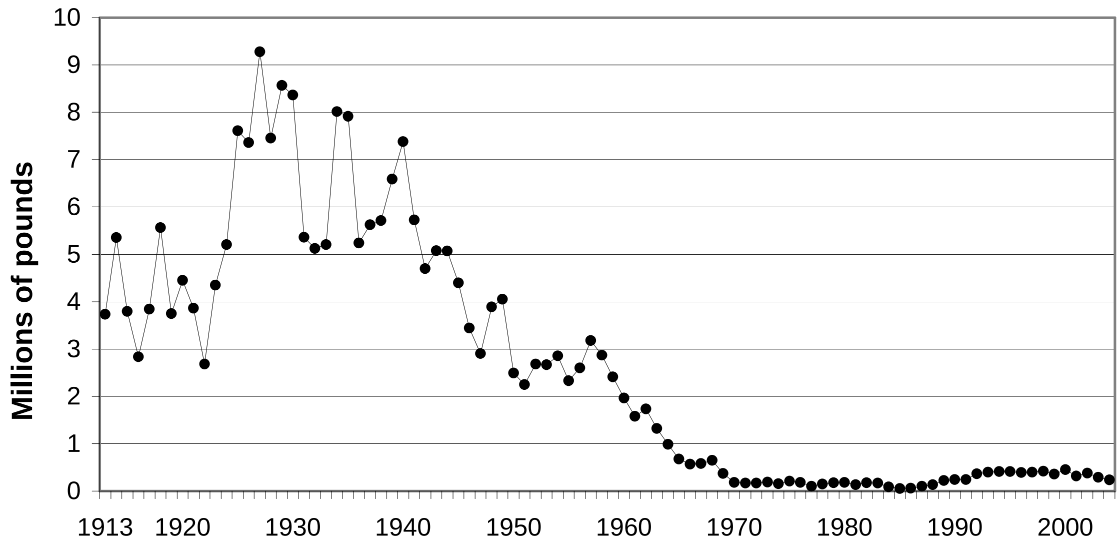

Figure 4.1. Commercial harvest of lake herring in Minnesota waters of Lake Superior, 1913-2004.

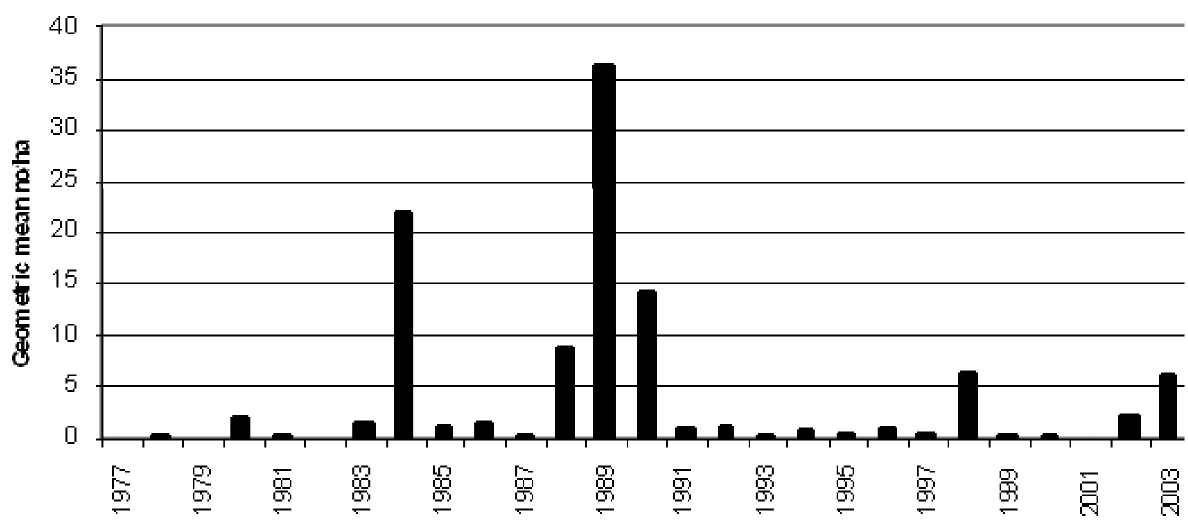

Figure 4.2. Lake herring year-class strength in Lake Superior, 1977-2003 (USGS, Ashland).

the fishery. The November closure is difficult for the commercial operators to accept, and has been a source of controversy since it was implemented. No other fish management agency imposes a spawning closure for lake herring, and there is pressure for Minnesota to remove the spawning closure and implement a total allowable catch (TAC) system so operators who want to fish during the spawning season may do so. Very few commercial operators make their living solely from the lake herring fishery, but many continue to fish part-time to supplement other income. Commercial operators are required to submit monthly reports that provide information necessary for the management of lake herring.

Deepwater Chubs

Deepwater chubs are two Coregonine species that along with sculpin and burbot are the primary prey for siscowet lake trout. To a lesser extent, lean lake trout and Chinook salmon also consume chubs. Species identification of chubs is difficult because of morphological variability within and among populations. In many cases, identification becomes subjective, especially among those not highly familiar with the taxonomy of chub species. Therefore, these species are combined under "chubs" for assessment and management purposes. Chubs have historically been a minor component in the Minnesota commercial fishery, and are mainly used in the smoked fish industry. Annual harvest of chubs in Minnesota waters of Lake Superior has fluctuated greatly, ranging from approximately 3,000 to 250,000 lb (Figure 4.3), and is largely dictated by market conditions. From 1980 – 2002, annual chub harvest has averaged less than 10,000 lb. Chub harvest is currently insignificant in Minnesota waters. Chub nets must be fished at depths greater than 300 feet to minimize bycatch of juvenile lake trout. Any increase in commercial chub fishing effort should be closely monitored so lake trout bycatch can be determined.

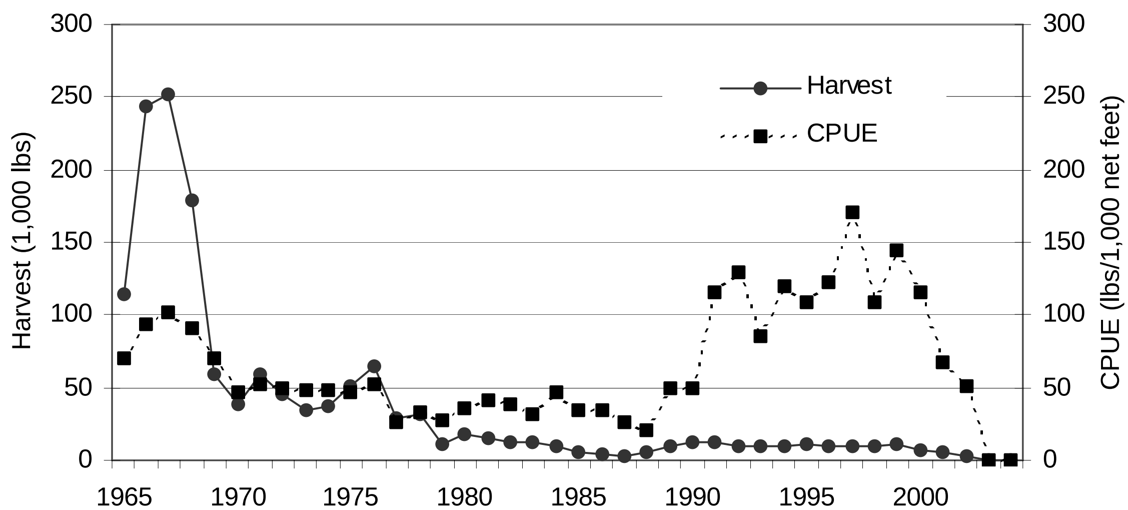

Figure 4.3. Harvest and CPUE (catch per unit effort) of chub taken in the commercial gill net fishery, Minnesota waters of Lake Superior, 1965-2004.

II. Goals and Objectives

Goal: Rehabilitate and protect self-sustaining Coregonine stocks (predominately lake herring) to support a stable production of predators and a limited commercial fishery.

Objectives:

1. Use hydroacoustic sampling and trawl surveys to monitor year-class strength and determine the biomass of lake herring in Minnesota waters of Lake Superior at least once every three years through 2015.

2. Investigate the age structure, catch per effort, and yield from the commercial fishery for lake herring in the Minnesota waters of Lake Superior annually.

3. Use results of acoustic surveys, commercial harvest, and bioenergetics modeling to determine the allocation of lake herring biomass and production among lake trout, other predators, and commercial harvest.

4. Determine a TAC for lake herring using hydroacoustic estimates, and explore the use of a population model to compliment the use of an acoustics-based TAC.

5. Work with commercial operators to implement a TAC-based commercial fishery that allocates harvest equitably among participants.

6. Limit the number of commercial operators along the Minnesota shoreline to 25.

III. Present Management

A. Regulations - There is no closed season or possession limit for the lake herring sport fishery. The commercial fishing regulations for lake herring and chubs are described in Minn. Stat. section 97C.835 and Minn. Rule, part 6260.1800. Major sections of the commercial regulations include: use of suspended nets only for lake herring; a limit of 50 commercial licenses; a total of 100,000 ft of lake herring net to be allotted among license holders; and a spawning season closure in November. Since 2001, an experimental lake herring assessment has been conducted the first eight days in November. This assessment was designed to estimate the potential yield of lake herring if netting in November was authorized. In the chub fishery, the minimum depth allowed for bottom sets is 300 feet or 50 fathoms within 1 mile of the shoreline, and no more than 120,000 feet are allocated to this fishery.

B. Stocking - No stocking.

C. Assessment - Lake herring stocks are assessed by monitoring commercial operators throughout the year, MNDNR gill net surveys, and USGS spring trawl surveys. In 1996 and 1997, a pilot study using acoustics to estimate prey biomass was conducted in the western arm of Lake Superior (Mason et al. 2005). From 2003-2005, acoustic surveys were conducted to estimate prey biomass, and determine the best design for a long-term survey program (Hrabik et al. 2005). Diet analysis is conducted on predators harvested in creel surveys and netting assessments. A commercial fishing production report is produced annually, and a report entitled *Lake Superior Commercial Fish Assessment Studies - Status of Lake Superior Fish Stocks* describes the general population trends of the major prey species (Geving and Schreiner 2005). Additionally, the LSTC is working on a lake herring report that describes the status and management of lake herring since 1973, when the last lake-wide description of lake herring status was produced (Lake Superior Herring Subcommittee 1973). A small commercial fishery is targeted at chubs and monitored by MNDNR. Commercial operators are allowed to harvest lake whitefish and round whitefish under permit. Reporting is required.

IV. Proposed Management

A. Regulations - Limit the total number of licensed commercial operators on Lake Superior to 25. Change the commercial fishery from an unlimited harvest fishery, with a November spawning closure, to a TAC-based fishery. Establish lake herring TAC based on 10% of the lower limit of the estimate of spawning stock biomass (lake herring > 12 in) determined by hydroacoustic survey estimates. The TAC will be established for a three-year period, based on the average of hydroacoustic estimates developed over the previous three years. Work with a sub-group of commercial operators to determine how the TAC will be allocated and what new rules will have to be implemented. Explore the potential for an experimental fishery targeted at round whitefish. Explore options to utilize and distribute trout and salmon incidentally caught in lake herring and chub nets.

B. Stocking - No stocking.

C. Assessment - Continue present MNDNR lake herring assessment program. Monitor population structure, and analyze age and growth rates to determine what portion of the population may be vulnerable as prey. Conduct hydroacoustic surveys and determine TAC at least once every three years to determine biomass of lake herring available for harvest. Develop internal hydroacoustic expertise to conduct surveys based on the design developed by Hrabik et al. (2005). Contract for a large research vessel capable of conducting hydroacoustics in conjunction with mid-water trawling to confirm species composition of biomass estimates. Encourage and support USGS to develop and conduct a lake-wide hydroacoustic sampling program that will complement and/or eventually replace a Minnesota program. A fall hydroacoustic assessment targeted at lake herring spawning stocks in the western arm of Lake Superior is being planned for 2006 (Yule et al. 2006). The assessment is a cooperative project, and will be conducted by USGS, MNDNR, WIDNR, and University of Minnesota - Duluth to compare summer and fall spawning stock biomass estimates. This would help determine whether the summer biomass estimates are of fish that spawn in Minnesota waters or fish that may spawn elsewhere in Lake Superior. Based on the results of this study, the percent of spawning stock biomass allocated for commercial harvest (TAC) may be reduced. Develop a new reporting system, and increase the intensity of commercial monitoring using additional personnel if a TAC system is implemented. Conduct intensive diet studies of sport fish once every five years to determine importance of Coregonines in the diet. Implement any standardized lake herring assessment protocols recommended by the LSTC.

V. Justification

Historically, lake herring have been the principal prey species for lake trout in Lake Superior (Dryer and Beal 1964). To reach the rehabilitation goal for lake trout and to support other predators, biologists believe lake herring must be the primary prey species (Hansen et al. 1994; Horns et al. 2003). Successful management of lake herring is the cornerstone of a stable fish community in Lake Superior. Since 1985, lake herring stocks have been recovering. However, since 2000 there has been a steady decline in commercial harvest and CPUE (Figure 4.4). Any changes in the commercial fishery must take this into consideration. The use of hydroacoustics has allowed us to estimate the biomass of lake herring. Using the size structure from the trawl catch, along with acoustic target strength in our summer hydroacoustic surveys, we have been able to estimate the biomass of mature adults (lake herring > 12 in). We estimate that initially a TAC of 10% of the lower limit of the spawning stock biomass estimates would allow for a viable fishery while adequately protecting the spawning stock so rehabilitation can continue (Bence 2005; Negus et al. *in preparation*). Many lake herring of spawning size have outgrown the ideal prey size for the majority of predators (Mason et al. 1998) allowing some to be allocated for commercial harvest. Moderate to large parental stock sizes have been present since the late 1980s, but in many years their reproduction has been limited. Some of the weakest year-classes have been produced under the largest stock sizes, suggesting a density-dependent effect on the survival of juveniles (Horns et al. 2003). It appears that density-independent factors such as major climatic events are more important

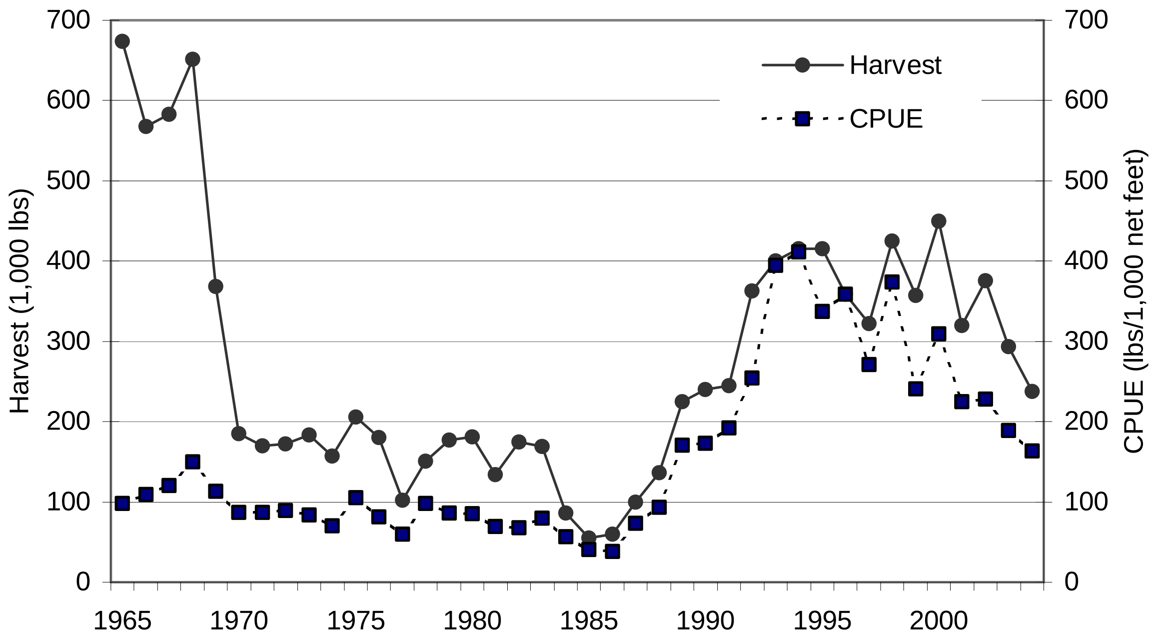

Figure 4.4. Harvest and CPUE (catch per unit effort) of lake herring taken in the commercial gill net fishery, Minnesota waters of Lake Superior, 1965-2004.

to recruitment than total egg deposition, as similar patterns in recruitment tend to occur lake-wide (Horns et al. 2003).

As predator abundance increases with lake trout recovery and naturalization of other salmonines, consideration should be given to reduced predator stocking. Likewise, a reduction in the number of commercial license holders and a conservative TAC, or a closed spawning season if a TAC is not enacted, should protect lake herring from overfishing. If a TAC is enacted, reducing the number of license holders will allow each operator to harvest a larger portion of the TAC, thus increasing each individual's potential income.

If a TAC system is implemented and works well as evidenced by additional strong year-classes, decisions can be made to modify harvest regulations and TAC. However, if abundance declines and the number of strong year-classes decrease, harvest will be lowered, and in the worst case, commercial harvest may have to be curtailed. The TAC may also be reduced to less than 10% if a lower biomass of spawning adults is determined in the fall hydroacoustics survey than that found in the summer survey. Reduced biomass in the fall survey may indicate that the fish detected in the summer survey spawn elsewhere, and spawning stock biomass in Minnesota is not as large as the summer hydroacoustic survey indicates. Seasonal timing of hydroacoustic surveys will continue to be analyzed to determine which season provides the best information for establishing TACs.

VI. Information Needs/Community Interactions

A better understanding of the trophic relationships in the Lake Superior fish community is necessary before more accurate food web models can be constructed. These models would aid in the ability to predict how much prey biomass the lake can support and in turn, how many predators could be supported by the biomass of prey. A better understanding of the linkage between Coregonines and the lower trophic level, mainly *Mysis* spp. and *Diporeia* spp, would be very useful in determining the potential biomass of prey in Lake Superior.

We will continue to experiment with the use of models to examine the population dynamics, stock-recruitment relationship, and production potential of lake herring stocks in Lake Superior. Better information on the diet of lake herring (Johnson et al. 2004a), lake herring interactions with other prey species, and the juvenile stages of predator stocks is also needed. Lake herring are now the major conduit for energy transfer between the zooplankton trophic level and the top predator level. Understanding the dynamics of lake herring stocks is critical to the success of future management for Lake Superior (Johnson et al. 2004b).

The interactions and life histories of Coregonines in the Great Lakes are not well understood. Many biologists believe that introgression has taken place, and habitats, behavior and reproduction now overlap between species. Basic information on life history and population dynamics of lake herring, deepwater chubs, and other coregonines in Lake Superior must be collected to better understand the roles these species play in the Lake Superior fish community. Before a commercial fishery for round whitefish can be considered, more information is needed on the bycatch of game fish species in gill nets set nearshore. Use of trap nets, or setting gill nets during times when game fish are not present should be investigated.

Rainbow Smelt

I. History

Rainbow smelt is an invasive species that entered Lake Superior in the early 1930s, and was first reported in Minnesota waters in 1946. During the 1950s, rainbow smelt became well established and supported a large commercial fishery in the Duluth-Superior area. Rainbow smelt also became a major prey species for recovering lake trout stocks and introduced Pacific salmon. Rainbow smelt were very abundant during the 1960s and 1970s, when they supported large commercial harvests and an active dip net sport fishery in the spring. Rainbow smelt abundance peaked in the 1970s, but began to decline sharply in 1976, a trend which has lasted until the present (Figure 4.5). Based on

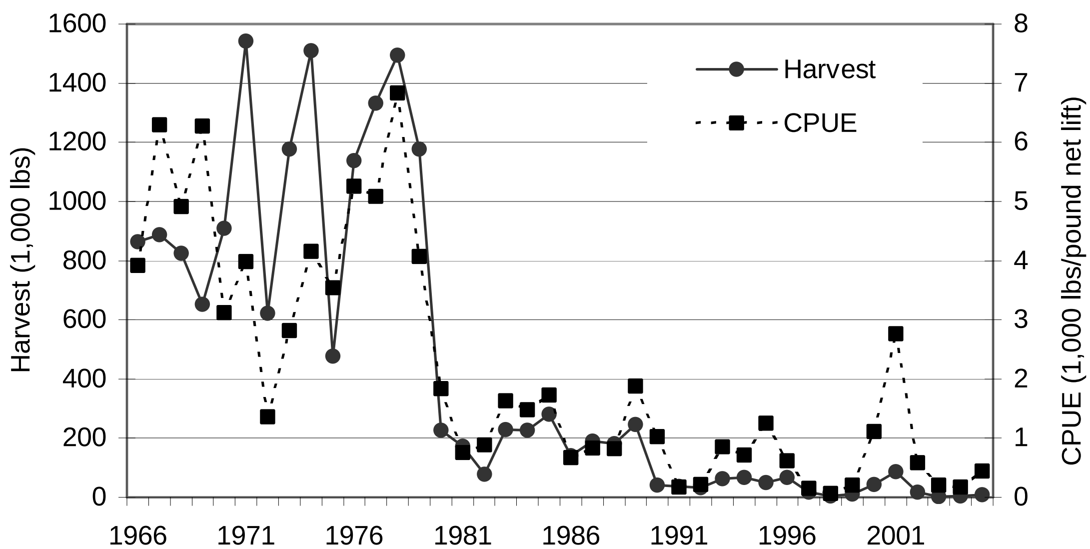

Figure 4.5. Harvest and CPUE (catch per unit effort) of rainbow smelt taken in the commercial pound net fishery, Minnesota waters of Lake Superior, 1965-2004.

records from the commercial fishery, rainbow smelt harvest from 1990 to 2004 declined to less than 5% of its peak level. Despite the low level of abundance, rainbow smelt are still important prey for salmonine predators in Minnesota's portion of Lake Superior, especially in the nearshore areas during spring and early summer. The decline of rainbow smelt in Minnesota mirrors the decline that has been observed lake-wide. It appears that the rainbow smelt decline was driven largely by predation (Negus 1995; Negus et al. *in preparation*; Bronte et al. 2003). Large rainbow smelt (>8 in) declined dramatically during the early 1980s, while abundance of lean lake trout and Pacific salmon increased. Diet studies (Conner et al. 1993) confirmed the presence of larger rainbow smelt in stomachs. More recent information indicates smelt > 8 in are scarce in both diets and assessments (Ray 2004).

Since the rainbow smelt decline, lake herring populations have rebounded throughout the lake suggesting an inverse relationship; however, a definitive cause-effect relationship has not yet been demonstrated. We anticipate no significant broadening of the size structure or increases in abundance of rainbow smelt if predation remains high. The amount of commercial harvest is insignificant when compared to predator demand (Figure 4.6, Negus et al. *in preparation*).

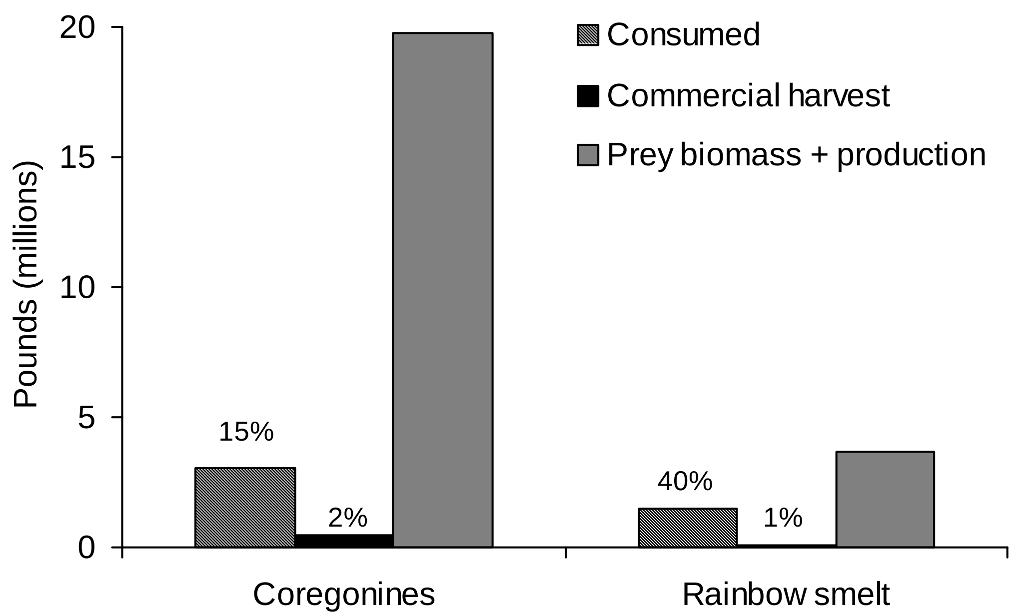

Figure 4.6. Amount of prey available (biomass + production), consumed by predators, and harvested commercially in Minnesota waters of Lake Superior in the year 2000.

II. Goals and Objectives

Goal: Provide a nearshore prey base sustained by natural reproduction that supports spring dip net and limited commercial fisheries.

Objectives:

1. Use hydroacoustic sampling and trawl surveys to determine the biomass of rainbow smelt in Minnesota waters of Lake Superior at least once every three years.

2. Annually, investigate the stock structure, year-class strength, and relative abundance of rainbow smelt.

3. Use bioenergetics modeling to determine the proportion of rainbow smelt consumed by predators, and compare to commercial fishery harvest.

4. Conduct predator diet surveys once every five years to determine the contribution of rainbow smelt as prey in the Lake Superior fish community.

5. Do not expand the commercial fishery for rainbow smelt at this time, and limit the present commercial fishery to a level that has minimal impact on the rainbow smelt population.

III. Present Management

A. Regulations - There is no closed season and no possession limit on rainbow smelt in the sport fishery. Transportation of live rainbow smelt is prohibited to prevent their introduction into inland lakes. Details on commercial fishing regulations for rainbow smelt in Lake Superior can be found in Minn. Stat. section 97C.835 and Minn. Rule, part 6260.1800.

B. Stocking - No stocking.

C. Assessment - Rainbow smelt are assessed through the use of MNDNR small mesh gill nets, USGS bottom trawls, MNDNR hydroacoustic surveys, and monitoring the commercial fishery. In Minnesota, the commercial fishery is an important information source for rainbow smelt assessment and has been used to reflect lake-wide abundance (Bronte et al. 2003). Diet studies of lake trout from the MNDNR assessment fishery are conducted annually, while diet studies from angler caught fish are conducted at least once every five years. Limited monitoring of the sport dip net fishery is conducted.

IV. Proposed Management

A. Regulations - Limit the commercial fishery for rainbow smelt to the one active commercial operator fishing for rainbow smelt in MN-1. Limit the number of pound nets used in the rainbow smelt fishery to five. If the present commercial operator in MN-1 discontinues fishing for rainbow smelt, reevaluate licensing another operator based on smelt abundance and information needs.

B. Stocking - No stocking.

C. Assessment – Continue to assess with MNDNR small mesh gill nets, USGS bottom trawling, and monitoring of commercial fishery in MN-1. Conduct hydroacoustic assessments at least once every three years to help determine rainbow smelt biomass.

V. Justification

Rainbow smelt is an invasive species that was accidentally introduced into the Great Lakes in 1912 (Van Ooston 1937). Although they are utilized as prey by salmonines, their overall effect on the fish community is not well understood and may be detrimental (Evans and Loftus 1987). Since rainbow smelt are restricted to nearshore waters, they do not have the same potential as lake herring to utilize the entire productivity of the Lake Superior system. Lake herring were the historical prey base in Lake Superior, and should be managed as the primary species to maximize productivity (Horns et al. 2003)

Biologists and anglers both agree that rainbow smelt are an important component of the prey base in the Lake Superior fish community. Many citizens also value smelt for human consumption. To protect more smelt to serve as prey, a few angling groups feel that both the commercial and sport dip net fishery for rainbow smelt should be closed. The number of participants in the sport dip net fishery has decreased over the last 20 years as smelt abundance has declined; however, dip net fishing for smelt still remains popular. Even in streams closed to dip netting, smelt abundance has decreased dramatically, indicating the dip net fishery has not caused the decline. Results from bioenergetics modeling indicate that the commercial fishery takes relatively few rainbow smelt compared to the predatory impact of the fish community (Negus 1995; Negus et al. *in preparation*). To prevent overexploitation of rainbow smelt, we propose to limit the commercial effort to no more than five pound nets. If rainbow smelt abundance increases dramatically, increased harvest effort may be considered.

VI. Information Needs/Community Interactions

There has been no direct evidence linking rainbow smelt to lake herring abundance. Selgeby et al. (1978) documented certain areas in Lake Superior where lake herring populations successfully reproduced in the presence of strong rainbow smelt populations. In other areas of the lake with large rainbow smelt populations, there was little successful lake herring reproduction. Anderson and Smith (1969) found that rainbow smelt and lake herring consumed similar prey types; however, Selgeby et al. (1994) suggests that there is little competition for food based on spatial and temporal separation of larvae of each species. Studies from inland lakes provide evidence that rainbow smelt prey heavily on larval Coregonines (Evans and Loftus 1987), and there is concern that larval salmonines are also used as prey by rainbow smelt. *Mysis relicta*, a small shrimp-like invertebrate, is the major prey used by both adult rainbow smelt and lake herring, but competition for Mysids between these species has not been documented. Since the late 1980s, rainbow smelt abundance has been low, while lake herring recruitment has been extremely variable, indicating little direct interaction (Bronte et al. 2003). Based on this scientific evidence, it is clear that more work is required to document the relationships between rainbow smelt and lake herring. We must also increase our understanding on the contribution of rainbow smelt to predator diets in the Lake Superior community based on spatial (nearshore vs. offshore) and temporal (seasonal) factors.

References

Anderson, E. D., and L. L. Smith, Jr. 1971. Factors affecting abundance of lake herring (*Coregonus artedii Lesueur*) in western Lake Superior. Transactions of the American Fisheries Society 100:691-707.

Baldwin, N. S., and R. W. Saalfeld. 1962. Commercial fish production in the Great Lakes 1867-1960. Great Lakes Fishery Commission, Technical Report 3, Ann Arbor, Michigan.

Bence, J. 2005. Overview of harvest management strategies. Harvest Management Strategies Workshop. Great Lakes Fishery Commission. Ann Arbor, Michigan.

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 60:1552-1574.

Conner, D. J., C. R. Bronte, J. H. Selgeby, and H. L. Collins. 1993. Food of salmonine predators in Lake Superior, 1981-87. Great Lakes Fishery Commission Technical Report 59, Ann Arbor, Michigan.

Dryer, W. R., and J. Beil. 1964. Life history of lake herring in Lake Superior. Fisheries Bulletin 63:493-529.

Evans, D. O., and D. H. Loftus. 1987. Colonization of inland lakes in the Great Lakes region by rainbow smelt, *Osmerus mordax*: their freshwater niche and effects on indigenous fishes. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2):249-266.

Geving, S. A., and D. R. Schreiner. 2005. Lake Superior commercial fisheries assessment studies. Minnesota Department of Natural Resources Performance Report, Project 3-IJ-12(3-393-R-3), St. Paul.

Hansen, M. J., M. P. Ebener, R. G. Schorfhaar, S. T. Schram, D. R. Schreiner, and J. H. Selgeby. 1994. Declining survival of lake trout stocked in the United States waters of Lake Superior during 1963-1986. North American Journal of Fisheries Management 14:395-402.

Horns, W. H., C. R. Bronte, T. R. Busiahn, M. P. Ebener, R. L. Eshenroder, T. Gorenflo, N. Kmiecik, W. Mattes, J. W. Peck, M. Petzold, and D. R. Schreiner. 2003. Fish community objectives for Lake Superior 2000. Great Lakes Fishery Commission, Special Publication 03-01, Ann Arbor, Michigan

Hrabik, T., D. R. Schreiner, M. Balge, and S. A. Geving. 2005. Development of a hydroacoustic design to quantify prey fish abundance in the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Investigational Report 530, St. Paul.

Johnson, T. B., W. P. Brown, T. D. Corry, M. H. Hoff, J. V. Scharold, and A. S. Trebitz. 2004a. Lake herring (*Coregonus artedi*) and rainbow smelt (*Osmerus mordax*) diets in western Lake Superior. Journal of Great Lakes Research 30(Supplement 1):407-413.

Johnson, T. B., M. H. Hoff, A. S. Trebitz, C. R. Bronte, T. D. Corry, J. F. Kitchell, S. J. Lozano, D. M. Mason, J. V. Scharold, S. T. Schram, and D. R. Schreiner. 2004b. Spatial patterns in assemblage structures of pelagic fish and zooplankton in western Lake Superior. Journal of Great Lakes Research 30(Supplement 1):395-406.

Lake Superior Lake Herring Subcommittee. 1973. A summary finding report on Lake Superior lake herring (*Coregonus artedi*) populations. Lake Superior Technical Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

Mason, D. M., T. B. Johnson, and J. F. Kitchell. 1998. Consequences of prey fish community dynamics on lake trout (*Salvelinus namaycush*) foraging efficiency in Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 55:1273-1284.

Mason, D. M., T. B. Johnson, C. J. Harvey, J. F. Kitchell, S. T. Schram, C. R. Bronte, M. H. Hoff, S. T. Lozano, A. S. Trebitz, D. R. Schreiner, E. C. Lamon and T. Hrabik. 2005. Hydroacoustic estimates of abundance and spatial distribution of pelagic fishes in western Lake Superior. Journal of Great Lakes Research 31:426-438.

Negus, M. T. 1995. Bioenergetics modeling as a salmonines management tool applied to Minnesota waters of Lake Superior. North American Journal of Fisheries Management 15:60-78.

Negus, M. T., D. R. Schreiner, T. N. Halpern, S. T. Schram, and D. M. Pratt. *In preparation*. Bioenergetic evaluation of prey consumption by predator fish in the western arm of Lake Superior in 2000.

Ray, B. A. 2004. Spatial and temporal variability in prey fish composition and predator diet characteristics in Lake Superior from 1986-2001. Master's thesis. University of Minnesota-Duluth, Duluth.

Selgeby J. H., C. R. Bronte, and J. W. Slade. 1994. Forage species. Pages 53-62 *in* M. J. Hansen, editor. The state of Lake Superior 1992. Great Lakes Fishery Commission Special Publication 94-1. Ann Arbor, Michigan.

Selgeby, J. H., W. R. MacCallum, and D. V. Swedberg. 1978. Predation by rainbow smelt (*Osmerus mordax*) on lake herring (*Coregonus artedii*) in western Lake Superior. Journal of the Fisheries Research Board of Canada 35:1457-1463.

Stockwell, J. D., L. M. Evans, D. L. Yule, O. T. Gorman, and G. A. Cholwek. 2005. Status and trends of prey fish populations in Lake Superior, 2004. Great Lakes Fishery Commission, Lake Superior Committee Meeting, Ann Arbor, Michigan.

Van Ooston, J. 1937. The dispersal of smelt (*Osmerus mordax*) in the Great Lakes Region. Transaction of the American Fisheries Society 66:160-161.

Yule, D., J. Stockwell, T. Hrabik, D. Schreiner, and S. Schram. 2006. Assessment of spawning ciscoe (*Coregonus artedii*) in the western arm of Lake Superior in 2006. Lake Superior Biological Station, USGS Project Proposal, Ashland, Wisconsin.

CHAPTER 5: LAKE TROUT

I. History

Lake trout have historically been the top predator in the Lake Superior fish community. Lake trout are adapted to the cold, clear, infertile waters of Lake Superior and historically were represented by many strains or stocks. Following the invasion of the sea lamprey, many of these stocks were reduced or eliminated. However, through natural reproduction by remnant stocks and management efforts by agencies, many areas of Lake Superior are again inhabited by predominately wild lake trout (Bronte et al. 2003; Ebener *in review*; Schreiner and Schram 1997). Lake trout rehabilitation efforts by agencies include: controlling sea lamprey abundance; stocking yearling lake trout; restricting commercial harvest; identification, protection and monitoring of spawning reefs; and the imposition of possession limits and seasons on the sport fishery.

Rehabilitation of lake trout in Minnesota has lagged behind that of other jurisdictions, but continues to progress. The reasons for this may include: the lack of remnant, self-reproducing lake trout stocks in Minnesota waters; extremely high lamprey mortality; high fishing mortality from commercial fishing prior to 1962 and recreational fishing after 1962; lower initial stocking rates; and less spawning habitat.

Despite the slower recovery of self-sustaining lake trout stocks in Minnesota, abundance has greatly increased over the last 35 years. Angler catch and catch-per-effort (CPUE) have increased greatly since the 1970s (Figure 5.1). From 1995 through 2004, the lake trout population has supported a major sport fishery with an average annual catch of approximately 19,000 fish (Halpern 2005). Lake trout have consistently been the primary species caught by anglers. Since 1995, voluntary release of lake trout has approximated 5 – 10% of the total lake trout catch. Natural reproduction has increased over the last 15 years, and the proportion of wild lake trout captured in the May assessment fishery has increased from 45% to nearly 75% in the last 10 years in Minnesota (Schreiner and Halpern 2005). In 2004, the proportion of wild lake trout in the sport fishery was about 65% in management zone MN-1, 75% in MN-2, and 85% in MN-3 (Figures 5.2 and 5.3). CPUE of stocked lake trout captured in the May assessment netting from each management zone (Figure 5.4) has increased since the assessment first began in 1963, but has decreased greatly since 1990 (Figure 5.4). CPUE of wild lake trout started to increase in about 1985, and, in general, has continued to increase in all management zones (Figure 5.4).

Presently, there are two major forms of lake trout in Minnesota waters. Lean lake trout are found nearshore, usually at depths less than 300 feet. This is the more popular form pursued by anglers and sold in fish markets. The siscowet lake trout is a deep-water form usually caught at depths greater than 300 feet. Traditionally, siscowet were fished commercially, and sold as smoked or salted lake trout. Although they are of limited food value due to high contaminant levels, the potential to develop a commercial fishery for siscowet lake trout exists because they are rich in omega-3 fatty acids, that are known to have beneficial health effects for humans. Because they were not as susceptible to lamprey predation, siscowet numbers remained relatively high during the decline of lean lake trout. If a demand for siscowet developed, the MNDNR would work with commercial operators to design a commercial siscowet fishery. The MNDNR has never stocked the siscowet strain of lake trout. Throughout this plan the term "lake trout" refers to lean lake trout.

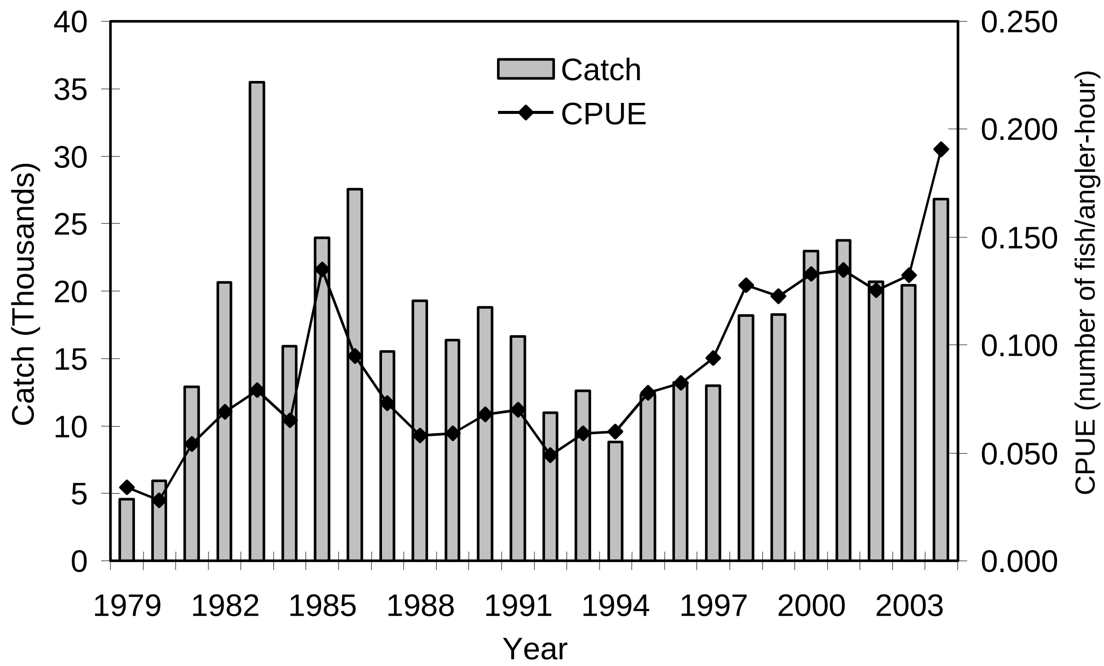

Figure 5.1. Catch and CPUE for lake trout in the summer Lake Superior creel survey, 1979-2004.

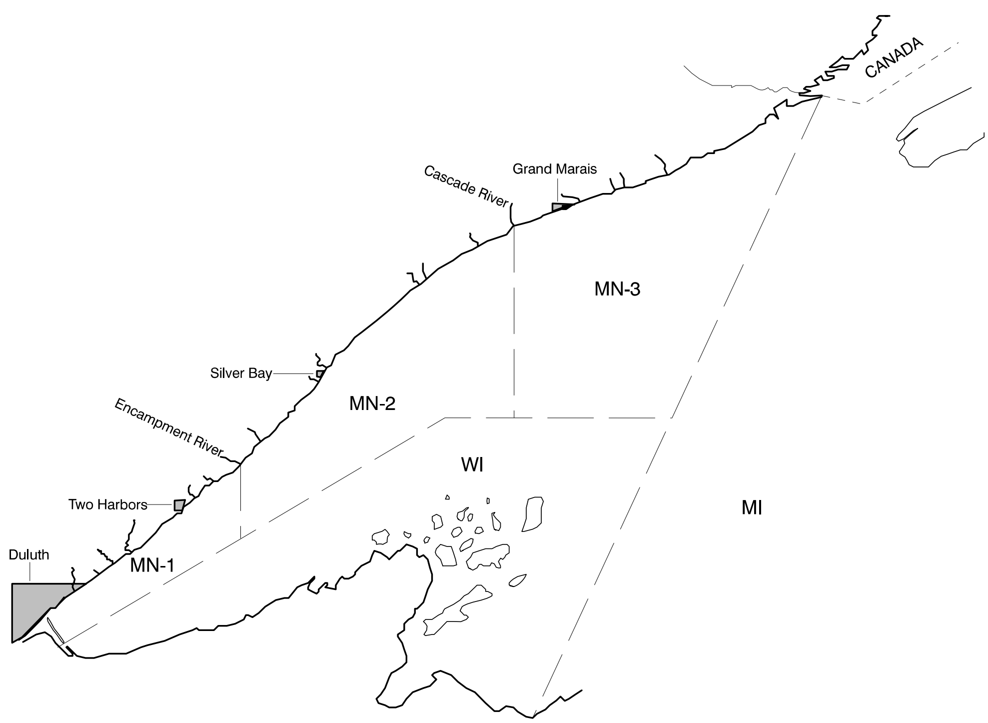

Figure 5.2. Management zones in the Minnesota waters of Lake Superior.

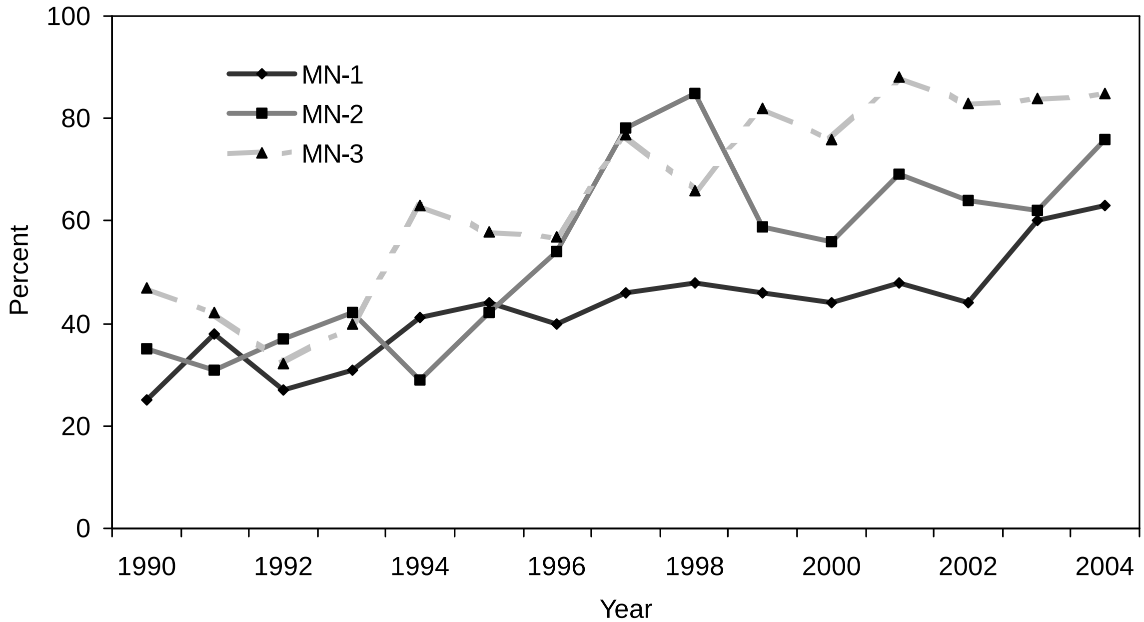

Figure 5.3. Percent wild lake trout by management zone from the Lake Superior summer creel survey, 1990-2004.

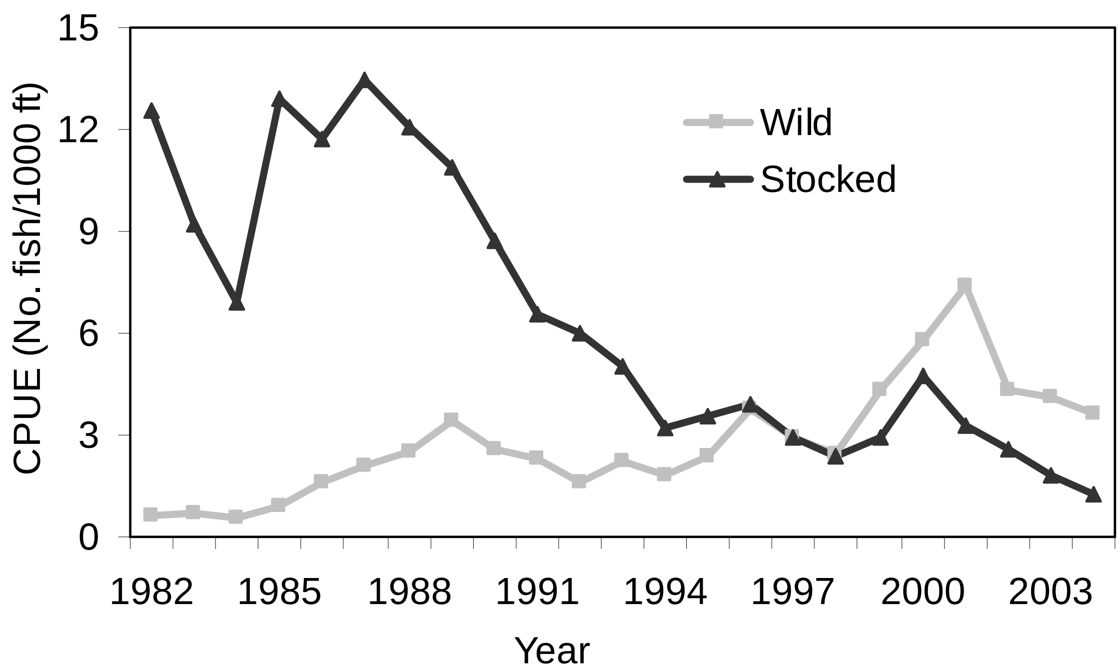

Figure 5.4. Catch per unit effort of stocked and wild lake trout in the May assessment, 1982-2004.

II. Goals and Objectives

Goal: Rehabilitate and maintain self-sustaining lake trout stocks capable of supporting a productive sport fishery.

Objectives:

1. Increase proportion of wild lake trout in the May assessment to 90% by 2015.

2. Use a Statistical Catch-at-Age (SCAA) model to determine the harvestable surplus, for each management zone, every five years.

3. Maintain lake trout total annual mortality rates below 45% to achieve the desired level of rehabilitation.

4. Reduce adult sea lamprey populations in cooperation with the Great Lakes Fishery Commission and the U.S. Fish and Wildlife Service until annual lamprey-induced adult lake trout mortality is less than 5%.

5. Reduce exploitation of spawning-sized lake trout in the sport fishery by promoting voluntary release of fish greater than 25 inches.

6. Locate and protect areas where lake trout successfully spawn.

7. Monitor forage biomass so it can be effectively managed to maintain lake trout yield.

III. Present Management

A. Regulations - The angling season for lake trout is December 1 through September 30th. The possession limit is three and there are no length limits. The commercial fishery for lake trout has been closed since 1962.

B. Stocking - Isle Royale strain yearling lake trout are presently stocked in Minnesota waters. No siscowet lake trout have been stocked by the MNDNR. Stocking quotas have been based on the revised *Lake Trout Restoration Plan for Lake Superior* (Hansen 1996). This plan gives criteria for determining when lake trout stocking should be discontinued in a management zone. In 2001, these criteria were met in MN-3, and stocking was discontinued in 2003. The stocking quota for Minnesota waters has decreased from 356,000 to 270,000 yearlings.

C. Assessment - Annual assessments are conducted in May and September using large mesh gill nets (4-1/2 inch stretch) targeting adult lake trout (ages 6-20), and during the summer with small mesh gill nets (1-1/2 inch – 2-1/2 inch in 1/4 inch increments) targeting juvenile lake trout (ages 3-6). Assessment netters assist with the large mesh assessments in management zones MN-2 and MN-3. Fall spawning assessments are conducted in alternate years in one historical spawning location in each management zone. An assessment of siscowet lake trout is conducted every three years according to protocols developed by the Lake Superior Technical Committee (Ebener 2003). The lake trout sport fishery is monitored by the Lake Superior summer creel survey. This survey is targeted mainly at the trolling fishery and is conducted annually from Memorial Day weekend to September 30. Charter captains are required to submit monthly reports of their fishing activities, and this information is summarized in an annual report (Halpern 2005). Commercial lake herring and chub netters are initially issued 20 possession tags for lake trout taken incidentally in their netting operations. These lake trout must be tagged and all information required by MNDNR must be reported. In 1996 and 1997 (Mason et al. 2005) and from 2003 to 2005 (Hrabik et al. 2005), hydroacoustic surveys of forage fish were conducted to estimate the food available for lake trout and other predators. Bioenergetics models have also been used to determine the food available for predatory fish (Ebener 1995; Negus 1995). Fry with thermally marked otoliths were stocked on a historical spawning reef to determine the survival of stocked early life stages of lake trout (Negus 2003). The success of this experiment is being monitored.

Otoliths have been used for aging lake trout since 1999. Aging is done according to standard aging protocols described in the *Lake Superior Fish Aging Manual* (Schreiner and Schram 2001).

IV. Proposed Management

A. Regulations - Propose changing the lake trout angling season to December 1 through the first full weekend in October (Appendix 5.1). Depending on the year, this could add up to seven days to the fishing season. Maintain the current possession limit at three lake trout, and promote voluntary release by anglers of lake trout larger than 25 in.

Continue to monitor total mortality using SCAA models, and do not allow the total annual mortality rate to surpass the 45% level. If total average mortality exceeds 45% in any zone for five consecutive years, or the average exceeds 50% for three consecutive years, sport harvest of lake trout will be reduced. Another measure of lake trout population health is spawning stock biomass (SSB). We are refining our lake trout model to develop SSB estimates. Once completed, SSB criteria will be developed and used in conjunction with total mortality to determine safe harvest levels. If reductions in harvest are required based on either method, the MNDNR will meet with the Lake Superior Advisory Group and interested citizens to determine the most appropriate methods to reduce harvest.

B. Stocking - Continue the present practice of not stocking lake trout in MN-3. Discontinue lake trout stocking in management zone MN-2 by 2007, and reduce stocking in management zone MN-1 from 232,000 to 170,000 yearlings annually. In 2010, re-evaluate the effectiveness of lake trout stocking in MN-1, and potentially reduce or discontinue stocking based on criteria in Hansen (1996) and percent contribution of stocked fish to the recreational fishery. Stock healthy fish as defined by MNDNR disease policy.

C. Assessment - Continue the annual Lake Superior summer creel survey, and the May juvenile and spawning assessments. Continue to conduct a siscowet assessment every three years. Re-evaluate the usefulness of the fall assessment during 2007. Utilize Geographical Information Systems (GIS) to relate spatial information to our assessment data. This is part of a lakewide effort being undertaken by all agencies involved in management of Lake Superior fish communities. Develop and maintain a SCAA model to assist in determining the harvestable surplus, or total allowable catch (Bence and Ebener 2002). Develop a set of criteria based on results from the SCAA model (total annual mortality, SSB, etc.) to determine if angler harvest needs to be decreased (see regulation section). Use otoliths to age lake trout in accordance with protocols set out in the *Lake Superior Fish Aging Manual* (Schreiner and Schram 2001). Collect diet information during all assessments, and from fish collected in the summer creel survey at least once every five years. Continue to monitor and report results of stocking early life history stages (Negus 2003).

V. Justification

Lake trout are given a high management priority in Lake Superior because they are a native species, are adapted to the cold-water habitat of Lake Superior, and are self-sustaining in most management zones. We are proposing changes in regulations that reflect the progress made in lake trout rehabilitation while protecting spawning adults.

Extending the lake trout season from December 1 through the first full weekend in October could add up to seven days to the fishing season, depending on the year. For the last five years, the average daily lake trout harvest in September was 139 fish. Based on this average, the estimated additional lake trout harvest would be from about 139 to 973 fish, or from 0.7 to 4.5 percent of the total summer recreational lake trout harvest. The actual numbers would likely be lower, since the average September harvest is based on the entire month of September, but fishing pressure drops off sharply toward the end of the month.

To help protect spawning-sized fish and keep natural reproduction at high levels, we initially proposed a 1 over 25-inch regulation for lake trout. This was specifically targeted at the MN-1 fishery where approximately 80% of the overall fishing pressure and lake trout harvest occurs. The majority of anglers were opposed to this regulation because they felt it would result in many large lake trout being returned to the water either dead or in poor condition. However, studies in the Great Lakes indicate relatively low hooking mortality rates for lake trout (Loftus and Taylor 1988). We agreed not to implement restrictive harvest regulations at this time; however, we still have long-term concerns about overharvest of spawning-sized lake trout and will continue to monitor the fishery and work with anglers to promote voluntary release of lake trout greater than 25 inches.

Total mortality is made up of natural, lamprey, and fishing mortality. Given a particular level of mortality, a SCAA model can be used to estimate the number of lake trout available for harvest. Healey (1978) suggested that a lake trout population that suffered more than 50% total mortality would decline. In *A Lake Trout Restoration Plan for Lake Superior* (Hansen 1996), the maximum target mortality level was set at 45% because models indicated the abundance of spawning lake trout declined when mortality exceeded 45% (Technical Fisheries Review Committee 1992; Ebener et al. 1989). The target total mortality of 45% or less should permit continued rehabilitation and provide for a productive sport fishery. By subtracting lamprey and natural mortality from total mortality, the target fishing mortality can be determined and the number of fish that may be harvested can be estimated. The harvest level is called the total allowable catch (TAC). This type of model is presently used to determine harvest quotas for tribal, sport, and state commercial fisheries in Wisconsin and Michigan. If total mortality is below 45%, restoration should proceed at a faster rate. Our model shows that total mortality in management units MN-2 and MN-3 is below the 45% level (Figures 5.5 and 5.6). However, there is a large recreational fishery in management zone MN-1, and the total mortality rate in MN-1 is approaching 45%. If total mortality rate in any zone exceeds 45% it will become necessary to impose more restrictive regulations on the recreational fishery.

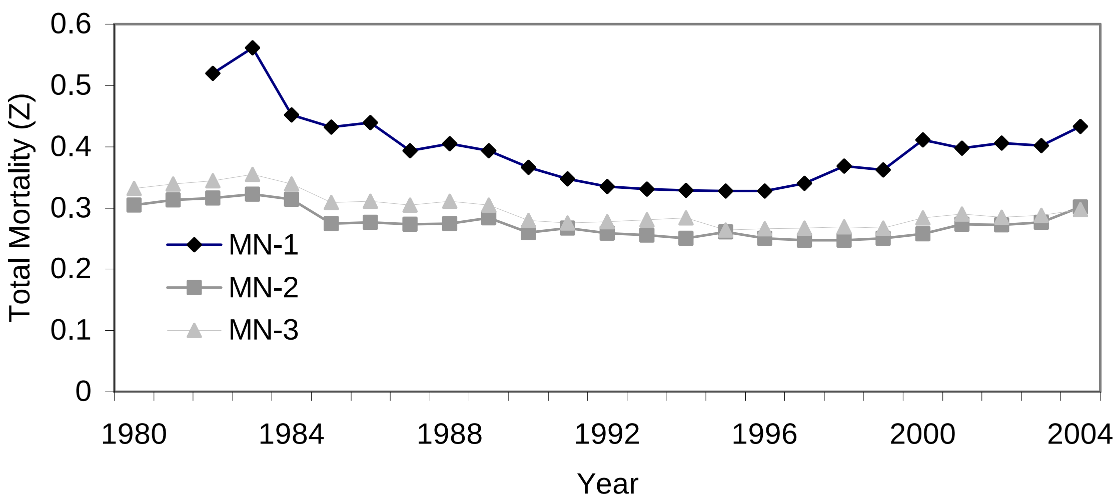

Figure 5.5. Total lake trout mortality estimates by management zone, 1980-2004.

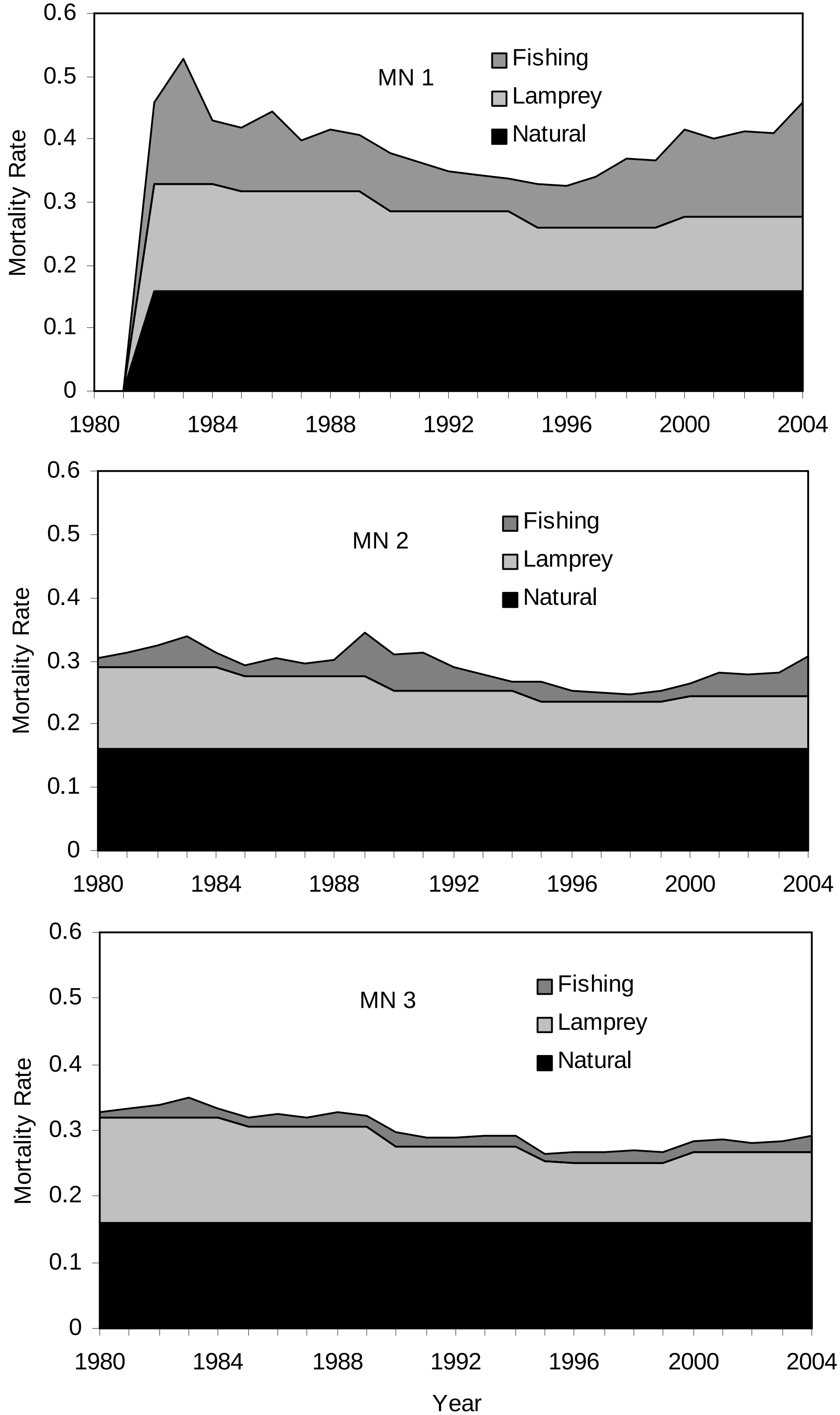

Figure 5.6. Lake trout mortality by source and Management Zone, 1980-2004.

Stocking has increased the number of lake trout in Minnesota waters and still contributes to the fishery in MN-1. Hansen et al. (1994) provided evidence that survival of recently stocked lake trout prior to 1995 was declining in most of Lake Superior. Survival of stocked lake trout in Minnesota waters has declined significantly in the last 10 years. The survival index of stocked lake trout has generally been less than one in recent years for all three management zones (Figure 5.7). At the same time, the abundance of wild lake trout, as measured by May CPUE, has exhibited a generally increasing trend since the late 1980s, and may be approaching fully rehabilitated levels (Corradin 2004; Wilberg et al. 2003). The lake trout rehabilitation process has been a major success, and wild lake trout have become established in all of Minnesota waters. This suggests that stocking levels should be further reduced. Stocking large numbers of yearling lake trout where wild populations exist may slow rehabilitation of native lake trout if stocked fish compete with wild fish for limited resources (Evans and Willox 1991; Corradin 2004). Decreased survival of stocked lake trout, along with decreased smelt abundance since the early 1990s, suggests that lake trout populations may be near the lake's carrying capacity (Kitchell et al. 2000). Reduced lake trout stocking should give wild lake trout a better chance for success, and may allow rehabilitation to proceed at a faster rate.

A variety of methods are being used to control lamprey in Lake Superior (Heinrich et al. 2003). The lampricide, TFM, is still the most important tool used to reduce lamprey populations, and new methods of application have allowed a 25% reduction in the amount of TFM used. The use of granular Bayluscide has enabled the treatment of lamprey-infested areas outside of river mouths. Treatment of lentic (open water) sea lamprey populations will be an important aspect of future lamprey control. The release of sterile males was used to reduce larval lamprey from 1991 to 1996; however, the supply of males for sterilization is limited. All sterilized males are now being used in the St. Mary's River, the largest breeding grounds for sea lamprey, to limit reproduction (Fodale and Cuddy *in review*). Pheromone-based control is a promising technique for lamprey control, and field trials have been conducted. However, synthesizing the pheromone in large enough quantities for management is necessary before it becomes widely used as a control technique (Sorensen and Vrieze 2003). Although streams in

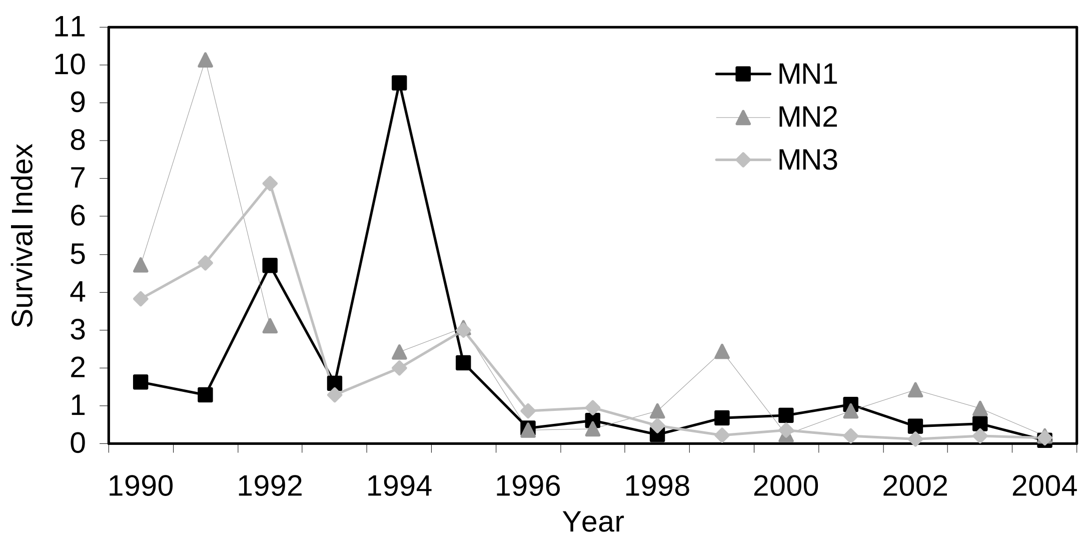

Figure 5.7. Stocked lake trout survival index by management zone, 1990-2004.

Minnesota produce very few lampreys, wounding rates in Minnesota waters remain among the highest in Lake Superior. A reduction in lamprey-induced lake trout mortality to less than 5% would increase the biomass of lake trout available for harvest and increase the rate of rehabilitation. If reductions in lamprey are to occur, funding for alternative lamprey control methods must remain available.

Asessment netting and creel surveys are the basis of the lake trout monitoring program and should be conducted annually. May surveys are standard for all agencies on the lake and will be continued. The need to continue the fall lake trout assessment should be critically reviewed, as similar information may be collected during the spawning assessment. Annual creel surveys are used to estimate fishing pressure and harvest by sport anglers. Along with assessment netting, this information is used to develop Statistical Catch-at-Age (SCAA) models. Criteria will be developed from model outputs, such as total mortality rate and spawning stock biomass, that will determine the total allowable catch (TAC), and serve to indicate whether changes in sport harvest of lake trout are necessary. This type of model is presently used to determine harvest quotas for tribal, sport, and state commercial fisheries in the Michigan (Bence and Ebener 2002) and Wisconsin waters of Lake Superior (Litton et al. 2002).

Diet studies of lake trout sampled during assessment netting and periodic diet sampling from the creel surveys give a seasonal perspective on forage use by lake trout. Along with the forage biomass estimates from the hydroacoustic studies mentioned above, these diet studies provide insight into the dynamics of the interactions between predator and prey (Negus 1995).

There was extensive discussion within the MNDNR on the proposal to expand the lake trout assessment. The department recognizes the century-old traditions of commercial fishing on Lake Superior and that the population of lake trout in MN-3 could biologically sustain the proposed increase in harvest. However, because of the recently proposed budget cuts in sea lamprey control by the federal government, the highly productive sport fishery, and the statewide philosophy of curtailing commercial netting for game fish, the department has decided not to implement the proposed expansion of lake trout assessment netting. The department has phased out commercial harvest of game fish on all other waters within state jurisdiction and has encouraged several Indian bands in Minnesota to refrain from commercial fishing for game fish. This decision is consistent with statewide management and legislative direction. As in the past, Lake Superior commercial operators under permit will continue to participate in the lake trout assessment program to collect scientific data, and all licensed commercial operators will be allowed to continue commercial harvest of approved nongame species.

The quantity and quality of available spawning habitat is an important limiting factor for any species. Identifying the location and quality of lake trout spawning habitat is essential for the protection of these important areas. It is critical to monitor the production of juvenile lake trout from these areas as shoreline development increases.

VI. Information Needs/Community Interactions

The relationship between wild and stocked lake trout needs to be monitored. Rehabilitation efforts have shown great success, and stocking of hatchery fish has been discontinued in management zone MN-3, and will be discontinued in MN-2 by 2007. Stocking must be further reduced in MN-1 to give wild fish the best chance of success. Assessments must be continued to monitor the results of reduced stocking, and to add to our understanding of the rehabilitation process.

Although progress has been made over the last 10 years, and much more is known about the status of lake trout in the Lake Superior fish community, it is necessary to continue to monitor the forage biomass, and to estimate the number of predators that can be supported in the Lake Superior community. This will permit the allocation of forage among various predators, and the recreational and assessment fishery. More information on the diet of lake trout and other predators during all life stages needs to be collected. Diet overlap among species at different life stages must be known in order to understand community relationships.

Improvement of sea lamprey control methods and development of alternative control methods must be continued in order to achieve the greatest productivity of lake trout and other species in Lake Superior. Although large lake trout are the favored target of sea lamprey in the Great Lakes, other species are attacked by sea lamprey when lake trout abundance is low. The frequency of lampricide treatment on streams and in lentic areas that consistently produce large numbers of sea lamprey larvae should be increased. The mechanism of larval survival from lampricide treatment should be investigated, and the knowledge obtained should be used to eliminate residual larval production. The contribution of lamprey from different potential sources (stream, lentic, migratory, etc.) should be determined, and these sources should be appropriately treated. New control technologies, such as the use of pheromones should be implemented as soon as practical.

Most information on historical lake trout spawning areas in Minnesota has come from interviews with commercial operators. Presently, there is little documentation of the exact locations of lake trout spawning or of the extent to which historical spawning reefs are currently being utilized. The substrate of much of the nearshore water of Minnesota has been mapped, and the quality for lake trout spawning has been estimated (Richards et al. 1999). This effort should continue to sample areas not yet mapped. Biological surveys are needed to assess the importance of these areas, and the production of juvenile lake trout that occurs in these areas.

References

Bence, J. R., and M. P. Ebener, editors. 2002. Summary status of lake trout and lake whitefish populations in the 1836 treaty-ceded waters of lakes Superior, Huron and Michigan in 2000, with recommended yield and effort levels for 2001. Technical Fisheries Committee, 1836 treaty-ceded waters of Lakes Superior, Huron and Ann Arbor, Michigan.

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 60:1552-1574.

Corradin, L. M. 2004. Recruitment and growth dynamics of lake trout in western Lake Superior. Master's thesis. University of Wisconsin-Stevens Point, Stevens Point.

Ebener, M. P. 1995. Bioenergetics of predatory fish in Western US waters of Lake Superior. Report of Red Cliff Band of Lake Superior Chippewa. Bayfield, Wisconsin.

Ebener, M. P., editor. 2003. Sampling and reporting protocols of the Lake Superior Technical Committee. Lake Superior Technical Committee, Ann Arbor, Michigan.

Ebener, M. P., editor. *In review*. The state of Lake Superior in 2000. Great Lakes Fishery Commission Special Publication, Ann Arbor, Michigan.

Ebener, M. P., J. H. Selgeby, M. P. Gallinat, and M. Donofrio. 1989. Methods for determining total allowable catch of lake trout in the 1842 treaty-ceded area within Michigan waters of Lake Superior, 1990-1994. Great Lakes Indian Fish and Wildlife Commission, Biological Services Division, Administrative Report 89-11, Odanah, Wisconsin.

Evans, D. O., and C. C. Willox. 1991. Loss of exploited indigenous populations of lake trout *Salvelinus namaycush*, by stocking of non-native stocks. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1):134-147.

Fodale, M., and D. Cuddy. *In review*. Sea lampreys. Pages 83-87 *in* M. P. Ebener, editor. The state of Lake Superior in 2000. Great Lakes Fishery Commission Special Publication, Ann Arbor, Michigan.

Halpern, T. N. 2005. Lake Superior Creel Survey, 2004. Minnesota Department of Natural Resources, Project F-29-R (P)-24, Study 4, Job 691, Completion Report, St. Paul.

Halpern, T. N. 2005. Charter fishing summary Minnesota waters of Lake Superior, 2004. Minnesota Department of Natural Resources, Lake Superior Area Report, St. Paul.

Hansen, M. J., editor. 1996. A lake trout restoration plan for Lake Superior. Great Lakes Fishery Commission, Ann Arbor, Michigan.

Hansen, M. J., M. P. Ebener, R. G. Schorfhaar, S. T. Schram, D. R. Schreiner, and J. H. Selgeby. 1994. Declining survival of lake trout stocked in the United States waters of Lake Superior during 1963-1986. North American Journal of Fisheries Management 14:395-402.

Healey, M. C. 1978. The dynamics of exploited lake trout populations and implications for management. Journal of Wildlife Management 42:307-328.

Heinrich, J. W., K. M. Mullett, M. J. Hansen, J. V. Adams, G. T. Klar, D. A. Johnson, G. C. Christie, and R. J. Young. 2003. Sea lamprey abundance and management in Lake Superior, 1957 to 1999. Journal of Great Lakes Research 29(Supplement 1):566-583.

Hrabik, T., D. R. Schreiner, M. Balge, and S. Geving. 2005. Development of a hydroacoustic design to quantify prey fish abundance in the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Investigational Report 530, St. Paul.

Kitchell, J. F., S. P. Cox., C. J. Harvey, T. B. Johnson, D. M. Mason, K. K. Schoen, K. Aydin, C. Bronte, M. Ebener, M. Hansen, M. Hoff, S. Schram, D. Schreiner, and C. J. Walters. 2000. Sustainability of the Lake Superior fish community: interactions in a food web context. Ecosystems 3: 545-560.

Loftus, A. J., and W. W. Taylor. 1988. An evaluation of lake trout (*Salvelinus namaycush*) hooking mortality in the Upper Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 45:1473-1479.

Mason, D. M., T. B. Johnson, C. J. Harvey, J. F. Kitchell, S. T. Schram, C. R. Bronte, M. H. Hoff, S. T. Lozano, A. S. Trebitz, D. R. Schreiner, E. C. Lamon, and T. Hrabik. 2005. Hydroacoustic estimates of abundance and spatial distribution of pelagic fishes in western Lake Superior. Journal of Great Lakes Research 31:426-438.

Negus, M. T. 1995. Bioenergetics modeling as a salmonine management tool applied to the Minnesota waters of Lake Superior. North American Journal of Fisheries Management 15:60-78.

Negus, M. T. 2003. Recovery of thermally marked otoliths from lake trout stocked as fry in Lake Superior. Minnesota Department of Natural Resources, Staff Report 60, St. Paul.

Richards, C., J. Bonde, D. Schreiner, J. Selgeby, G. Cholwek, and K. K. Yin. 1999. Mapping lake trout spawning habitat along Minnesota's North Shore. NRRI Technical Report NRRI/TR-99-01, Duluth, Minnesota.

Schreiner, D. R., and S. T. Schram. 1997. Lake trout rehabilitation in Lake Superior: maintaining our progress. Fisheries 22:12-14.

Schreiner, D. R., and T. N. Halpern. 2005. Report to the Lake Superior Committee, Great Lakes Fishery Commission, 2005 Annual Meeting, Ann Arbor, Michigan.

Schreiner, D. R., and S. T. Schram, editors. 2001. Lake Superior fish aging manual. Great Lakes Fishery Commission, Miscellaneous Publication (CD), Ann Arbor, Michigan.

Sorensen, P. W., and L. A. Vrieze. 2003. The chemical ecology and potential application of the sea lamprey migratory pheromone. Journal of Great Lakes Research 29 (Supplement 1):66-84.

Technical Fisheries Review Committee. 1992. Status of the fishery resource—1991, a report by the Technical Fisheries Review Committee on the assessment of lake trout and lake whitefish in treaty-ceded waters of the upper Great Lakes: State of Michigan. Mimeo Report, Ann Arbor, Michigan.

Wilberg, M. J., Hansen, M. J., and Bronte, C. R. 2003. Historic and modern abundance of wild lean lake trout in Michigan waters of Lake Superior: implications for restoration goals. North American Journal of Fisheries Management 23:100-108.

Appendix 5.1: Example of proposed seasons and limits Lake Superior and tributaries

Brook Trout and Splake combined

	Open Season*	Possession Limit	Aggregate Limit	Size Limit
Lake Superior Tributaries above posted boundaries	April 17-Sept 30	5	5	Only 1 over 16"
Lake Superior and Tributaries below posted boundaries	April 17- Sept 6	1	5	Minimum size limit: 20"

Rainbow Trout

<table>
<tr><th></th><th>Open Season*</th><th colspan="2">Possession Limit</th><th>Aggregate Limit</th><th>Size Limit</th></tr>
<tr><td>Lake Superior Tributaries above posted boundaries</td><td>April 17-Sept 30</td><td colspan="2">Catch & Release only</td><td></td><td></td></tr>
<tr><td rowspan="2">Lake Superior and Tributaries below posted boundaries</td><td rowspan="2">Continuous</td><td>Clipped</td><td>3</td><td>5</td><td>Minimum size limit:16"</td></tr>
<tr><td>Unclipped</td><td>Catch & Release only</td><td></td><td></td></tr>
</table>

Brown Trout

	Open Season*	Possession Limit	Aggregate Limit	Size Limit
Lake Superior Tributaries above posted boundaries	April 17-Sept 30	5	5	Only 1 over 16"
Lake Superior and Tributaries below posted boundaries	Continuous	5	5	Only 1 over 16" Minimum size limit:10"

Lake Superior - Other Species

Species	Open Season*	Possession Limit and Size
Lake Trout	Dec. 1- through first full weekend in Oct.	3
Chinook, Coho, and Pink Salmon	Continuous	5 Combined, Minimum size limit 10"
Walleye	May 13-March 1, 2007	2, Minimum size limit 15"
Northern Pike	May 13-March 1, 2007	2
Smelt	Continuous	No Limit

*Actual dates may change based on year, 2009, 2010, etc.

CHAPTER 6: CHINOOK SALMON

I. History

Chinook salmon were first introduced into Lake Superior by the Michigan Department of Natural Resources in 1967 (Peck et al. 1994). Minnesota introduced spring-run Chinook salmon in 1974, and converted to fall-run Chinook salmon in 1979 because of better growth rates and disease-free spring-run eggs were not available (Close et al. 1984). When the Chinook salmon program was started, it was expected to create a put-grow-take fishery with no natural reproduction. However, natural reproduction is now responsible for the majority of the Chinook salmon landed lake-wide (Peck et al. 1999).

Chinook salmon stocking has averaged over 300,000 fingerlings annually in Minnesota (Figure 6.1). In order to determine the contribution from stocking and the extent of natural reproduction, a lake-wide stocking evaluation was conducted, which followed three year-classes (1988-1990) of stocked Chinook salmon (Peck et al. 1999). Returns to the summer sport fishery in Minnesota from 1990 to 1994 indicated that natural reproduction accounted for 43% of the Chinook salmon caught. Stocked fish contributed 57% to the Minnesota summer fishery, with 31% of the stocked fish originating from Minnesota. Percent contribution of Minnesota stocked Chinook salmon to the summer sport fishery has declined since the lake-wide study to under 5% in recent years (Figure 6.2), with 95% being naturally reproduced fish. Harvest and catch rates for all Chinook salmon in the summer creel have increased. From 1995-2004, the average harvest of Chinook salmon was 4,052, while the average catch rate was 0.024 fish/angler-hour (Figure 6.3). Chinook salmon abundance is largely dependent on natural reproduction and migration from other jurisdictions in Lake Superior.

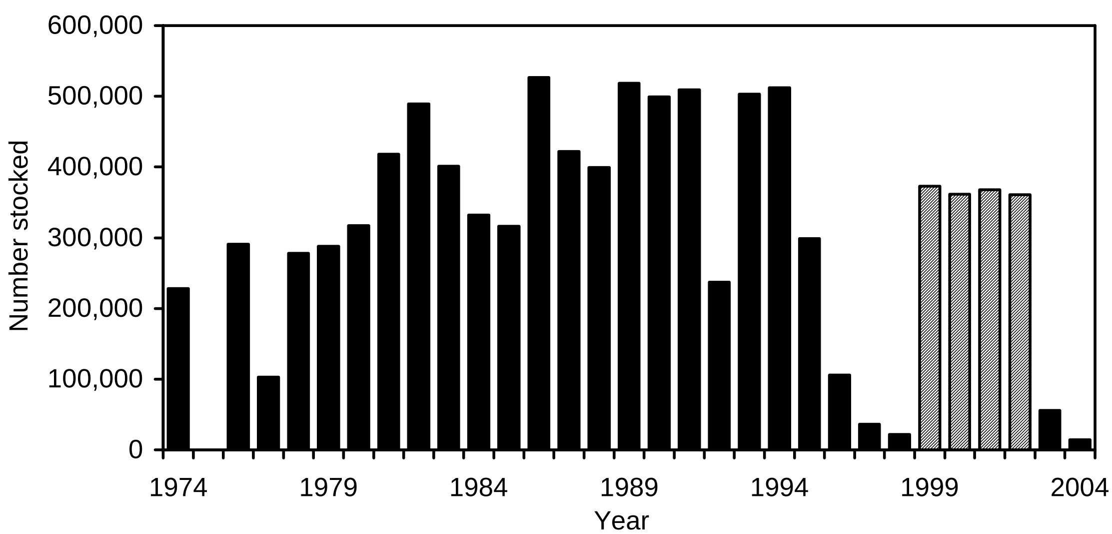

Figure 6.1. Chinook salmon stocked in Minnesota waters of Lake Superior, 1974-2004. Lake Huron strain Chinook salmon were stocked from 1999-2002 (cross-hatched bars).

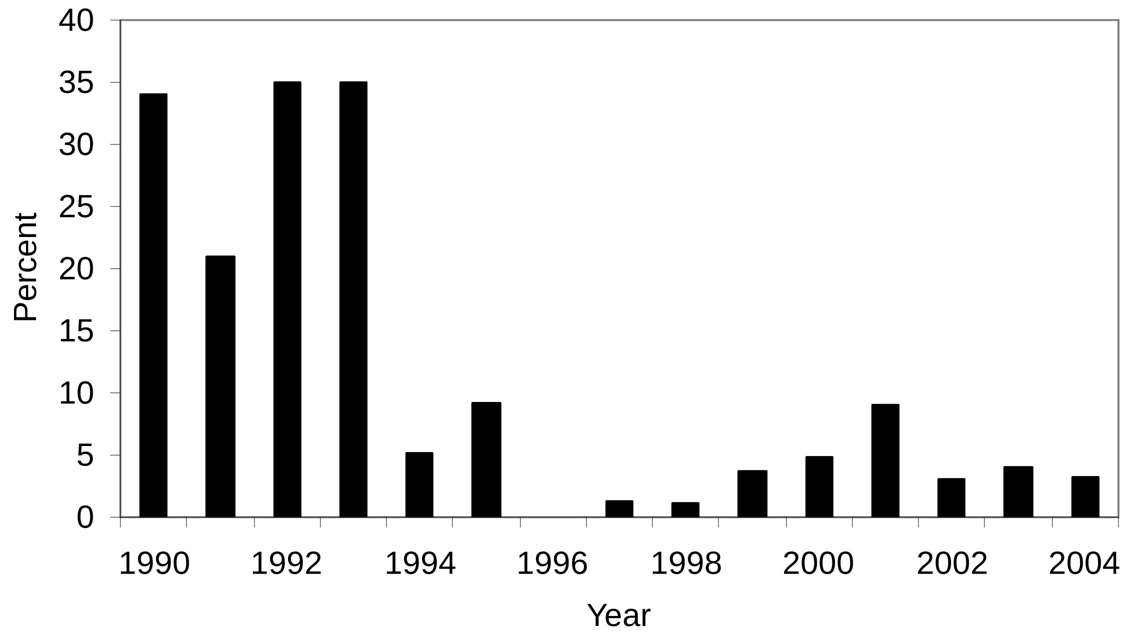

Figure 6.2. Percent of Chinook salmon of Minnesota hatchery origin harvested in the summer sport fishery in Minnesota waters of Lake Superior, 1990-2004. Many or all Chinook salmon stocked in Minnesota were not marked from 1991-1996.

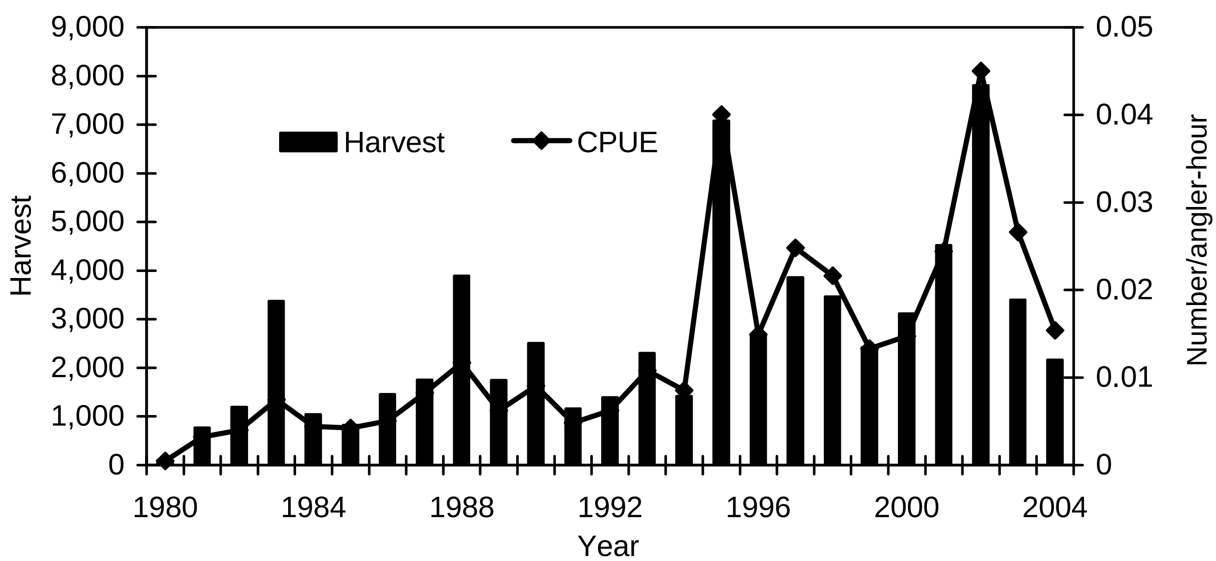

Figure 6.3. Catch-per-unit-effort (CPUE) and harvest of Chinook salmon in the summer creel survey, 1980-2004.

Catch of Chinook salmon in the fall stream fishery declined to 52 fish in 2003 (Figure 6.4). The average percent contribution of Chinook salmon of Minnesota hatchery origin to the fall stream fishery is 64% (Fall creels 1991-1994, 2003). Returns of Chinook salmon to the French River Trap peaked in 1986 and have steadily decreased (Figure 6.5), prompting the re-evaluation of the program according to criteria in the 1995 LSMP. Since 1994, trap returns to the French River have been insufficient to meet the 150,000 fingerling target level (1995 LSMP). The 1995 plan also proposed catch objectives for the summer boat fishery and the fall stream fishery of 1,600 and 1,000 Chinook salmon. The objective for the summer fishery has been met, while catches in the fall fishery have remained below 1,000 Chinook salmon since 1991. After a series of public input meetings in 1998, the decision was made to extend the stocking program using an outside source of eggs for four years, 1999-2002, after which the program would use returns to the French River trap as a brood source (Appendix 6.1). Criteria were established to determine the future of the program and stated that the Chinook salmon stocking program would be discontinued in 2006 or before, if the annual return of mature Chinook salmon to the French River trap fell below 75 BKD-free pairs for 3 consecutive years starting in 2003. Returns allowed the spawning of just 13, 20 and 9 pairs in 2003, 2004, and 2005, respectively. It was recommended that the stocking program be discontinued based on the low rates of return.

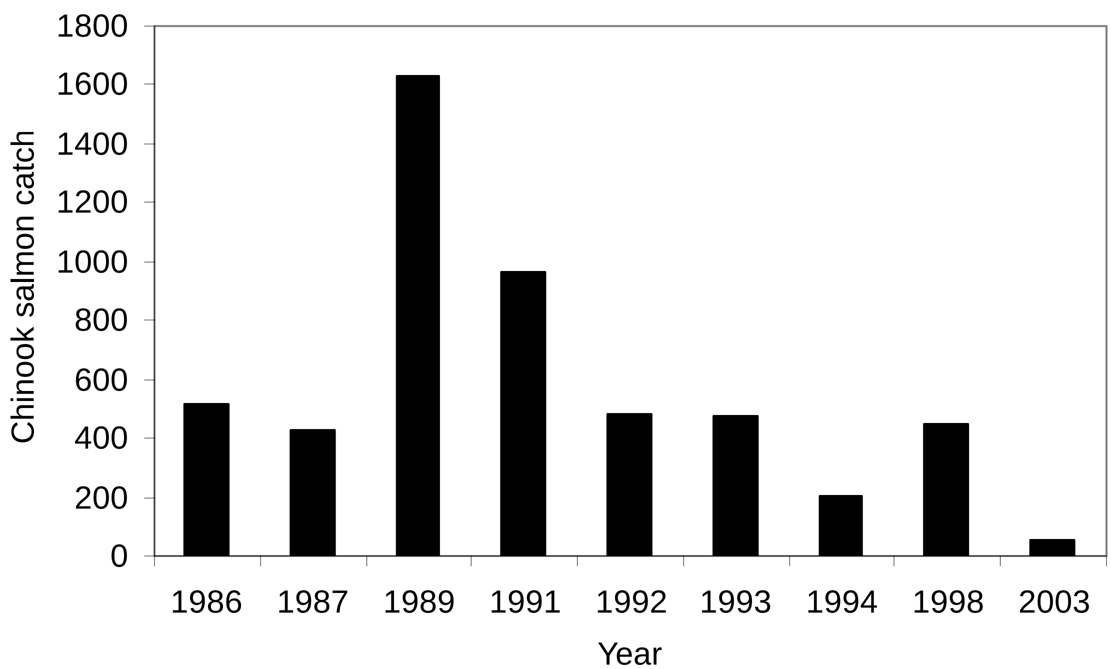

Figure 6.4. Catch estimates of Chinook salmon in fall creel surveys, 1986-2003.

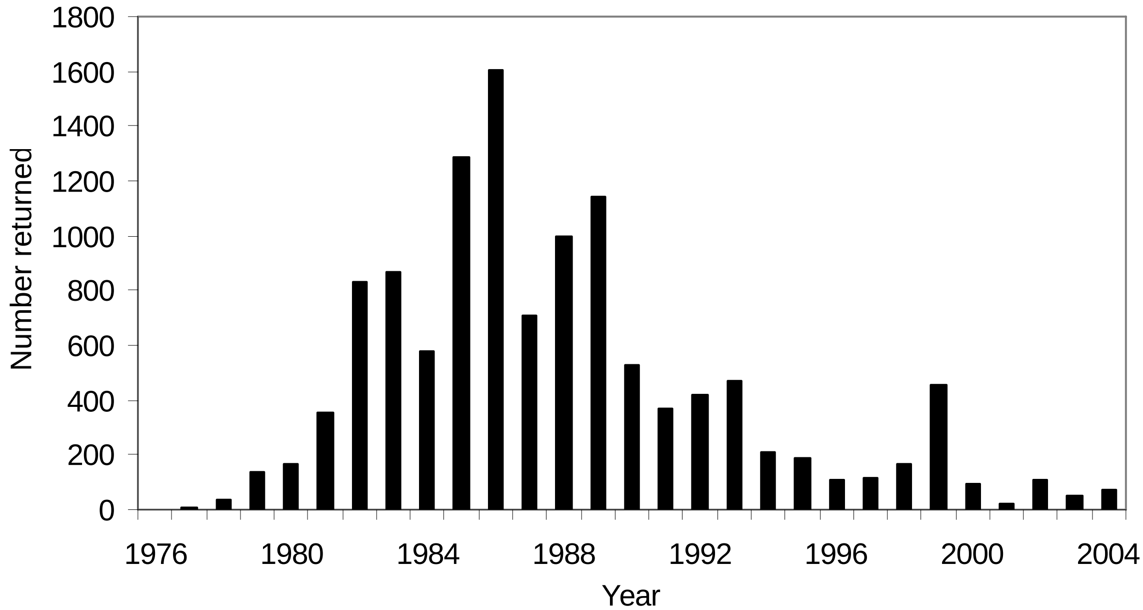

Figure 6.5. Returns of adult Chinook salmon to the French River trap, 1976-2004.

II. Goals and Objectives

Goal: Provide a diverse summer sport fishery, sustained by natural reproduction that allows anglers the opportunity to harvest Chinook salmon.

Objectives:

1. Sustain an average annual catch of 2,500 Chinook salmon from the summer boat fishery, realizing that there will be large annual fluctuations.

2. Coordinate with other jurisdictions involved in wild Chinook salmon management since very little natural reproduction takes place in Minnesota streams.

III. Present Management

A. Regulations - There is no closed season for Chinook salmon. The bag limit is 5 when combined with coho, pink, and Atlantic salmon. There is a minimum size limit of 10 in.

B. Stocking – All available eggs are taken from Chinook salmon returning to the French River trap in an attempt to meet the 355,000 fingerling target level. Eggs are tested for BKD and only disease-free eggs are used to produce fingerlings. The eggs are reared to fingerling size at the French River Cold Water Hatchery. Experimental stocking of larger-sized (29-39/lb) fingerlings resulted in improved return rates to the French River trap. When capacity allowed, fingerlings were reared to the larger size. Because full quotas of Lake Huron strain fingerlings were reared from 1999-2001, regular-sized fingerlings were reared (92/lb). As the collection site for broodstock, the French River is given the highest stocking priority and receives 100,000 fingerlings, with the Lester, Baptism, and Cascade rivers each receiving 85,000, when available, for a total of 355,000 fingerlings. Since 2003, Chinook salmon returns to the French River have not been large enough to meet the French River target, so no fish were stocked in the other streams.

C. Assessment - Chinook salmon are assessed by three methods in Minnesota: creel surveys, charter captain reports, and returns to the French River trap. The summer creel survey monitors Chinook salmon harvested in the boat fishery while the fall creel survey monitors Chinook salmon caught in the streams during the spawning run. Very few Chinook salmon are taken incidentally in assessment nets. Stream electrofishing surveys that target juvenile steelhead have sampled small numbers of naturally reproduced Chinook salmon.

IV. Proposed Management

A. Regulations - No change.

B. Stocking - Based on low returns to the French River trap that did not meet established criteria, it was recommended to discontinue stocking Chinook salmon.

C. Assessment - Conduct a summer lake creel survey annually to monitor angler harvest. Monitor and summarize charter captain reports annually.

V. Justification

Despite four years of intensive stocking (Figure 6.1), returns to the French River trap continue to be low (Figure 6.5). Returns of stocked Lake Huron strain Chinook salmon should have peaked from 2003-2006 based on the historical high returns of 3-5 year-old fish to the French River trap. Maintenance of summer and fall fisheries for Chinook salmon is desirable from the perspective of providing diverse fishing opportunities to Lake Superior anglers. Natural reproduction occurring largely outside Minnesota with immigration to Minnesota has enabled harvest objectives to be met for the summer boat fishery, but not the fall stream fishery. Minnesota appears to lack sufficient spawning habitat to sustain significant runs of naturalized Chinook salmon. Because the summer boat fishery is supported by over 95% wild fish, and Chinook salmon stocked in Minnesota constitute an average of less than 5% of the harvest, discontinuing stocking will not significantly impact this fishery. The fall fishery will be affected by discontinuing the stocking program since an average of 64% of Chinook salmon harvested in the fall creel are of Minnesota hatchery origin. However, the fall harvest in recent years has been a very small number of fish. Of the estimated 52 fish caught in the 2003 fall creel, 26 Chinook salmon were of stocked origin. Returns to the fall creel and the French River trap have declined to low levels despite high levels of stocking and favorable stream flows, indicating that the fish community dynamics have changed such that significant fall runs and a feral brood stock cannot be supported through reasonable stocking effort.

Lake Superior may be at carrying capacity for predators (Kitchell et al. 2000). Chinook salmon consume more forage per individual than any other Lake Superior species (Negus 1995). Rainbow smelt abundance is very low, and stocks of lake herring have not yet rebounded to historic levels (see Chapter 4). Evidence suggests that the primary forage for Chinook salmon are now coregonines (Ostazeski et al. 1999). With the restoration of lake trout, establishment of naturalized Chinook salmon populations, and concerns over the forage base, stocking Chinook salmon is no longer necessary or prudent. The cost-effectiveness of stocking Chinook salmon is being examined by most agencies working on Lake Superior (Ebener *in review*).

VI. Information Needs/Community Interactions

More information on the interaction between Chinook salmon and their forage base, and between Chinook salmon and other predators in Lake Superior is necessary. Diet studies of Chinook salmon should be conducted at least once every five years to evaluate changes. Seasonal and juvenile diet studies also need to be conducted. Movement and distribution of Chinook salmon throughout the lake are poorly understood and abundance estimates need further work. Initial bioenergetics modeling has been completed, but the model should be refined using the new information collected over the last 10 years.

References

Close, T. L., S. E. Colvin, and R. L. Hassinger. 1984. Chinook salmon in the Minnesota sport fishery of Lake Superior. Minnesota Department Natural Resources, Division of Fish and Wildlife, Section of Fisheries Investigational Report 380, St. Paul.

Ebener, M.P., editor. *In review*. The state of Lake Superior in 2000. Great Lakes Fishery Commission Special Publication.

Kitchell, J.F., S. P. Cox, C. J. Harvey, T. B. Johnson, D. M. Mason, K. K. Schoen, K. Aydin, C. Bronte, M. Ebener, M. Hansen, M. Hoff, S. Schram, D. Schreiner, and C. J. Walters. 2000. Sustainability of the Lake Superior fish community: interactions in a food web. Ecosystems 3:545–560.

Negus, M. T. 1995. Bioenergetics modeling as a salmonine management tool applied to Minnesota waters of Lake Superior. North American Journal of Fisheries Management 15:60-78.

Ostazeski, J. J., S. A. Geving, T. N. Halpern, and D. R. Schreiner. 1999. Predator diets in the Minnesota Waters of Lake Superior, 1997-98. Minnesota Department of Natural Resources Division of Fish and Wildlife, Completion Report, St. Paul.

Peck, J. W., T. S. Jones, W. R. MacCallum, and S. T. Schram. 1999. Contribution of hatchery-reared fish to Chinook salmon populations and sport fisheries in Lake Superior. North American Journal of Fisheries Management 19:155-164.

Peck, J. W., W. R. MacCallum, S. T. Schram, D. R. Schreiner and J. D. Shively. 1994. Other salmonines. Pages 31-47 *in* M. J. Hansen, editor. The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1, Ann Arbor, Michigan.

Appendix 6.1: Chinook Salmon Program Criteria

MN-DNR CHINOOK SALMON PROGRAM
JULY 1998

Time Period - Extend stocking from outside source for 4 more years 1999 - 2002. From 2003-2006 use returns to the French River trap for an egg source.

Egg source - Agree to go outside the French River return. Most reliable source appears to be Michigan.

Egg numbers - Requires from 500,000 - 700,000 green eggs based on survival.

Fingerling Target - 355,000 to be distributed as follows: French River - 100,000; Lester River - 85,000; Baptism River - 85,000; Cascade River 85,000. All fingerlings will be fin-clipped so contribution to the fishery and spawning stocks can be determined.

Evaluation - Evaluate from 2000 - 2006.

a. Returns to the lake fishery will be monitored in the summer creel from 2000 - 2006.
b. Returns to the French River trap will be monitored from 2002 - 2006.
c. Returns to the fall stream fishery will be monitored by a minimum of two fall creel surveys from 2002 - 2006.

Criteria:

Discontinue the Chinook salmon stocking program in 2006, or before, if the annual return of mature Chinook salmon to the French River trap falls below 75 BKD-free pairs for three consecutive years starting in 2003.

Discuss status of Chinook stocking program in 2006 or before, if, as stated in the Lake Superior Management Plan: 1. Natural reproduction of Chinook salmon continues and harvest objectives are met by wild fish, as determined from the results of the stocking evaluation. 2. If it can be demonstrated that forage abundance has decreased to extremely low levels, then a conservative approach to Chinook salmon stocking (reduction or elimination) is warranted.

Time Frame - We will attempt to procure the required eggs starting July 1998 and continue to stock from an outside source through spring of 2002 (4 years). We will evaluate these year-classes through 2006 when the majority of fish will have passed through the fishery and/or returned to the French River trap.

CHAPTER 7: COHO SALMON

I. History

Coho salmon were stocked in the Minnesota waters of Lake Superior from 1969 through 1972 (Hassinger 1974). Stocking was discontinued in 1972 based on slow growth rate, small size of creeled fish, low return rate, late spawning migration, and high cost of the hatchery product. Failing to meet management goals, the stocking program was discontinued in 1972.

Coho salmon have become naturalized throughout Lake Superior. Coho salmon fluctuate with Chinook salmon as the second or third most frequently caught salmonine behind lake trout in the summer fishery (Halpern 2005). Coho salmon are also a secondary target species in the winter and early spring shore fisheries (Ostazeski and Morse 2001). Spawning occurs in Minnesota tributaries, but reproductive success is low due to limited habitat. Natural reproduction in other jurisdictions and migration to Minnesota waters account for the success of the fishery. Coho salmon have a three-year life cycle with anglers catching primarily two-year-old fish (Bronte et al. 2003). As a result, fluctuations in year-class strength strongly impact catch and harvest in the fisheries. From 1980 to 2004, the harvest of coho salmon ranged from 229 to 11,652 fish (Figure 7.1). The average summer harvest of coho salmon in Minnesota waters from 1995-2004 was 3,261. The fall fishery for coho salmon in Minnesota is very limited.

Despite the relatively small size of coho salmon, popularity and interest in the coho salmon fishery is high. A hatchery program for coho salmon is a low priority given the higher expense of raising a species that requires more time in the hatchery compared to yearling of other species. Contributions of hatchery coho salmon to the Michigan fishery have been poor, constituting less than 10% (Peck 1992), and stocking has been discontinued in all but a small area of Michigan waters.

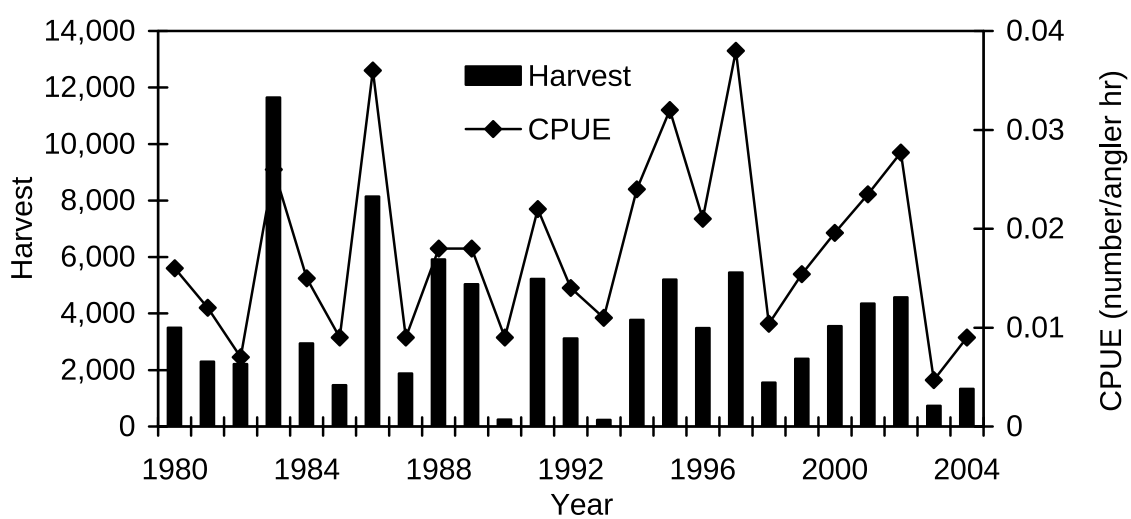

Figure 7.1. Harvest and catch rates of coho salmon in summer boat fishery in the Minnesota waters of Lake Superior, 1980-2004.

II. Goals and Objectives

Goal: Provide a diverse sport fishery sustained by natural reproduction that allows anglers the opportunity to harvest coho salmon.

Objectives:

1. Sustain an average annual catch of 3,000 coho salmon from the summer fishery based on natural reproduction, realizing that there will be large annual fluctuations.

2. Coordinate with neighboring jurisdictions on wild coho salmon management since very little production of coho salmon occurs in Minnesota tributaries.

III. Present Management

A. Regulations - There is no closed season for coho salmon. The bag limit is 5 when combined with Chinook, pink and Atlantic salmon. There is a minimum size limit of 10 in.

B. Stocking - No stocking.

C. Assessment - Coho salmon in Minnesota are assessed by three methods: creel surveys, charter captain reports, and returns to the French and Knife river traps. In most years, fewer than 25 coho salmon are captured in each of the French and Knife river traps. Very few are taken incidentally in lake trout assessment nets. Stream electrofishing surveys targeting juvenile steelhead have sampled a small number of naturally reproduced coho salmon.

IV. Proposed Management

A. Regulations - No changes in present regulations.

B. No stocking.

C. Assessment - Conduct winter creel survey once every three years. Continue to conduct a Lake Superior summer creel survey annually. Monitor and summarize charter captain reports annually. Monitor the French River and Knife river traps to count adults entering those two rivers. Work closely with other agencies to determine the proportion of coho salmon harvested in Minnesota that are produced in other jurisdictions. Continue to monitor catch to ensure overexploitation does not occur.

V. Justification

Coho salmon have provided a high quality fishery based on natural reproduction. Competition with other migratory species may exist as coho salmon ascend tributary streams each fall in search of suitable spawning habitat. They probably utilize some of the same spawning areas and food items as brook, brown, and rainbow trout (Fausch and White 1986). In the lake, foraging competition may exist among coho salmon, Chinook salmon, and sub-adult lake trout (Harvey and Kitchell 2000).

Year-class strength of coho salmon fluctuates based on stream conditions during early life stages and abundance of parental stock, which could be affected by a combination of climate, fishing mortality and predation. Fluctuating year-class strength relates directly to harvest and catch rates since the fisheries are predominantly based on a single year-class.

VI. Information Needs/Community Interactions

More information on the interactions between coho salmon and their forage base, and coho salmon and other species in Lake Superior is necessary. Diet surveys conducted every five years are needed to identify overlaps between coho salmon and other Lake Superior species at all life stages. A winter creel survey is needed every three years to document the variable fishery for coho salmon that takes place in Minnesota waters. Habitat utilization and seasonal movement patterns of coho salmon should be determined using hydroacoustics, archival tags and possibly telemetry, to enhance our understanding of their role in the Lake Superior fish community.

References

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970–2000. Canadian Journal of Fisheries and Aquatic Sciences 60:1552-1574.

Fausch K. D., and R. J. White. 1986. Competition among juveniles of coho salmon, brook trout and brown trout in a laboratory stream and implications for Great Lakes tributaries. Transactions of the American Fisheries Society 115:363-381.

Halpern, T. N. 2005. Lake Superior summer creel survey 2004. Minnesota Department of Natural Resources, Project F-29-R (P)-24, Study 4, Job 691, Completion Report, St. Paul.

Harvey, C. J., and J. F. Kitchell. 2000. A stable isotope evaluation of the structure and spatial heterogeneity of a Lake Superior food web. Canadian Journal of Fisheries and Aquatic Sciences 57:1395-1403.

Hassinger, R. L. 1974. Evaluation of coho salmon (*Oncorhynchus kisutch*) as a sport fish in Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries Investigational Report 328, St. Paul.

Ostazeski, J. J., and S. D. Morse. 2001. Lake Superior winter creel survey 2001. Minnesota Department of Natural Resources, Project F-29-R (P)-21, Study 4, Job 569, Completion Report, St. Paul.

Peck, J. W. 1992. The sport fishery and the contribution of hatchery trout and salmon in Lake Superior and tributaries at Marquette, Michigan, 1984-1987. Michigan Department of Natural Resources Fisheries Research Report 1975, Ann Arbor, Michigan.

CHAPTER 8: PINK SALMON

I. History

In 1956, approximately 21,000 pink salmon fry were accidentally introduced into the Current River in Ontario (Nunan 1967), became established and are now naturalized in Lake Superior. In Minnesota, the first pink salmon were caught in 1959 by anglers fishing in the Sucker and Cross rivers (Eddy and Underhill 1976). Based on creel survey results and angler reports, pink salmon have never attained the abundance in the summer boat fishery that Chinook and coho salmon have, but have provided a significant fall stream fishery in some years. In Lake Superior, pink salmon abundance increased from the 1960s through the 1970s, then declined to extremely low levels during the late 1980s (Peck et al. 1994). From 1984-1995, the annual harvest by summer lake anglers has averaged less than 200 in Minnesota. However, since the mid-1990s pink salmon abundance has again started to increase as indicated by higher harvest levels (Figure 8.1) and number of spawning adults reported by anglers in the fall fishery. Given that pink salmon normally live for only two years, harvest of pink salmon is extremely variable because anglers are fishing only one year-class.

Pink salmon normally enter Minnesota streams in mid-September to spawn. After eggs are deposited in gravel redds, the fish die. Little is know about the specific life history of pink salmon in Minnesota streams, but in British Columbia where pink salmon are native, the eggs hatch in about 125 days where they remain as sac fry. In April and May, the sac fry emerge and almost immediately migrate downstream to the ocean. It is very rare to find any pink salmon juveniles after mid-July in tributary streams. Pink salmon normally take two years to mature, but may occasionally live to three years in Lake Superior. Pink salmon are the smallest of the Pacific salmon in Lake Superior and average less than two pounds. There is no targeted management program for pink salmon; however, they are included in the combined Pacific salmon harvest limit.

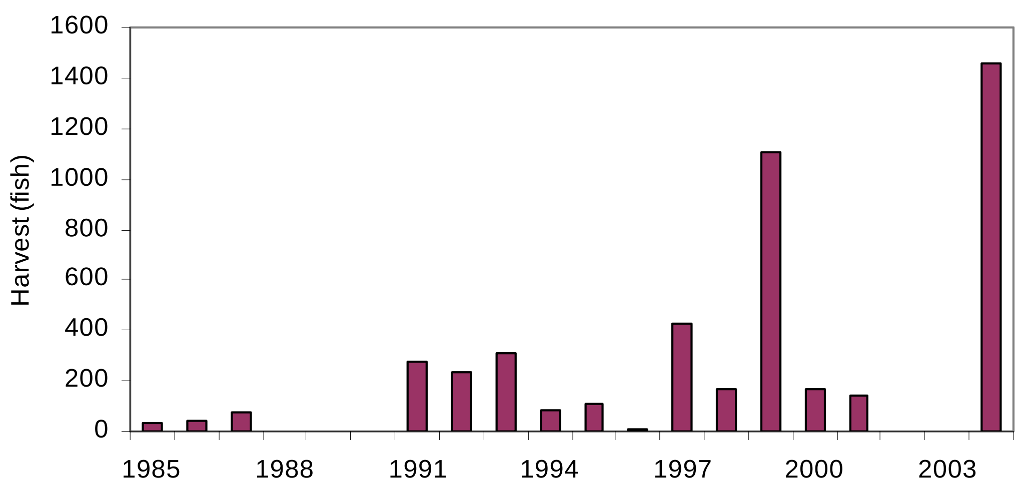

Figure 8.1. Pink salmon harvested in the summer Lake Superior creel survey, 1985-2004.

II. Goals and Objectives:

Goal: Maintain the opportunity to harvest naturalized pink salmon that originate from tributaries in Minnesota and other states.

Objective:

1. Allow angler harvest of pink salmon in Lake Superior and tributary streams.

III. Present Management

A. Regulations - There is no closed season in Lake Superior and in tributaries below posted boundaries. The bag limit is 5 in combination with Chinook and coho salmon, with a minimum size of 10 in.

B. Stocking – Pink salmon have never been stocked in Minnesota.

C. Assessment – Conduct annual summer creel surveys on Lake Superior. Conduct fall creel surveys intermittently to monitor fall run species. Monitor adult catches at the French and Knife River fish traps.

IV. Proposed Management

A. Regulations – Maintain present regulations.

B. Stocking - No stocking recommended.

C. Assessment - Continue with present assessment program and also record presence of pink salmon in coaster brook trout assessments conducted once every five years.

V. Justification

Pink salmon have become established as part of the Lake Superior fish community. Pink salmon are not stocked by any management agency on Lake Superior. They provide a limited summer and fall sport fishery. Their impact on other species in the Lake Superior fish community is unknown, but at this time appears to be minimal.

North Shore streams are relatively unproductive and can support only a limited number of fish (Waters et al. 1990). Juvenile pink salmon are reported to leave the stream as fry immediately after swim-up. This behavior results in little competition between pink salmon and juveniles of other migratory species. Spawning pink salmon adults do have the potential to impact other Pacific salmon and coaster brook trout for a short period of time as they compete for spawning areas. There is one reported observation of spawning male pink salmon attacking male brook trout and displacing them from females in spawning condition in a Lake Huron tributary (Kocik and Jones 1999). However, since pink salmon spawn relatively early in Minnesota (mid-September) compared to coaster brook trout (mid-October), their impact may be limited.

VI. Information Needs/Community Interactions

Interactions between pink salmon and other migratory species in Lake Superior and tributary streams need to be determined. More research should be conducted on the life history and food habits of pink salmon to determine their impact on the Lake Superior fish community.

References

Eddy, S., and J. C. Underhill. 1976. Northern fishes. University of Minnesota Press, Minneapolis.

Kocik, J. R., and M. L. Jones. 1999. Pacific salmonines in the Great Lakes basin. Pages 455-488 *in* W. W. Taylor and C. P. Ferreri, editors. Great Lakes fisheries policy and management. Michigan State University Press, East Lansing.

Nunan, P. J. 1967. Pink salmon in Lake Superior. Ontario Fish and Wildlife Review 6:8-13.

Peck, J. W., W. R. MacCallum, S. T. Schram, D. R. Schreiner, and J. D. Shively. 1994. Other salmonines. Pages 35-52 *in* M. J. Hansen, editor. The state of Lake Superior in 1992. Great Lakes Fishery Commission, Special Publication 94-1, Ann Arbor, Michigan.

Waters, T. F., M. T. Doherty, and C. C. Krueger. 1990. Annual production and production: biomass ratios for three species of stream trout in Lake Superior tributaries. Transactions of the American Fisheries Society 119:470-474.

CHAPTER 9: RAINBOW TROUT

This chapter incorporates the recently published *Rainbow Trout Management Plan for the Minnesota Waters of Lake Superior* (RTMP) (Schreiner 2003). The 2003 RTMP replaced a version developed 10 years earlier called the *1992 North Shore Steelhead Plan* (NSSP)(Schreiner 1992). The change in the title from "steelhead" to "rainbow trout" reflects the inclusion of the Kamloops strain of rainbow trout in management of the rainbow trout resource. The title change in no way reflects a reduced effort by the Minnesota Department of Natural Resources (MNDNR) to manage steelhead. It does recognize the reality that Kamloops are currently part of the rainbow trout management program in Minnesota and cannot be segregated from steelhead management.

The format of the RTMP was modified slightly to fit the format of the Lake Superior Management Plan. The habitat section is included in the general habitat chapter (Chapter 3). We also made some clarifications in the present management section, and modifications and minor updates in the proposed management section that were not part of the 2003 RTMP; however, much of the chapter remains identical to the 2003 RTMP.

Many individuals and organizations interested in rainbow trout management in Lake Superior came together to develop and support the RTMP. A planning group called the Rainbow Trout Advisory Group was formed and donated much time and energy to developing the RTMP. Their efforts are greatly appreciated. Many of these individuals were also members of the Lake Superior Advisory Group, and were instrumental in producing the LSMP, as described earlier.

I. History

Anadromous rainbow trout (steelhead) from the west coast of North America were first introduced into the Minnesota waters of Lake Superior in 1895 (Hassinger et al. 1974). The species has become naturalized and supports an important recreational fishery. Minnesota has approximately 180 miles of tributary streams accessible to steelhead, of which a more limited portion is suitable for spawning. For the most part, these areas supported a good fishery for naturalized steelhead from the 1940s through the 1960s. During the 1970s and 1980s, fishing pressure increased and anglers perceived that the number of steelhead were declining. In response, the MNDNR initiated a number of programs to enhance steelhead during this period. In several streams, upstream barriers to migration were altered to permit fish passage, and in-stream structures were designed to increase the amount and quality of habitat available to juvenile steelhead. From 1981-1992 natural reproduction of steelhead was supplemented by stocking large numbers of steelhead fry, usually in tributaries above the first barrier. A portion of the stocked fry came from eggs that were collected from adult steelhead returning to the French River trap. However, the majority of eggs used for fry production came from fish captured in the Little Manistee River trap in Michigan. Stream surveys indicated that fry stocking had increased the number of age 0+ steelhead in the streams, but that survival of fry to age 1+ was variable and dependent largely on environmental conditions.

Starting in the 1970s, experimental stocking of rainbow trout yearlings began in Minnesota as an attempt to augment the wild steelhead stocks. A large number of rainbow trout strains, both natural and domestic, were available. In 1972 and 1973, three domestic strains of rainbow trout (Donaldson, Madison, and Kamloops) were stocked and their performance in Lake Superior was evaluated (Close and Hassinger 1981). Results indicated that the Kamloops strain was the best suited for a put-grow-and-take fishery that would augment the growing harvest from the naturalized steelhead fishery. In 1976, Minnesota began a Kamloops stocking program with the goal of establishing a put-grow-and-take migratory rainbow trout fishery. Yearling Kamloops are reared in the hatchery and stocked annually. Kamloops returning to the French River trap are used as the egg source for the hatchery-reared fish. Kamloops are stocked as yearlings, live in the lake, and first return to spawn in streams at ages 3-5. The Kamloops program has increased fishing opportunities and provided for an expanded harvest of rainbow trout. Since 1997, when catch and release regulations were implemented for wild steelhead, the Kamloops program has provided the only significant harvestable rainbow trout fishery in Minnesota's portion of Lake Superior. Where stocked, Kamloops have a tendency to stage off river mouths in fall, winter and early spring. This provides additional shore-fishing opportunities that would not otherwise be available. This accessibility and the opportunity for harvest have made the Kamloops program popular with many anglers. However, the program is unpopular with anglers that support self-sustaining steelhead management, which often creates conflict among the user groups.

Efforts to augment the steelhead fishery were only partially successful, and despite the enhancement programs, anglers and biologists remained concerned because the number of wild steelhead continued to decline through the 1980s. These trends were documented through returns to the French River trap and low numbers of steelhead sampled during creel surveys.

To address the decline of wild steelhead in the Minnesota waters of Lake Superior, the MNDNR, Division of Fisheries developed the NSSP (Schreiner 1992). Public input on the NSSP was received at a series of public meetings held in the winter of 1991-1992. Many changes were made to the plan based on this public comment. However, as expected, there was not unanimous support for all the proposed strategies.

The NSSP was implemented in 1992, modified during the development of the LSMP, and was scheduled for revision after 10 years, in 2002. Management strategies for rainbow trout detailed in the NSSP and the LSMP included: restrictive angling regulations, revised stocking strategies, beaver dam removal and increased beaver trapping, the construction of migratory fish traps and monitoring stations, a shore-wide genetics study, an economics study, and a variety of other projects. The NSSP was written to be flexible, and a number of modifications were made when it was incorporated into the LSMP. All objectives and many of the strategies outlined in the original plan have been addressed (Appendix 1). A steelhead plan progress report has been published annually over the last 10 years, and a biennial newsletter is published to continually update anglers and other interested citizens on the progress of the Lake Superior management program. A wide variety of reports and publications are available that describe the results of studies and assessments proposed in the NSSP.

The goal of the NSSP "to stop the decline of adult steelhead and gather the necessary information to rehabilitate wild steelhead stocks" has largely been accomplished. The decline in adult steelhead numbers has been reversed and although there are still information needs relevant to wild steelhead, the knowledge base on steelhead in Minnesota has grown significantly over the last 10 years. The purpose of the RTMP and this chapter is to utilize the information gained and work closely with interested citizens to continue restoration of wild steelhead stocks. Citizen participation included extensive dialog with the Rainbow Trout Advisory Group, solicitation of comments from the general public, and discussions with interested anglers about the rainbow trout fishery. As always, there were differences among user groups on how best to proceed, and the Rainbow Trout Advisory Group discussed those differences at length. Although no single group or individual is supportive of every strategy put forth in the plan, most have accepted the long-term goals and are interested in seeing restoration of wild steelhead continue. The information that follows is an attempt to build on the successes of the past plan and move forward with restoration efforts.

II. Goals and Objectives

Goal: Rehabilitate steelhead stocks using Minnesota strain fish to achieve a level that will allow limited angler harvest largely supported by naturally reproducing populations.

Objectives:

1. Protect or improve steelhead habitat in North Shore watersheds by maintaining suitable stream flows, water temperatures,

water quality, and access to spawning and nursery areas.

2. Continue to investigate the factors limiting sustained production of naturalized steelhead in the Minnesota waters of Lake Superior by monitoring the fishery and conducting research.

3. Implement management strategies to rehabilitate naturalized steelhead populations in the Knife River with a target of 1,000 spawning fish by 2010.

4. While the rehabilitation plan is in progress, continue to provide a rainbow trout fishery that utilizes Kamloops, while attempting to minimize any negative impacts on naturalized steelhead populations.

5. Coordinate with MNDNR, Ecological Services Division, U.S. Department of Agriculture, and interested citizens to monitor the cormorant population on Knife Island and if necessary, reduce their potential impact on emigrating Knife River steelhead.

6. With the assistance of angling organizations, increase efforts to locate and contact willing landowners to acquire easements and angler access to North Shore streams, and develop a map depicting locations where angler access is currently available along North Shore streams.

III. Present Management

A. Regulations – These regulations apply to the Minnesota waters of Lake Superior and its tributaries below the posted boundaries. The rainbow trout season is continuous. The possession limit is three rainbow trout, all of which must have a clipped adipose fin. All rainbow trout with an adipose fin must be released. The minimum size is 16 inches for rainbow trout with clipped adipose fins. In tributaries to Lake Superior above the posted boundary, no harvest of any rainbow trout is allowed. There are a number of fishing sanctuaries that have been established to protect spawning steelhead and their redds. Fishing for all species in most of these areas is annually closed from September 1 to May 31. A few areas are permanently closed to angling. See current fishing regulations for details.

B. Stocking - In Minnesota two different rainbow trout stocking programs are used to supplement the rainbow trout fishery in Minnesota. The first program is an attempt to rehabilitate steelhead numbers along the Minnesota shoreline by stocking both fry and yearling life stages of Minnesota strain steelhead in selected streams. The second program is to provide a geographically limited put-grow-and-take fishery for Kamloops rainbow trout that may be phased out if the wild steelhead populations recover and can provide an acceptable harvest fishery, or if negative impacts of Kamloops on wild steelhead become measurable.

Steelhead yearlings are reared at the French River Cold Water Hatchery, and gametes for the program are collected from unclipped Knife River steelhead captured at the Knife River trap. A total of 40,000 yearlings are reared annually with financial assistance from the Lake Superior Steelhead Association. All hatchery-reared Knife River yearlings will be identified with a non-harvest fin clip (adipose fin will not be removed), and/or some type of tag/mark if an acceptable method can be developed. From 2003-2007, all 40,000 yearlings will be stocked into the Knife River system in an attempt to increase steelhead numbers. During the winter of 2007, the MNDNR will meet with the Rainbow Trout Advisory Group to review the status of rehabilitation on the Knife River, and reevaluate the yearling program and other management strategies.

Initially, the most effective stocking locations in the Knife River system will be determined through an experimental process. Steelhead will not be stocked into headwater areas considered wild brook trout waters. To identify effective steelhead stocking locations, approximately 50% of the hatchery-reared steelhead yearlings will be stocked above the Knife River trap, while the remaining portion of hatchery-reared yearlings will be stocked below the trap. Differential survival to adult will be evaluated to determine the most effective stocking location by monitoring trap returns 3-5 years after stocking. Initial survival of smolts stocked above the trap will be determined by monitoring their downstream movement through the Knife River smolt trap.

If the Knife River rehabilitation program is successful and the estimated number of both wild and hatchery-reared steelhead returning to the Knife River adult trap exceeds an average of 1,000 fish per year for three consecutive years, the MNDNR will meet with the Rainbow Trout Advisory Group to reevaluate and reduce or discontinue the yearling stocking program in the Knife River. If stocked yearlings prove to be an effective rehabilitation strategy, yearlings not stocked into the Knife River will be considered for stocking into other streams agreed upon by the MNDNR and the Rainbow Trout Advisory Group. The yearling program will be considered unsuccessful if the average return of hatchery-reared steelhead to the Knife River trap is less than 1% for 3 consecutive year-classes. The program would also be considered unsuccessful if the production costs of the yearling program become prohibitive. If the yearling program is not successful after stocking 5 year-classes, the MNDNR will meet with the Rainbow Trout Advisory Group to reevaluate and potentially discontinue the program

All adults returning to the Knife River trap that were derived from stocked steelhead yearlings will either be passed directly above the Knife River trap so they can spawn on their own, or be transported to the French River hatchery where gametes will be taken and reared to the fry stage. All fry originating from adults produced in the Knife River yearling program will be stocked back into the Knife River system. Hatchery survival from egg to fry ranges from 60-80%, while survival from egg to fry in the wild seldom exceeds 5-10%**.** Evaluations are being conducted to determine what method is most productive in producing smolts.

The fry stocking program for other streams will also utilize Minnesota strain steelhead as a source of gametes. The French River is stocked only with fry from wild adults returning to the French River. To produce a dependable source of fry for stocking in other Minnesota streams, the MNDNR is working to establish a captive Knife River strain brood stock. The brood stock is being created by collecting downstream migrants (both age 1+ and age 2+) from the Knife River smolt trap, which are then reared to adult at the French River Cold Water Hatchery. This is an innovative program that has not yet been fully evaluated. The goal is to produce 500,000 fry annually to be stocked every other year into selected streams (Table 9.1)**.** Streams are not stocked with fry if they have very limited fishing access or if they have demonstrated good natural wild steelhead reproduction. Streams managed for Kamloops are given a lower priority for steelhead fry stocking, and in years of low fry numbers they will not be stocked (priority 3).

Approximately 200 pair of adults will be necessary to produce the fry quota for this program. If successful and hatchery space is available, the number of fry produced might be increased. Brood stock will continually be replaced from wild Knife River juveniles as described above. If the creation of brood stock is not achievable or becomes cost prohibitive, the program will be reevaluated and potentially discontinued. Criteria to reevaluate the program include: 1) unmanageable disease outbreak in captive brood stock; 2) survival from green egg to swim-up fry averages less than 50% for 3 consecutive years; 3) swim-up fry production averages less than 500,000 for 3 consecutive years with full complement of brood stock; 4) program becomes cost prohibitive; and 5) information from genetic monitoring indicates there are negative genetic impacts to wild steelhead.

The Kamloops stocking program will continue. However, because of the potential negative consequences of interbreeding with wild steelhead (Close 1999; Miller et al. 2004; Negus 1999), Kamloops stocking will not be expanded outside the present stocking area and efforts are and will continue to be made, to reduce straying from this area. Kamloops yearlings are reared at the French River Cold Water Hatchery and gametes for the program are collected from adults that return to the French River trap. Two streams are presently stocked with Kamloops (Table 9.2). In an

Table 9.1. Proposed Lake Superior steelhead fry stocking quotas, frequency, locations, and priority in Minnesota.

Management Area/Stream	Tributary Number	Stocking Quota	Stocking frequency[1]	Stocking location[2]	Priority
Duluth Area					
Amity	S-5-1	100,000	E	2.4	2
Lester	S-5	100,000	O	12.9	3
French[3]	S-11	150,000	A	8.5	1
Stewart	S-19	100,000	E	7.7	1
Silver	S-21	50,000	O	6.6	3
Gooseberry	S-26	50,000	O	13.0	2
Finland Area					
Split Rock	S-29	150,000	O	3.9	2
East Beaver	S-35	100,000	E	3.6	2
Baptism	S-38	150,000	O	6.0	2
Cross	S-52	50,000	E	4.0	1
Grand Marais Area					
Temperance	S-53	100,000	E	0.6	1
Cascade	S-64	50,000	E	3.6	1

[1] A – Annual; O – Odd Years; E – Even Years
[2] Miles Above Mouth
[3] Fry from wild adults returning to French River.

Table 9.2. Proposed Lake Superior Kamloops yearling stocking quotas and locations in Minnesota.

Stream	Tributary Number	Stocking Quota
Lester	S-5	32,500
McQuade Harbor/Talmadge	S-7	25,000
French	S-11	35,000

attempt to reduce Kamloops straying, all fish will be stocked directly into the stream when flow conditions permit. The Chester Creek quota has been moved to the Lester River. If the combined return of adult Kamloops to the anglers and to the spawn taking operation at French River averages less than 1% for 3 consecutive years, the Kamloops program will be reevaluated. Also, in relation to rehabilitation of wild steelhead, the Kamloops program will be reevaluated and possibly phased out or dis continued if: 1) genetic introgression is demonstrated and significant as measured by the occurrence of steelhead x Kamloops hybrids or by tracking a diagnostic allele; 2) steelhead abundance rebounds to produce an acceptable fishery where Kamloops are not stocked; or 3) steelhead continue to decline only in areas with a heavy Kamloops presence. A phase-out of Kamloops stocking will not occur without discussions between the Rainbow Trout Advisory Group and the MNDNR.

C. Assessment - A variety of techniques will continue to be used to assess the rainbow trout fishery and its management in Lake Superior. Continuation of the rainbow trout assessment program is essential to build on the long-term data series so changes can be documented and trend analysis can be conducted.

Stream surveys and population assessments are conducted on Lake Superior tributaries to determine the abundance and survival of juvenile rainbow trout, along with physical and chemical characteristics of each stream. Index stations have been established as described in *North Shore Index Station Assessment 1992-1999* (Morse 2000), and are assessed annually to determine the abundance of juvenile rainbow trout produced through natural reproduction. Annual juvenile steelhead assessments at index stations on North Shore tributaries will continue.

Angling pressure, catch, and catch rate of rainbow trout are determined from creel surveys conducted in the spring, summer, and intermittently in the fall and winter on the Minnesota waters of Lake Superior. The spring creel survey targets rainbow trout, and has been conducted almost every year since 1970. The summer creel survey targets the lake fishery, but includes rainbow trout caught during this period. The fall creel survey targets the Chinook salmon run, but also includes rainbow trout that are caught during this season. The winter survey normally targets the Kamloops and coho fishery that routinely develops along the Minnesota shoreline from Duluth to Two Harbors.

An annual spring creel survey will be conducted to document fishing pressure, catch and catch rate during the spring rainbow run. A winter creel survey targeting the nearshore rainbow trout fishery will be conducted once every three years. When required, the surveys can be used to evaluate angler views and perspectives on the resource and its management.

The French, Knife, and Little Knife river traps have been used to assess returns of adult rainbow trout. The French River trap has been in place since the mid-1970s, and is also used to collect feral brood stock for gamete production of both steelhead and Kamloops. In the spring of 1994, a smolt trap was constructed as part of the existing dam on the French River to determine the number of juvenile steelhead emigrating downstream that originated from fry stocking. The smolt trap has greatly increased the amount of information collected on steelhead in a medium-sized North Shore stream, and has helped document the effectiveness of fry stocking. The Little Knife River trap was operated from 1988 – 2004. Important data were collected to determine trap efficiency, the smolt-adult relationship, smolt survival, and other information that can be related to steelhead populations in a small stream. The Knife River adult trap was constructed in 1995 (Fish Pro 1993) and first operated in 1996. The Knife River smolt trap was constructed in 1996 and first operated in 1997. Important biological data have been collected on the wild populations that spawn in the Knife River and the juveniles they produce. Gametes are also collected from both wild and hatchery reared adults returning to spawn in the Knife River. Insufficient time has passed to determine the smolt-adult relationship in this stream, but monitoring of both adults and smolts will continue. Construction and operation of the Knife River trap has decreased the need for operating the Little Knife River trap.

The French and Knife river traps will be used to collect gametes and assess returns of adult rainbow trout, and to quantify the number of juveniles emigrating to the lake annually. Trap data will be compiled to determine: smolt-adult relationship, adult-smolt relationship, relationship of stocked fry to smolts, contribution of stocked fry to returning adults, return rate of stocked yearlings, and general population biology. Annual progress reports are produced on each major assessment technique, and on the overall status of the steelhead population.

Experimentation using the video camera mounted in the Knife River trap took place in fall 2004. Trap operation was modified by re-routing flow through the fish ladder. Results were mixed as fish were able to migrate upstream past the camera, but ID was difficult when the water was turbid. Viewing the film and counting fish required much more time than expected. The video camera will not be used for data collection until the abundance of adult steelhead surpasses a level where subsampling is required (a total spring return of 500-600 adults per year). Much of the critical information collected, and the future information required to evaluate rehabilitation of steelhead, can only be gained by handling individual fish. If important projects require sampling fish beyond the 500-600 fish target, we will continue to run the trap until project goals are reached. The Rainbow Trout Advisory Group will continue to be updated and informed on the status of using the video camera.

Operation of the Little Knife River trap was discontinued in 2004, and the grates removed to allow uninhibited fish passage. We do not anticipate operation of the Little Knife River trap in the near future.

IV. Proposed Management

A. Regulations - No major changes in harvest regulations are proposed for rainbow trout in Lake Superior and its tributaries at this time. If wild steelhead rehabilitation progresses and the angler catch rate for steelhead greater than 16 inches from the spring creel exceeds 0.10 fish per angler hour for 3 consecutive years shorewide, the MNDNR will meet with interested citizens to develop appropriate harvest regulations and reconsider stocking strategies.

Anglers have requested that the MNDNR investigate simplifying regulations that apply to Lake Superior tributaries. Recent management changes, and no harvest regulations for wild steelhead have eliminated the need for sanctuaries in two locations. We propose to eliminate the sanctuary on the Little Knife River since the Little Knife River trap will no longer be operated. We also propose to eliminate the seasonal sanctuary on Stanley Creek and the Knife River and its tributaries above County Road 9, but keep County Road 9 as the posted boundary. This would expand angling opportunities for brook trout by approximately one month, but still protect all rainbow trout from harvest. On the Knife River, we also propose to create a permanent sanctuary between the cables on the second falls, similar to the permanent closure at the first falls. These changes will simplify the sanctuary regulations, allow increased angler opportunity, but will not increase steelhead harvest. To protect vulnerable steelhead from being continuously foul hooked, we will investigate creating a permanent closure just below the Superior Street Bridge on the Lester River. All proposed regulation changes must be approved through the rule-making process.

Law enforcement activities directed at the spring rainbow trout run will continue to be a high priority for the MNDNR Division of Enforcement. Enforcement officers and MNDNR fisheries staff will monitor rainbow trout angling in the Knife River Marina. If illegal activities are documented or high levels of hooking mortality are observed, we will work with the marina operator to eliminate fishing in the marina. A balanced approach between education and enforcement, with increased cooperation among anglers, should result in better awareness and compliance with rainbow trout regulations.

B. Stocking – Continue the present stocking program implemented in 2003, and include the following proposals:

1) Review the status, and reevaluate the Knife River steelhead stocking program with the Rainbow Trout Advisory Group during the winter of 2007.

2) With the discontinuation of the Chinook salmon program (see chapter 6), consider utilizing the vacant rearing area to: 1) rear approximately 400,000 steelhead produced by brood stock to post-fry size (1-1.5 inches). These fish would be stocked above barriers. Increasing the size of the fry may provide a survival advantage and potentially increase the effectiveness of the fry stocking program above barriers; 2) increase the number of fall Kamloops fingerlings for fly-in stocking to inland trout lakes; and 3) implement other hatchery programs.

3) Create an area along the North Shore that demonstrates what type of production wild fish can maintain without supplemental stocking. Specifically, this would curtail the stocking of steelhead fry into the Brule River. The Brule River has a good run of

wild steelhead, and has been removed from the fry-stocking list. This would create a zone of no steelhead stocking from north of the Cascade River to the Canadian boarder (management zone MN-3). The present Brule River quota will be reassigned among other streams scheduled for stocking in odd-numbered years. Fry stocking quotas are listed in Table 9.1.

4) Redistribute 15,000 Kamloops from the French River quota and 10,000 Kamloops from the Lester River quota to the McQuade Harbor/Talmadge River area. This will spread out the shore fishing pressure for Kamloops and provide anglers with increased opportunities to harvest Kamloops between Duluth and the French River. It should also reduce straying of Kamloops up the shore beyond the French River. Discontinue stocking the Talmadge River with steelhead fry to reduce chances of interbreeding with Kamloops that return to the Talmadge River.

C. Assessment - Continue the assessment program implemented in 2003. Coordinate with the MNDNR, Ecological Services Division to monitor the cormorant population on Knife Island. If appropriate, establish a focus group of citizens interested in steelhead survival, citizens interested in cormorants, and natural resource managers to determine the most acceptable methods to minimize cormorant predation on steelhead in the area around Knife Island. Work with the fisheries construction crew to remove the Little Knife River trap as soon as practical.

V. Justification

Since 1992, the decline in the number of wild steelhead has reversed and although annual variations may be large, catch rates from the spring fisheries in most streams have increased over the low levels of the early 1990s (Figure 9.1) (Ostazeski 2005). Based on the information collected from 1992 – 2004 and discussions with various angling groups, strategies are being implemented to increase the rehabilitation rate of wild steelhead populations in selected areas. In addition, the plan allows for continuation of the Kamloops program in a geographically limited area until wild steelhead populations recover and can provide an acceptable harvest fishery, or until negative genetic impacts of Kamloops on wild steelhead are demonstrated by production of steelhead x Kamloops hybrids in the wild. We will continue to pursue the goal of a wild, self-sustaining steelhead fishery, but recognize the desire by many anglers to take a more active

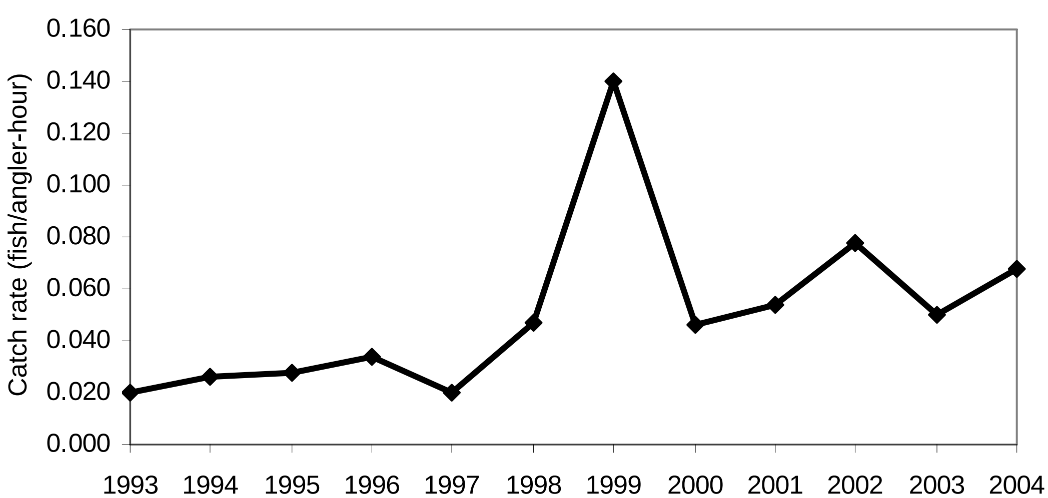

Figure 9.1. Catch rates for unclipped steelhead of legal size (> 16 inches) from spring anadromous creel surveys 1993-2004.

management approach in selected areas to determine if the rate of rehabilitation can be enhanced.

Much of the information gained since 1992 has directed the strategies described in the RTMP and highlighted in the present management section above. These strategies include:

- Continuing to implement restrictive harvest regulations to protect the wild steelhead, while allowing harvest from the hatchery-based Kamloops program.

- Stock steelhead fry above barriers to supplement natural reproduction of steelhead. Information gained from the smolt trap on the French River indicates that smolts produced from stocked fry are 10 times more likely to survive than hatchery-reared yearlings. The creation of a Knife River brood stock should supply a stable source of gametes for fry production. This is an experimental program that will require some modifications to optimize, but has the potential to increase smolt production. One concern with establishing any type of brood stock is domestication that takes place in the hatchery. We will minimize this domestication by annually supplementing the brood stock from wild Knife River emigrants. Also, by stocking only fry, more natural selection will occur in both the stream and lake environments helping to ensure that only the best adapted fish survive to spawn. However, even by implementing these strategies, there is risk that genetic diversity may be reduced through stocking activity.

- Stock yearling steelhead to bolster the Knife River run, as it is the one known major stream where the numbers of adult steelhead have not significantly rebounded. While survival of hatchery-reared yearlings has been disappointing, if a large number of yearlings are stocked in one stream, the number of adults returning to spawn is likely to increase. Wild downstream migrants captured in the Knife River smolt trap suggested that returning adults would increase in 2003 and 2004, as they did, but will decline in 2005 and 2006. The option of not stocking the stream and letting wild steelhead recover without intervention is genetically safer for wild steelhead and may have a higher chance of success, even though it may take longer. Despite being produced from wild Knife River gametes, experimental evidence indicates that stocked yearlings and the adults derived from these yearlings will be less fit (create fewer returning spawners) than the wild steelhead in the Knife River system. A decrease in survival of fry produced by hatchery-reared Knife River steelhead to age-2 smolts was recently documented in a study by research scientists at the University of Minnesota, validating the risks of yearling stocking (Caroffino et al. *in review*). Although the study only investigated survival to one life stage, any reduced fitness could be heritable and retard or significantly decrease the chance for long-term rehabilitation of steelhead in the Knife River. We plan to monitor the long-term consequences of hatchery supplementation at the Knife River by continuing to work with researchers at the University of Minnesota. Reduced fitness of stocked steelhead in other river systems has also been demonstrated (Reisenbichler and McIntyre 1977; Miller 1990). In contrast, recent studies using conservation hatchery techniques similar to those used on the Knife River have found no negative impacts on wild steelhead from stocking hatchery-reared steelhead. Although similar to the Knife River, the studies have not been conducted long enough to be conclusive. Despite the risks described above, many anglers feel there may be an even larger risk in allowing the present population of steelhead to decline further. We will continue to analyze the information collected on this important topic, and apply adaptive management strategies to minimize genetic risk while attempting to increase the number of steelhead spawners in the Knife River system. Discussions with the Rainbow Trout Advisory Group to review the yearling stocking program in the Knife River are scheduled for the winter of 2007.

- Continue the Kamloops stocking program at its present level, while acknowledging that there is a significant reproductive and genetic risk to wild steelhead. The major risk is that Kamloops can spawn and hybridize with wild steelhead, which reduces the effective number of spawning wild steelhead, and increases the potential for hybrids. If hybrids do not survive, or survival is less than wild steelhead (Miller et al 2004), wild steelhead gametes are "wasted." This situation is similar to that used in sterile male programs where reductions in pest organisms is the major goal. There is also a significant risk that surviving hybrids could reproduce and cause genetic introgression, which decreases fitness of the overall steelhead population. Despite this risk, many anglers would like the Kamloops program to continue or expand. Over one-half of the angling pressure in the spring fishery is directed at Kamloops and the catch rates of Kamloops are generally much higher than those of steelhead (Figure 9.2). In addition, winter creel surveys show that fishing pressure for Kamloops surpasses spring fishing pressure for all rainbow trout strains. Presently, Kamloops are the only rainbow trout that can be harvested in Minnesota's portion of Lake Superior. The Kamloops fishery is a relatively low cost hatchery program that provides a fall, winter, and early spring shore fishery for rainbow trout where it otherwise would not exist.

  Many studies on West Coast steelhead and salmon have described the negative consequences that domesticated hatchery fish have on wild fish stocks (Bisson et al. 2002). Based on studies conducted by MNDNR research biologists and university scientists, hybridization between Kamloops and wild steelhead can occur, and if detected in the wild would be detrimental to wild steelhead rehabilitation efforts through dilution of steelhead gametes as described above. Specific studies have shown that:

  - When in close proximity, Kamloops and steelhead will interbreed and produce hybrid juveniles in the wild (Close 1999).
  - Kamloops eggs have higher mortality than steelhead eggs under natural stream conditions (Negus 1999).
  - Steelhead fry are much more wary than Kamloops when startled (Negus 1999).
  - Relative survival of stocked steelhead fry to age -1 in North Shore streams was 5 times greater than survival of Kamloops fry to age -1 (Miller et al. 2004).
  - Juvenile steelhead have a significantly higher survival rate than hybrid juveniles (steelhead-Kamloops cross) under natural stream conditions (Miller et al. 2004).

  In all studies, hybrids had lower survival than steelhead. Hybrids between steelhead and Kamloops performed at an intermediate level, with the maternal steelhead cross having higher survival than the maternal Kamloops cross. Results from the above studies suggest that when steelhead and Kamloops interbreed, the hybrid juveniles do not survive as well as pure steelhead. Steelhead gametes used to produce non-surviving hybrids, which otherwise may have created wild steelhead, are essentially "wasted." In addition, when hybrids are produced there is risk of genetic introgression with the consequences of reduced fitness for the wild steelhead population. No positive benefits to steelhead by hybridizing with Kamloops were found in any of the studies cited above.

  A portion of Dr. Miller's work attempted to identify Kamloops-steelhead hybrids that may already be present in Minnesota streams. Based on the sampling methods and genetic techniques used, he was unable to determine if hybrids existed because the techniques used could not identify a diagnostic marker for Kamloops. We will continue to investigate the influence of Kamloops on the genetics of wild steelhead as new tools and methods are developed.

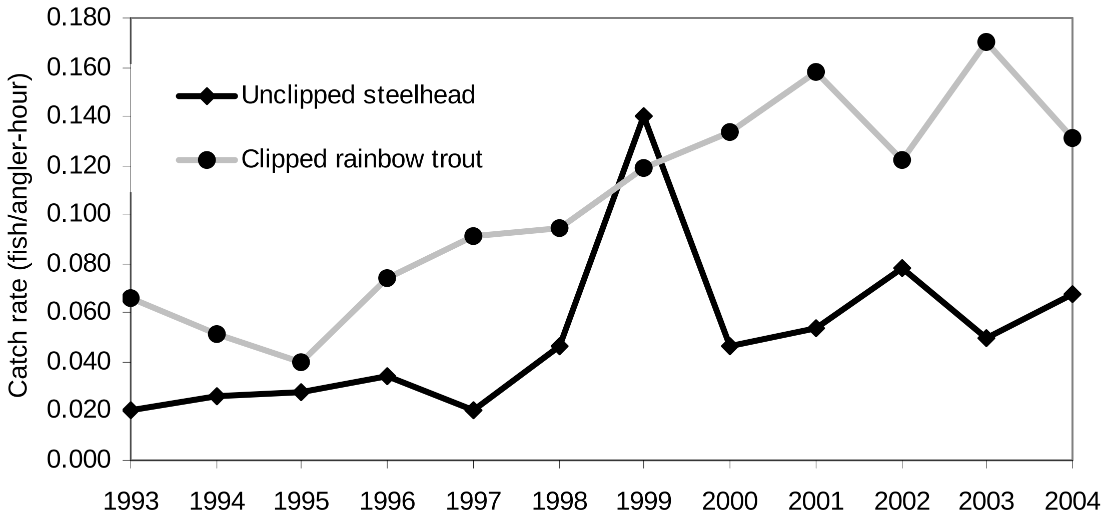

Figure 9.2. Catch rates for steelhead and Kamloops strain rainbow trout of legal size (> 16 inches) from spring anadromous creel surveys 1993-2004.

Lacking proof of introgression or other measurable impacts of Kamloops on steelhead, outside the controlled studies referenced above, we are reluctant to discontinue the program. An alternative to elimination of the entire program is to restrict Kamloops stocking to a limited geographic area and attempt to reduce straying from that area so the hybridization risk is minimized. We have proposed to redistribute some Kamloops from the French and Lester river quotas to be stocked in the McQuade Harbor/Talmadge River area. We anticipate this will spread out the shore fishing pressure for Kamloops, and provide anglers with increased opportunities to harvest Kamloops between Duluth and the French River. It should also reduce straying of Kamloops up the shore beyond the French River. We will also discontinue stocking the Talmadge River with steelhead fry to reduce the potential for interbreeding with Kamloops that return to the Talmadge River. Other fish management agencies on Lake Superior have expressed concern about the genetic consequences of Minnesota's Kamloops program, and support efforts to restrict their use in Lake Superior.

- Work with other agencies and private citizens to protect, enhance, and maintain fish habitat. Continued development in the Lake Superior watershed is changing the habitat in Minnesota tributaries and in the near-shore portion of the lake. Most of these changes have negative effects on fish populations that inhabit these areas. Any effort the angling and environmental community can exert to manage development in order to protect or enhance the long-term health of these fisheries and ecosystems will be critical. Partnering with other agencies on watershed-scale projects will enhance the ability to accomplish this goal. The densities of beaver in riparian areas have increased as forest types have changed in the Lake Superior watershed. Beaver dams block fish passage, eliminating the use of large stream sections for spawning and nursery areas by migratory fish.

Based on information gathered to date, we feel the strategies implemented in the RTMP provide a reasonable approach for the protection and rehabilitation of wild steelhead stocks on Minnesota's North Shore, while at the same time, addressing the diversity of angler concerns. As mentioned throughout this chapter, this approach is not without risk. Our management is oriented toward the long-term benefits for wild, self-sustaining steelhead populations. Although we have incorporated a hatchery component into the rainbow trout management program, a large hatchery-based effort is not proposed, as it increases risks to wild steelhead stocks that still remain along the North Shore (Krueger et al. 1994; Caroffino et al. *in review*). Adaptive management will continue to be used to adjust management strategies as new information becomes available. However, it must be recognized that results from some strategies will not be known for some time because steelhead can live up to nine years. Anglers must be patient if valid results are to be obtained. Undoubtedly, there will be changes throughout the life of the plan as fish populations respond to management actions, environmental changes, or other influences. Future modification of the plan will be initiated based on scientific information and will occur with input from interested citizens.

VI. Information Needs

Genetics related

- Examine both the short-term and long-term influence from stocking hatchery-reared yearlings and fry derived from hatchery-reared adults on wild Knife River steelhead.

- Continue to search for diagnostic genetic markers that will identify Kamloops, and investigate the influence of Kamloops on the genetic composition of naturalized steelhead populations.

- Explore methods to reduce Kamloops straying and minimize potential for interbreeding with wild steelhead populations (ex. sterilization, stocking location, increased harvest, run timing, etc).

- Experiment with cryopreservation of steelhead sperm to maximize effective population size for production of steelhead gametes and minimize mortality of adult males by decreasing the time they spend in the hatchery.

- Experiment with Kamloops to determine the best method(s) to eliminate or minimize passage through the Knife River trap, and determine the potential for upstream movement under a variety of stream conditions when the fish-way and video camera are being used.

- Investigate potential to modify timing of Kamloops egg take in an attempt to reduce interbreeding with wild steelhead.

Assessment

- Continue with trap operations to determine adult-smolt and smolt-adult relationships.

- Determine return rates for stocked yearlings.

- Evaluate efficacy of stocking fry derived from hatchery-reared adults versus the natural reproduction of passed hatchery-reared adults in the Knife River system.

- Continue to document characteristics of the fisheries through regular creel surveys.

- Experiment with fish passage and camera operations at the Knife River Trap to determine most effective monitoring methods.

- When adult steelhead harvest resumes, monitor extensively to determine how the fish population and angling pressure responds to the expectation of increased exploitation.

- Investigate the impact of catch-and-release fishing on rainbow trout during the spawning run.

Community interactions

- Investigate steelhead interactions with Kamloops, other predators, and forage species in both Lake Superior and its tributary streams.

- Examine the effects of environmental variables on rainbow trout populations.

- Determine physical habitat preference of rainbow trout in Lake Superior.

- Utilize bioenergetics modeling techniques to estimate carrying capacity of rainbow trout juveniles in North Shore streams and their potential impact on native species.

- Investigate interactions between stocked steelhead and resident brook trout populations.

- Investigate displacement of wild steelhead by hatchery-reared steelhead (all life stages).

References

Bisson, P. A. and eleven other authors. 2002. Hatchery surpluses in the Pacific Northwest. Fisheries 27(12):16-27.

Caroffino, D. C., L. M. Miller, A. R. Kapuscinski, and J. J. Ostazeski. *In review*. One year of parental hatchery experience reduces success of steelhead fry stocked into their naturalized environment. Canadian Journal of Fisheries and Aquatic Sciences.

Close, T. L. 1999. Spawning interactions of hatchery and naturalized anadromous form rainbow trout *Oncorhynchus mykiss* in a Lake Superior tributary. Minnesota Department of Natural Resources, Section of Fisheries Investigational Report 473, St. Paul.

Close, T. L., and R. Hassinger. 1981. Evaluation of Madison, Donaldson and Kamloops strains of rainbow trout *Salmo gairdneri* in Lake Superior. Minnesota Department of Natural Resources, Section of Fisheries Investigational Report 372, St. Paul.

Fish Pro. 1993. Knife River fish trap feasibility study. Report to the Minnesota Department of Natural Resources, St. Paul.

Hassinger, R. L., J. G. Hale, and D. E. Woods. 1974. Steelhead of the Minnesota North Shore. Minnesota Department of Natural Resources, Section of Fisheries Technical Bulletin 11, St. Paul.

Krueger, C. C., D. L. Perkins, R. J. Everett, D. R. Schreiner, and B. May. 1994. Genetic variation in naturalized rainbow trout (*Oncorhynchus mykiss*) from Minnesota tributaries to Lake Superior. Journal of Great Lakes Research 20:299-316.

Miller, L., T. Close, and A. R. Kapuscinski. 2004. Lower fitness of hatchery and hybrid rainbow trout compared to naturalized populations in Lake Superior tributaries. Molecular Ecology. 13:3379-3388.

Miller, W. H. 1990. Analysis of salmon and steelhead supplementation. Bonneville Power Administration, Division of Fish and Wildlife, Project 88-100, Portland, Oregon.

Morse, S. D. 2000. North Shore index station assessment, 1992-1999. Minnesota Department of Natural Resources, Lake Superior Area Report, St. Paul.

Negus, M. T. 1999. Survival traits of naturalized, hatchery and hybrid strains of anadromous rainbow trout during egg and fry stages. North American Journal of Fisheries Management 19:930-941.

Ostazeski, J. J. 2005. Spring anadromous creel survey, 2004. Minnesota Department of Natural Resources, Project F-29-R(P)-24, Study 4, Job 691, Completion Report, St. Paul.

Ostazeski, J. J., and S. D. Morse. 2002. Spring anadromous creel survey, 2001. Minnesota Department of Natural Resources, Project F-29-R(P)-21, Study 4, Job 569, Completion Report, St. Paul.

Reisenbichler, R. R., and J. D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, *Salmo gairdneri*. Journal of Fisheries Research Board of Canada. 34:123-128.

Schreiner, D. R., editor. 1992. North Shore steelhead plan. Minnesota Department of Natural Resources, St. Paul.

Schreiner, D. R., editor. 1995. Fisheries management plan for the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Section of Fisheries Special Publication 149, St. Paul.

Schreiner, D. R., editor. 2003. Rainbow trout management plan for the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Section of Fisheries Special Publication No. 157, St. Paul.

Tureson, F. 1994. Culture activities report: Knife River steelhead rearing program. Minnesota Department of Natural Resources, Section of Fisheries Report, St. Paul.

CHAPTER 10: BROOK TROUT

I. History

Brook trout are the only native anadromous salmonines in Lake Superior. Brook trout that spend part of their life in Lake Superior are referred to as coasters (Becker 1983). Coaster brook trout were once widely distributed among Lake Superior tributaries below the natural barriers (Newman and Dubois 1996; Waters 1987). Smith and Moyle (1944) give early accounts of the popular coaster brook trout fishery. By the 1880s, coaster stocks had been reduced by overfishing and habitat degradation (Horns et al. 2003). Settlement and transportation on the North Shore exerted continued fishing pressure on remnant stocks. Very few anecdotal reports of coaster brook trout in Minnesota waters exist (Newman and Dubois 1996).

Previous management efforts to rehabilitate the coaster fishery in Minnesota have involved stocking of different strains and sizes of brook trout. Stocking records before 1970 are incomplete, although it is known that many hatchery-reared brook trout were stocked mostly in lakes and streams above barriers to provide inland fishing opportunities for brook trout. Since 1970, domestic brook trout were stocked in Lake Superior harbors and bays in attempt to create put-grow-take fisheries. Results were mostly limited to returns within the first month of stocking, and the programs were deemed unsuccessful (Halpern 1995). In the mid-1980s, a three-year experimental stocking program of Nipigon strain brook trout in the French River yielded just seven returns. Since 1987, there has been no stocking program to establish coaster brook trout by the MNDNR in the Minnesota waters of Lake Superior. The Grand Portage Band of Chippewa, assisted by the U.S. Fish and Wildlife Service, has stocked three reservation area streams with eyed eggs and/or fry from Nipigon strain brook trout from 1992 through 2002, with stocking gaps in 1997 and 2001 to allow assessment of natural reproduction (Grand Portage Band of Lake Superior Chippewa 2005). There is evidence of at least some adults returning to spawn, and natural reproduction occurring in stocked streams (Newman 2000).

The *Fish Community Objectives for Lake Superior* (Horns et al 2003) supports brook trout rehabilitation. A resurgence of interest in coaster brook trout has lead to the development of a brook trout rehabilitation plan for Lake Superior supported by the Great Lakes Fishery Commission (Newman et al. 2003). Recent research has focused on filling information needs identified the plan. Genetic investigations support the idea that coaster brook trout are ecological variants of resident stream brook trout that migrate to Lake Superior and return to tributaries or nearshore areas to spawn, and are genetically indistinct from stream resident populations (D'Amelio 2002, Burnham-Curtis 1996, 2000). Ground water is known to be important in spawning site selection for brook trout (Curry and Noakes 1995). A regional assessment of ground water resources on Minnesota's North Shore and tributaries found only two ground water locations, indicating that ground water is a limiting factor in brook trout rehabilitation in Minnesota (Ostazeski and Schreiner 2004).

Brook trout are highly susceptible to angling pressure, and overfishing is one of the primary causes cited for the decline of coaster brook trout (Newman et al. 2003). To protect and potentially enhance coaster brook trout production in Minnesota, restrictive regulations below the posted boundaries were implemented in 1997. They included a closed season from the day after Labor Day until the inland trout opener in mid-April, a 20-inch minimum length limit, and a possession limit of one fish. Agencies basin-wide have similar restrictive regulations in place. Surveys conducted in 1997 and 2002 to assess the impact of the regulations detected no significant shorewide changes (Figure 9.1) (Prankus and Ostazeski 2003), but there have been anecdotal reports of more large brook trout caught since the surveys were conducted.

Environmental degradation and changes in the fish community have occurred in the Lake Superior basin since brook trout stocks were abundant. The original logging of the basin increased water temperatures and the range of flows, removed instream cover, and increased sedimentation. Introductions and naturalization of non-native species since the early 1900s as well as dramatic changes in the Lake Superior fish community may have also have had adverse effects on brook trout. There may also have been a loss of local adaptation and genetic diversity where brook trout have been extirpated.

Loss of genetic diversity, habitat degradation, and changes in the Lake Superior fish community are all obstacles to the successful rehabilitation of brook trout. Management agencies on Lake Superior, are working to protect remaining brook trout stocks in Lake Superior and gather information to address problems facing brook trout rehabilitation. The Coaster Brook Trout Scientific Synthesis Meeting held in October 2003 at the University of Minnesota Cloquet Forestry Center compiled existing information, identified information needs, and helped form a common understanding of how coaster brook trout rehabilitation may proceed in Lake Superior (Schreiner et al. 2004). Successful rehabilitation will be a long-term process that may take decades depending on habitat, the status of remnant stocks, and interactions with other species. If establishing original forest and stream conditions is required, it may take generations for coaster brook trout rehabilitation to occur. Continued cooperation of agencies, stakeholders, and researchers must occur. Agencies realize that coaster brook trout rehabilitation will require the maintenance of restrictive regulations, and may require limiting fishing opportunity for other species. Coaster brook trout are unlikely to support a harvest fishery and expectations need to focus on "existence" value. Biologists agreed that the presence of remnant stocks, suitable habitat, and appropriate strain all need to be addressed before stocking programs are implemented. Furthermore, any stocking that is conducted should be done in an adaptive management context with well-framed plans for evaluation and criteria for success (Schreiner et al. *in review*).

II. Goals and Objectives

Goal: Protect and maintain self-sustaining coaster brook trout stocks in the Minnesota waters of Lake Superior in original locations where practical.

Objectives:

1. Identify and protect remnant coaster brook trout populations, and prioritize suitable streams for rehabilitation projects.

2. Protect and rehabilitate essential in-stream habitat through watershed management, focusing on high priority streams for coaster brook trout rehabilitation.

3. Support research directed at answering questions on basic brook trout biology.

4. Coordinate with other agencies on coaster brook trout management, and apply successful techniques.

5. Work cooperatively with the Grand Portage Band of Chippewa to monitor the results of the various coaster brook trout stocking strategies being implemented by the Band.

III. Present Management

A. Regulations – The season is open from the Saturday nearest April 15 through Labor Day in Lake Superior and tributaries below the posted barriers. The limit is one with a minimum size of 20 inches. This may be in combination with brown trout and rainbow trout for an aggregated limit of five. Above the posted boundaries, the season is from the Saturday nearest April 15 through September 30. Above the posted boundaries, with the exception of the St. Louis River and its tributaries, the bag limit is 10 brook trout with only one over 16 inches.

B. Stocking - No stocking (below barriers) to enhance coaster brook trout has been done in Minnesota since 1987.

C. Assessment - Brook trout are assessed in Minnesota through creel surveys, returns to the French and Knife river traps, and through special fall electrofishing surveys. The spring creel survey estimates an average catch of 369 brook trout from 1995 through 2004. Very few brook trout are caught in the Lake Superior summer creel survey. Fall spawning assessments specifically targeting below barrier populations of brook trout using electrofishing were conducted in 1997 and 2002 to assess effects of the regulation changes. Very few brook trout greater than 12 inches were caught in these surveys (Figure10.1). A regional groundwater survey using remote thermal infrared imaging occurred in 2003 and 2004, and found limited ground water accessible to migratory brook trout in tributaries or the Lake Superior shoreline in Minnesota. A stream crossing survey to assess and prioritize impediments affecting fall-run anadromous fish was completed in 2004 (Figure10.2).

IV. Proposed Management

A. Regulations - Maintain present regulations for below boundary areas of Lake Superior tributaries. Consider use of seasonal sanctuaries in selected locations where protection of spawning populations is necessary. Continue enforcement of regulations to ensure compliance. Recommend regulations for tributaries above posted boundaries change to conform with the statewide bag limit of 5, with only one over 16 inches (Appendix 5.1). The aggregate limit with brown trout will be five for above boundary tributaries.

B. Stocking – No stocking is recommended at this time. Coordinate with agencies conducting stocking experiments, and closely monitor results of the stocking experiments by the Grand Portage Band of Chippewa. Stocking above barriers should be done such that genetic integrity of below barrier populations is maintained.

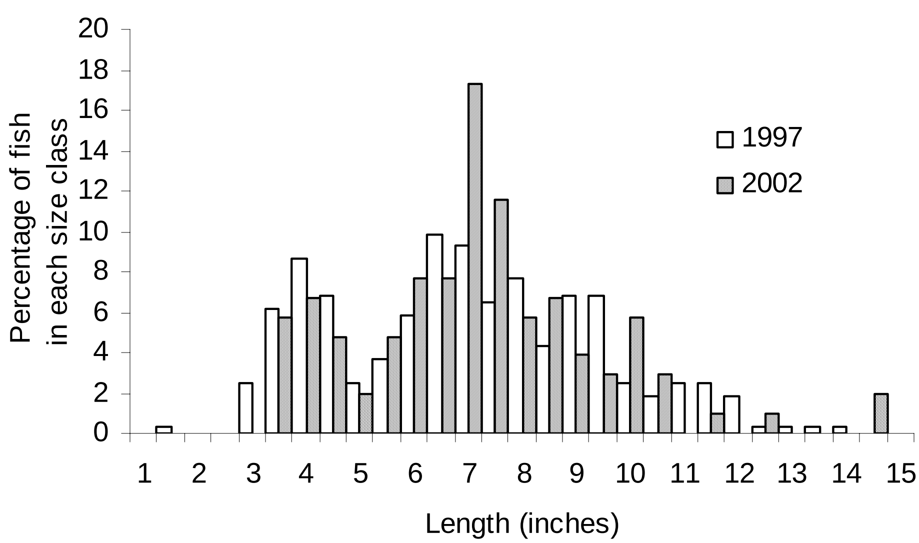

Figure 10.1. Length frequencies of brook trout sampled in fall electrofishing surveys below barriers in 1997 and 2002.

Figure 10.2. Perched culvert at the Devil Track River Highway 61 road crossing.

C. Assessment – Continue spring and summer creel surveys. Monitor the French and Knife river traps to determine the number of adults entering and juveniles leaving these two rivers. Conduct a fall survey to assess spawning brook trout every five years to determine impact of restrictive regulations. Gather tissue samples from creel surveys and special assessments for comparison to the developing basin-wide genetic database. Perform habitat surveys in streams that have potential for brook trout reproduction. In streams that lack groundwater, investigate the feasibility of creating artificial upwellings and determine their use by spawning brook trout.

V. Justification

Presently, restrictive regulations are in place basin-wide and are designed to protect spawning-size coaster brook trout. The full effect of these regulations may not be known for some time as compliance and awareness increase, and brook trout recruit to protected sized classes. The strategy that carries the least genetic risk allows rehabilitation to occur without stocking. This will require time for remnant stocks to build and/or recolonization to occur. Stocking on top of a native population carries risks to the genetic integrity of the population (Utter and Epifino 2002). Since 2002, anecdotal reports from anglers indicate that there may be increasing numbers of large brook trout using North Shore streams. Reducing the bag limit and aggregate limit for brook trout above posted boundaries will simplify regulations, and may increase emigration, potentially enhancing coaster brook trout populations.

Several agencies are engaging in experimental stocking programs that may provide information on limiting factors for brook trout in their jurisdictions that may be applicable to North Shore tributaries (Schreiner et al. *in review*). However, there is potential for brook trout stocked in neighboring jurisdictions to emigrate and negatively compromise the genetic integrity of remnant coaster brook trout populations through a variety of genetic means (Utter 2003). Close coordination with agencies conducting stocking experiments is needed as stocking is implemented and as results become available. Given the likelihood of remnant coaster brook trout populations using Minnesota tributaries stocking is not recommended at this time.

Assessment of spawning brook trout populations should continue every five years to assess the impact of restrictive regulations and to determine the impact of experimental stocking by other agencies on populations of coaster brook in Minnesota. More detailed habitat assessment in streams that have the greatest potential for brook trout reproduction should be undertaken so that the most suitable streams can be identified. Because groundwater is known to be a critical habitat requirement for brook trout spawning, attempts to locate areas of groundwater intrusion below barriers should continue. If populations are to be self-sustaining, proper habitat must be present and it must be protected. Projects restoring and protecting watersheds should be supported. Improvements to road crossings that impede fish passage should be made as funds becomes available (Ostazeski 2004).

VI. Information Needs/Community Interactions

Researchers and agency managers identified six key areas of focus for future research (Schreiner et al. 2004). Continued assessment of genetic structure of populations lake-wide is necessary. This can be accomplished through increased biological surveys. Information on how groundwater influences coaster brook trout distribution and abundance, and greater understanding of how land-use practices affect hydrology should assist restoration efforts. Use of lake habitat by coaster brook trout including the extent of shoal spawning is largely unknown. In Minnesota, streams that have the best potential for coaster brook trout restoration must also have adequate shoreline (lake) habitat to support young coasters as they leave the stream. Although not ideal, streams and lake habitat in the area of the Split Rock River and Grand Portage Bay may provide the greatest potential for coaster restoration in Minnesota. Experimental projects to evaluate the potential for restoration in these areas should be conducted before any large scale programs are implemented. Despite restrictive regulations, the extent that angler induced mortality limits coaster brook trout recovery should be examined. Few published studies exist on the interactions of coaster brook trout and other naturalized salmonines in Lake Superior. Research on biotic interactions with coho salmon and rainbow trout in streams and nearshore areas is needed.

References

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison.

Burnham-Curtis, M. K. 1996. Mitochondrial DNA variation among Lake Superior brook trout populations: summary of genetic analyses. U.S. Fish and Wildlife Service, Ashland Fisheries Resource Office, Completion Report, Ashland, Wisconsin.

Burnham-Curtis, M. .K. 2000. Genetic profiles of selected brook trout *Salvelinus fontinalis* populations from Lake Superior. Research completion report prepared for U.S. Department of the Interior, Fish and Wildlife Service, Ashland Fisheries Resource Office, Ashland, Wisconsin.

Curry, R. A., and D. L. G. Noakes. 1995. Groundwater and the selection of spawning sites by brook trout (*Salvelinus fontinalis*). Canadian Journal of Fisheries and Aquatic Sciences 52:1733-1740.

D'Amelio, S. 2002. Conservation genetics and metapopulation structure of brook trout (*Salvelinus fontinalis*) in Nipigon Bay (Lake Superior, Ontario). MS Thesis. Trent University, Peterborough, Ontario.

Grand Portage Band of Lake Superior Chippewa. 2005. A coaster brook trout rehabilitation plan for the Grand Portage Reservation, 2005 - 2015. Grand Portage, Minnesota.

Halpern, T. 1995. Brook trout in the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources, Lake Superior Area Report, St. Paul.

Horns, W. H., C. R. Bronte, T. R. Busiahn, M. P. Ebener, R. L. Eshenroder, T. Gorenflo, N. Kmiecik, W. Mattes, J. W. Peck, M. Petzold, and D. R. Schreiner. 2003. Fish community objectives for Lake Superior. Great Lakes Fishery Commission, Special Publication 03-01, Ann Arbor, Michigan.

Newman, L. E. 2000. The Grand Portage Project, a successful model for the reintroduction of Lake Superior coaster brook trout populations. Proceedings of the Wild Trout VII Symposium, Yellowstone National Park, U.S. National Park Service, Washington D.C.

Newman, L. E., and R. B. DuBois, editors. 1997. Status of brook trout in Lake Superior. Brook Trout Subcommittee, Lake Superior Technical Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

Newman, L. E., R. B. Dubois, T. N. Halpern, editors. 2003. A brook trout rehabilitation plan for Lake Superior. Great Lakes Fishery Commission, Miscellaneous Publication 2003-03. Ann Arbor, Michigan.

Ostazeski, J. J. 2004. Road crossing survey of Minnesota's north shore tributaries to Lake Superior for fish passage. Minnesota Department of Natural Resources, Lake Superior Area Completion Report, St. Paul.

Ostazeski, J. J., and D. S. Schreiner. 2004. Identification of ground water intrusion areas on the Lake Superior shoreline and selected tributaries in Minnesota. Minnesota Department of Natural Resources, Lake Superior Area Completion Report, St. Paul.

Pranckus, M. T., and J. J. Ostazeski. 2003. Coaster brook trout status in Minnesota-Lake Superior tributaries following regulation changes. Minnesota Department of Natural Resources, Lake Superior Area Completion Report, St. Paul.

Schreiner, D. R., K. Cullis, and J. Schuldt. 2004. Lake Superior coaster brook trout initiative. Great Lakes Fishery Commission, Project Completion Report, Ann Arbor, Michigan.

Schreiner, D. R., K. I. Cullis, M. C. Donofrio, G. J. Fisher, L. Hewitt, K. G. Mumford, D. M. Pratt, H. Quinlan, and S. J. Scott. *In review*. Management perspectives on coaster brook trout rehabilitation in the Lake Superior Basin. North American Journal of Fisheries Management.

Smith, L. L., Jr., and J. B. Moyle. 1944. A biological survey and fishery management plan for the streams of the Lake Superior north shore watershed. Minnesota Department of Conservation, Technical Bulletin 1, St. Paul.

Utter, F. 2003. Genetic impacts of fish introductions. Pages 357 – 378 *in* E. M. Hallerman, editor. Population genetics: principles and applications for fisheries scientists. American Fisheries Society, Bethesda, MD.

Utter, F., and J. Epifanio, 2002. Marine aquaculture: genetic potentialities and pitfalls. Reviews in Fish Biology and Fisheries 12:59 - 77.

Waters, T. F. 1987. The Superior North Shore. University of Minnesota Press. Minneapolis.

CHAPTER 11: BROWN TROUT

I. History

Since introduction into Lake Superior into the 1890s, brown trout have established naturalized anadromous populations in tributaries primarily in Wisconsin. The Brule River in Wisconsin supports the largest known run of brown trout in Lake Superior (Bronte et al. 2003). In Minnesota, attempts to establish anadromous populations in a number of streams met with limited success. Brown trout are rarely caught in tributary streams below the barrier, and are only occasionally caught during the summer boat fishery, as reported from summer creel surveys. Clerks observed an average of less than two brown trout from 1995 to 2004 in the summer creel. Annual returns to the Knife River trap from 1996 to 2004 have averaged 43 brown trout, while annual returns to the French River trap averaged less than 2 brown trout from 1995 to 2004.

Experimental stockings of 63,000 yearling and 170,000 fingerling brown trout in the St. Louis River from 1985 to 1987 were not successful in significantly increasing the catch in the summer boat fishery from 1988 to 1992. Fish caught in Minnesota are the result of limited natural reproduction below the barriers, fish migrating to the lake from above the first barrier, and fish originating from other states. Habitat for brown trout along Minnesota's shoreline and tributaries below the first barrier is marginal, as it is for other fall spawning anadromous species.

II. Goals and Objectives

Goal: Maintain the opportunity to harvest naturalized brown trout that originate from tributaries in Minnesota and other states.

Objective:

1. Allow angler harvest of brown trout in Lake Superior and tributary streams with minimal management activities.

III. Present Management

A. Regulations - There is no closed season in Lake Superior and in tributaries below posted boundaries. The bag limit is 5 in combination with rainbow trout, brook trout, and splake with a minimum size of 10 in, with not more than one over 16 inches. Above posted boundaries the aggregate limit is 10.

B. Stocking - Brown trout have not been stocked since 1987.

C. Assessment – Conduct annual summer creel surveys on Lake Superior. Monitor adult and juvenile catches at the French and Knife river traps.

IV. Proposed Management

A. Regulations – Maintain present regulations except for changing the aggregate limit to five above the posted boundary to conform with statewide regulations (Appendix 5.1).

B. Stocking - No stocking below barriers. For stocking above barriers refer to MNDNR fisheries stream management plans.

C. Assessment - Continue with present assessment program.

V. Justification

North Shore streams are relatively unproductive and can support only a limited number of anadromous salmonines (Waters et al. 1990). When the carrying capacity of the stream is exceeded, juveniles tend to leave the stream early or die. If they are forced to leave early, at a small size, they suffer high mortality and few fish return as adults. There is some evidence that brown trout in streams may prey on steelhead fry and displace brook trout stocks (DeWald and Wilzbach 1992). If the priority for anadromous trout in Minnesota is steelhead, then brown trout should not be stocked. Brown trout have also been shown to negatively impact brook trout (Fausch and White 1981; Sorensen et al. 1995). Therefore, attempting to augment anadromous brown trout populations in Minnesota tributaries may not support the goal of restoring coaster brook trout.

VI. Information Needs/Community Interactions

Interactions between brown trout and other anadromous species in Lake Superior and tributary streams need to be determined.

References

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970–2000. Canadian Journal of Fisheries and Aquatic Sciences 60:1552-1574.

DeWald, L., and M. A. Wilzbach. 1992. Interactions between native brook trout and hatchery brown trout: effects of habitat use, feeding and growth. Transactions of the American Fisheries Society 121:287-296.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Sciences 38:1220-1227.

Sorensen, P. W., J. R. Cardwell, T. Essington, and D. E. Weigel. 1995. Reproductive interactions between sympatric brook and brown trout in a small Minnesota stream. Canadian Journal of Fisheries and Aquatic Sciences 52:1958-1965.

Waters, T. F., M. T. Doherty, and C. C. Krueger. 1990. Annual production and production: biomass ratios for three species of stream trout in Lake Superior tributaries. Transactions of the American Fisheries Society 119:470-474.

CHAPTER 12: WALLEYE

I. History

Two walleye populations are present in the Minnesota waters of Lake Superior. Most originate from the St. Louis River population, while a much smaller population is present in the Pigeon River. The St. Louis River estuary forms the border between Wisconsin and Minnesota, and management objectives and regulations are the same for both states. The Pigeon River forms the border between Ontario and Minnesota and is located within the Grand Portage Indian Reservation.

The St. Louis River strain of walleye is anadromous, spending most of its adult life in western Lake Superior while utilizing the St. Louis River estuary for spawning and growth during the juvenile life stage (Schram et al. 1992). The St. Louis River estuary is the area of the St. Louis River from the Fond du Lac dam to the Duluth and Superior harbor entries. Angler exploitation of walleye in the estuary increased after the Western Lake Superior Sanitary District began operation in 1978. Improved water quality increased the residency time of adult walleye in the estuary, and improved angler attitudes towards harvesting more of this resource. The St. Louis River walleye population is considered rehabilitated, and provides a high quality fishery in an urban setting.

The Pigeon River population is considered in need of rehabilitation, and the Grand Portage Band is working on strategies to address specific population and habitat needs (Hoff 2003). This population was probably never very large, and the rehabilitation target has been set at 1,000 spawners (Hoff 2003).

The status of walleye in the St Louis estuary has been assessed in 20 out of 25 years between 1980 and 2004. Gill net catch rates have remained relatively constant between 3.0 and 8.0 per lift since 1980 (Figure 12.1). Walleye captured in the spring spawning run are significantly larger than those captured in the summer gill net assessment. This size difference is due to immature fish not being part of the spawning population, and the movement of larger walleye into Lake Superior during the summer. Growth rates for St. Louis River strain walleye are relatively slow because of the time spent in the cold water of Lake Superior. Slow growth makes this population more vulnerable to overharvest when compared to many inland walleye populations.

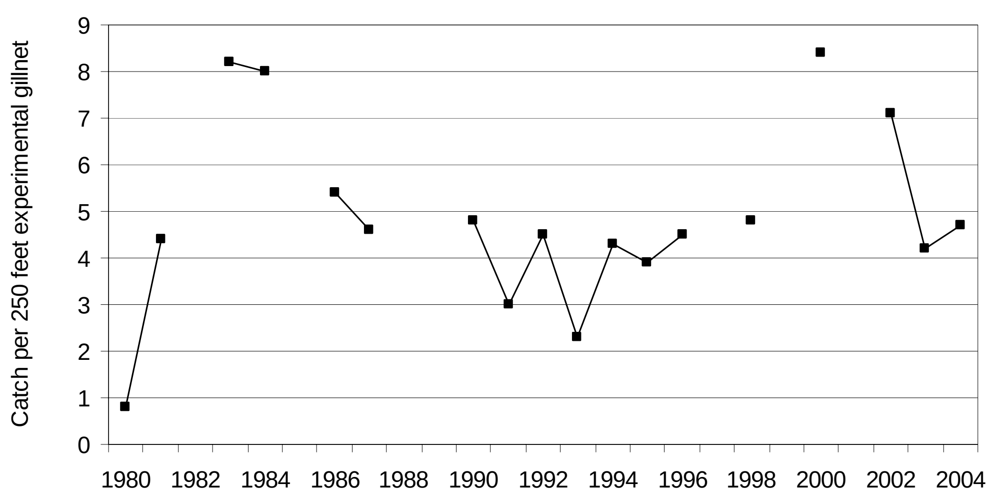

Figure 12.1. Gill net catch rates for walleye in the St. Louis River estuary from 1980-2004.

Creel surveys were conducted on the estuary intermittently from 1980 - 2003, and in 2003 indicated an approximate doubling of angler effort when compared to previous surveys (Table 12.1). Lake Superior creel surveys indicate that few walleye are harvested in the Minnesota waters of Lake Superior. Results from the 1989 and 2003 creel surveys in the estuary indicated two of the highest walleye catch rates in the state (Beard and Spurrier 1990; Lindgren 2004).

Introduction of invasive species such as ruffe, goby, and zebra mussel has complicated walleye management in the St. Louis River estuary. Initially, there was concern that ruffe would displace yellow perch - a major prey item of walleye. To date, there is no evidence that ruffe have negatively impacted walleye populations in the estuary.

II. Goal and Objectives

Goal: Maintain, enhance, and rehabilitate walleye populations that spawn in the St. Louis River estuary and Pigeon Rivers.

Objectives:

1. Manage walleye populations in cooperation with the Wisconsin Department of Natural Resources, Ontario Ministry of Natural Resources, and Grand Portage Band of Ojibwe since both populations are a shared resource.
2. Maintain high catch rate and quality size structure of St. Louis River walleye through harvest regulations.
3. Monitor walleye population dynamics through assessments in the St. Louis River estuary.
4. Protect walleye spawning and nursery habitat below the Fond du Lac Dam.
5. Coordinate management and rehabilitation of the Pigeon River walleye population with the Grand Portage Band and OMNR.

III. Present Management

A. Regulations - Walleye regulations in Minnesota are consistent between Lake Superior and the St. Louis estuary. The walleye season runs from the second Saturday in May to March 1st with a possession limit of 2 and a 15-in minimum harvest length. A fish sanctuary (no fishing allowed) is maintained from the Minnesota-Wisconsin boundary cable to the Fond du Lac Dam. Also, angling is prohibited between the Highway 23 bridge and the Minnesota-Wisconsin boundary cable from March 1st through May 18th. The Pigeon River walleye regulations are different from those in Minnesota’s portion of Lake Superior. In the Pigeon River, the season runs from the second Saturday in May to mid-April (check annual MN fishing regulations) with a possession limit of six and no size restrictions.

Table 12.1. Estimates of walleye fishing pressure, harvest, harvest rates, and catch rates from St. Louis River estuary in 1980, 1981, 1982, 1989, and 2003.

Year	Pressure (angler hours)	Harvest	Harvest rate (fish/angler hours)	Catch rate (fish/angler hours)
1980	179,745	45,718	0.254	*
1981	149,900	24,141	0.161	*
1982	134,829	23,816	0.177	*
1989	111,276	17,833	0.161	0.414
2003	295,621	42,876	0.145	0.410

* Released fish were not included in the 1980, 1981, and 1982 creel surveys.

B. Stocking - The St. Louis River estuary is used as a walleye egg source for stocked lakes within the St. Louis River watershed. The MNDNR has a policy to return 10% of the fry from 10% of collected eggs back into the waters from which they were taken. For the St Louis estuary, this averages approximately 3 million fry per year. The Pigeon River has been stocked with walleye fry by the Grand Portage Band.

C. Assessment - Population dynamics of walleye in the estuary during the summer are monitored annually by MNDNR using gill nets. The spawning population is monitored each spring during egg-taking operations just below the Fond du Lac Dam. Angler harvest has been monitored with creel surveys with the last one was conducted in 2003. Shallow areas within the estuary are critical to the survival and growth of juvenile walleye. Relative abundance of juvenile walleye is monitored annually by WIDNR in these shallow areas by seining. In the Pigeon River, the Grand Portage Band conducts annual assessments for walleye.

IV. Proposed Management

A. Regulations - The regulations for the Pigeon River are more liberal than in Lake Superior. There is potential that the Grand Portage Band may implement more conservative regulations for Pigeon River walleye in the future, and we would support this action.

B. Stocking - Continue stocking 10% of St. Louis River strain walleye fry back into the estuary. Do not increase walleye stocking as a means to control the ruffe population. This technique was not successful during experimental stocking conducted from 1989-1993. The Grand Portage Band has proposed stocking 8,000 fingerlings of the Pigeon River strain as discussed in the walleye rehabilitation plan for Lake Superior (Hoff 2003).

C. Assessment - Continue annual summer gill net assessments through 2006 in the estuary. Beginning in 2008 conduct assessments only in even years, with a full population assessment scheduled every 10 years. Conduct a creel survey to quantify angler pressure and harvest once every three years, if funding is available. During the creel survey, determine angler attitudes towards walleye management strategies in the estuary.

V. Justification

The St. Louis River estuary and Lake Superior walleye fishery provide an opportunity for both Minnesota and Wisconsin residents to catch trophy walleye in an urban area. The anadromous behavior and slow growth rates of walleye in the estuary, coupled with the potential for high fishing pressure, make the population vulnerable to overexploitation by anglers. A decrease in walleye size structure as a result of overexploitation would take many years to reverse. Conservative regulations on both the lake and river are justified to protect the quality of this important fishery. In the 2003 creel survey, 79% of Minnesota anglers and 68% of Wisconsin anglers expressed support for the current harvest regulations. Spawning and nursery habitat is critical for successful walleye reproduction in the estuary. Protection and enhancement of shallow water nursery areas within the estuary, and continuation of clean-up efforts by agencies working on the St. Louis River Remedial Action Plan (RAP) should continue. Clean-up efforts should focus on the toxic substances found in the sediment.

VI. Information Needs/Community Interaction

More detailed information on walleye management in the St. Louis River estuary can be obtained in the *Lake Management Plan for St. Louis Bay* (MNDNR Duluth Area Fisheries 2003). The influence that angler harvest has on the size structure of walleye in the estuary needs to be examined as fishing pressure and harvest has increased significantly since 1989. The relationship between ruffe and walleye in the estuary should continue to be evaluated. Rehabilitation strategies implemented in the Pigeon River by the Grand Portage Band should be monitored and shared with the other management agencies on Lake Superior.

References

Beard, T. D., and J. R. Spurrier. 1990. Completion report - St. Louis River creel recreational survey 1989. Minnesota Department of Natural Resources, Project F-29-R(P), St. Paul.

Hoff, M. H., editor. 2003. A rehabilitation plan for walleye populations and habitats in Lake Superior. Great Lakes Fishery Commission, Miscellaneous Publication 2003-1, Ann Arbor, Michigan.

Lindgren, J. P. 2004. A stratified random roving creel survey of the winter fishery on the St. Louis River Estuary, St. Louis County, Minnesota; A stratified random access based creel survey of the open water fishery on the St. Louis River Estuary, St. Louis County, Minnesota. Minnesota Department of Natural Resources, Project F-29-R (P)-23, Study 4, Job652, Completion Report, St. Paul.

MNDNR, Duluth Area Fisheries. 2003. St. Louis Bay Lake Management Plan. Minnesota Department of Natural Resources, St. Paul.

Schram, S. T., T. L. Margenau, and W. H. Blust. 1992. Population biology and management of the walleye in western Lake Superior. Wisconsin Department of Natural Resources, Technical Bulletin 177, Madison.

CHAPTER 13: LAKE STURGEON

I. History

The lake sturgeon is native to the Minnesota waters of Lake Superior. It is Minnesota's largest and most long-lived fish. Historical records indicate sturgeon can exceed 300 lb and 100 years of age. Sturgeon do not reach spawning age until they are 15-25 years old, and may not spawn every year. Because of their longevity, slow growth, and late age of maturity, they are vulnerable to overharvest. Two river systems tributary to Lake Superior in Minnesota - the St. Louis and the Pigeon - once supported lake sturgeon populations below the upstream barrier.

The St. Louis River estuary supported a large lake sturgeon population and fishery. The population was extirpated due to poor water quality, degraded habitat, and overfishing. Water quality within St. Louis River estuary has dramatically improved since the Western Lake Superior Sanitary District began operation in 1978. Angling for and possession of sturgeon is currently prohibited in the Minnesota waters of Lake Superior and the St. Louis River estuary.

The Pigeon River forms the border between Ontario and Minnesota and is located within the Grand Portage Indian Reservation. The Pigeon River historically had a small lake sturgeon population that is present in small numbers. Recently the Grand Portage Band has expressed interest in rehabilitating this population through a stocking program. *A Lake Sturgeon Rehabilitation Plan for Lake Superior* (Auer 2003) discusses the need to use a Lake Superior strain if any stocking program is to be undertaken. The band is presently searching for an appropriate Lake Superior strain. The band is also planning to do some assessment work in the lower portion of the Pigeon River, before any stocking program begins.

In 1984, a program to rehabilitate lake sturgeon in the St. Louis River estuary began (Schram et al. 1999). This program focused on stocking fingerling sturgeon, and on evaluating the success of stocking with annual summer gill net assessments. The Wisconsin Department of Natural Resources (WIDNR) initiated a similar program using both fingerlings and fry in 1983. Initially, Wolf River strain sturgeon from Wisconsin were used by both agencies because no sturgeon egg source from Lake Superior was available. Use of the Wolf River strain was discontinued in 1995 due to genetic concerns. In 1998, the Sturgeon River strain from Lake Superior was stocked; however, an inconsistent supply of gametes did not meet management objectives and stocking was discontinued in 2000.

Survival of stocked fingerlings appears to be excellent, with the establishment of year-classes corresponding to each year of stocking (Schram et al. 1999). Coded-wire tags were implanted in all fingerling sturgeon stocked by the MNDNR. Both tagged and untagged sturgeon were captured in the assessments suggesting that fry and fingerlings stocked by both the MNDNR and WIDNR influenced year-class strength. Gill net CPUE from summer assessments peaked at 6.5 juvenile lake sturgeon per lift in 1996 (Figure 13.1). The subsequent decline in CPUE reflects fewer juveniles in the estuary, since stocking was greatly reduced after 1995 and discontinued in 2000. We expect CPUE to increase in the future as natural reproduction by returning adults increases the number of juvenile sturgeon in the estuary. In general, lake sturgeon migrate out of the estuary and into Lake Superior at approximately 20 in, which corresponds to ages 3 and 4. WIDNR has documented an increase in catch rates of larger lake sturgeon in gill net assessments conducted along the Wisconsin shoreline of Lake Superior. Since about 1998, MNDNR began capturing an increasing number of lake sturgeon along the North Shore in their summer and spring lake trout assessments. Recently, anglers in the St. Louis River estuary have reported incidental catches of some sturgeon > 50 in, suggesting the potential return of spawning adults. Large adults have also been observed below the Fond du Lac Dam in the spring.

Figure 13.1.Gill net catch rates for lake sturgeon in the St. Louis River estuary from 1980-2004.

Harvest of lake sturgeon in the Minnesota waters of Lake Superior and St. Louis River estuary is prohibited. However, if rehabilitation continues to progress, a self-sustaining population could provide an exceptional trophy fishery. Even then, only a limited harvest could be allowed.

II. Goals and Objectives

Goal: Reestablish a self-sustaining population of lake sturgeon in western Lake Superior.

Objectives:

1. Monitor juvenile and sub-adult lake sturgeon population dynamics cooperatively with WIDNR in the St. Louis River estuary and Lake Superior.

2. Annually monitor lake sturgeon spawning activity, flow, and daily spring water temperatures below Fond du Lac Dam in historical spawning areas.

3. Complete a habitat enhancement project that creates 3 spawning riffles below Fond du Lac Dam in a historical sturgeon spawning area.

4. Cooperate with the Grand Portage Band and OMNR on the management and rehabilitation of the Pigeon River sturgeon population.

5. Continue to participate in the lake sturgeon workgroup of the Lake Sturgeon subcommittee of the Lake Superior Technical Committee.

III. Present Management

A. Regulations - Harvest of lake sturgeon in Lake Superior, St. Louis River estuary and the Pigeon River is prohibited.

B. Stocking - The stocking phase of the sturgeon rehabilitation program in the estuary was completed in 2000. A study to evaluate the differential survival of fry and fingerlings reared from Sturgeon River (Lake Superior) strain gametes was not completed because adequate gametes were not available during the entire evaluation period (1998-2002).

C. Assessment – Lake sturgeon population assessments are conducted during early July in most years. The 1854 Authority initiated a radio-telemetry study of 25 sub-adult lake sturgeon in the spring of 2005. This information will help determine the habitat use and distribution of sub-adults in the estuary.

IV. Proposed Management

A. Regulations - Maintain present regulations. Investigate potential for a sport fishery in the estuary after population is considered self-sustaining. Continue with seasonal fishing closure between Highway 23 bridge and the Minnesota-Wisconsin boundary cable. Continue permanent sanctuary between Minnesota-Wisconsin boundary cable and the Fond du Lac Dam.

B. Stocking – No stocking in St. Louis River estuary.

C. Assessment - Continue annual summer gill net assessments through 2006 in the estuary. Beginning in 2008 conduct assessments only in even years. Document lake sturgeon spawning activity below Fond du Lac Dam through visual observations in the spring.

V. Justification

The lake sturgeon is native to Lake Superior, the Pigeon River, and the St. Louis River estuary. Rehabilitation of sturgeon in Minnesota will return this fish to a portion of its native range. Successful rehabilitation within the St. Louis River estuary may provide a "trophy" fishery for anglers. However, establishment of a sport fishery will be highly restrictive and will be contingent upon a self-sustaining population that has adequate numbers to support a limited fishery. Rehabilitation of lake sturgeon in the Pigeon River is important to the Grand Portage Band of Chippewa for cultural reasons.

VI. Information Needs/Community Interactions

More detailed information on lake sturgeon management in the St. Louis River estuary can be obtained in the *Lake Management Plan for St. Louis Bay* (MNDNR, Duluth Area Fisheries 2003). Additional information should be collected on the ecology of lake sturgeon while they reside in the St. Louis River estuary and Lake Superior. Specific information needs include: interaction with other species in the community, locations of critical habitat for all life stages found in the estuary and in Lake Superior, age at maturity, diet, growth rate, and lifespan.

Levels of contaminants in St. Louis River sturgeon and their effects on these fish are presently unknown and should be determined when the opportunity exists. Habitat requirements must be determined and habitat must be protected if rehabilitation is to succeed. The status of lake sturgeon in the Pigeon River is unknown and should be determined before a stocking program is initiated.

References

Auer, N.A., editor. 2003. A lake sturgeon rehabilitation plan for Lake Superior. Great Lakes Fishery Commission, Miscellaneous Publication 2003-02. Ann Arbor, Michigan.

MNDNR. 2003. St. Louis Bay Lake Management Plan. Minnesota Department of Natural Resources, St. Paul.

Schram, S. T., J. Lindgren, and L. M. Evrard. 1999. Reintroduction of lake sturgeon in the St. Louis River, western Lake Superior. North American Journal of Fisheries Management 19:815-823.

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Edited by:

Paul J. Wingate, Fisheries Research and Policy Manager