Chapter 8

The Aquatic Community Part 1: Fish and their Habitat

Attleboro National Fish Hatchery, Atlantic Salmon

Photograph by: William W. Hartley, U.S. Fish and Wildlife Service

Lake Superior Lakewide Management Plan
2000

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EXECUTIVE SUMMARY

The Lake Management Plan written for the aquatic community of Lake Superior is an extension of work conducted by the Lake Superior Committee and Lake Superior Technical Committee (which includes state, provincial, and federal members charged to establish fish community objectives for the Lake Superior basin, under the authority of the Joint Strategic Plan for Management of Great Lakes Fisheries) and provides a necessary link between the Binational Program for Lake Superior and the Great Lakes Fishery Commission. The Aquatic Community LaMP addresses issues primarily related to fish communities of Lake Superior and not lower trophic levels such as plankton, zooplankton, and benthos. The Aquatic Committee of the Lake Superior Work Group is less than one year old and thus did not have enough time to write a fully developed LaMP. The document represented here reflects the best effort by the Committee in the time available.

Aquatic habitat in the Lake Superior basin is classified into five basic types: offshore; nearshore; embayments; tributaries; and inland lakes. Each of these habitats has a specific assemblage of aquatic life that overlap to some extent but by in-large are unique. The offshore habitat makes up roughly 75 percent of the total surface area of Lake Superior and includes all waters deeper than 80 meters. The nearshore habitat is the open water portion of Lake Superior less than 80 meters deep. Embayments are subject to seiche and compose the nearshore areas that are connected to Lake Superior, but exhibit unique physical properties because they are partially protected from the physical dynamics which occur in Lake Superior. Tributaries includes all rivers and streams that empty into Lake Superior and are not subject to seiche. Inland lakes are bodies of water spatially separated from Lake Superior, but located within the drainage basin.

Generally, loss of habitat is an issue only in the tributary, embayment, and inland lake habitats, not the offshore and nearshore habitats. Most of the nearshore and offshore habitat is basically the same as historic times, whereas the vast majority of the embayment, tributary, and inland lake habitat has borne the brunt of habitat destruction. This is not to say that all is completely well with the nearshore and offshore environment for the aquatic community of Lake Superior -- just that these two habitats have few encroachments compared to the other habitats. The offshore and nearshore habitat types of Lake Superior are probably in sufficient quantity and quality to allow achievement of fish community and environmental objectives, but the tributary, embayment, and inland lake habitats do not have sufficient amounts of habitat to allow achievement of fish community or environmental objectives.

The principal stresses to aquatic habitat in Lake Superior include: shoreline development in embayments and inland lakes; hydroelectric facilities; barrier dams; over-exploitation; industrial effluents; mining waste; wetland dredging; atmospheric deposition; agricultural practices; timber harvesting practices; exotic species; potential impacts of sea lamprey control through barriers and lampricides; Great Lakes shipping; and wetland filling. Atmospheric deposition, exotic species, and sea lamprey control are stresses to the aquatic community which have lake-wide effects, whereas most of the other stresses have more localized effects.

Most of the action plans listed in the Aquatic Community LaMP are intended to gather information on specific aquatic resources rather than to fix problems with the ecosystem. The gathering of basic biological and ecological information must occur first in order to understand the linkages between the aquatic community and habitat. Restoration of the Lake Superior ecosystem can only occur once we understand the linkages between habitat and the aquatic community structure and function. The Aquatic Committee views the lack of information to be as much an impediment to restoring the health of the aquatic community as the actual destruction that has been inflicted on the ecosystem.

Action Plans

Four high-priority action plans for funding are described in this LaMP. The highest priority action plan is to develop a standardized lakewide acoustic monitoring program to evaluate status of the pelagic fish community, costing $739,000 over a four-year time period. The second action plan is to identify and quantify critical habitat for key indicator species by electronically mapping lake bottom substrates and will cost $100,000 annually for an unspecified period of time. The third action plan is to determine the population status and abundance of lake sturgeon in historic spawning streams and to quantify their spawning habitat in these streams. The sturgeon project will cost $60,000 over 3-5 years. The fourth action plan is to add critical and important fish habitat to an existing GIS-based map for Lake Superior. The map project may not have any cost associated with it. Ten other action plans are also identified in the Plan, but few of them have time lines or dollar values associated with them.

A significant advantage of integrating the Lake Superior Committee with the Lake Superior Work Group is that the agencies represented on the Lake Superior Committee have a substantial number of monitoring programs already in place for evaluating aquatic ecosystem health and measuring the response of the aquatic ecosystem to management actions. The management agencies have already committed a substantial amount of money to various research and assessment projects and some of these projects have the long-term commitment necessary for measuring management actions and understanding community dynamics. For each of the principal monitoring projects we describe (1) who is conducting the study, (2) what are the goals and objectives of the study, (3) what general methods are being used, (4) what are some results, (5) who are contact people, and (5) what source document is the primary reference for the study.

Figure 8-1. Action Summary

Project	Lead Agency/ Funding Source	Funded	Needs Funding
Identification of Lake Sturgeon Spawning Habitat	OMNR, Environment Canada, GLIFWC, U.S. EPA CEM	X	
Juvenile Lake Sturgeon Habitat Requirements	USFWS, U. S. Dept. of Interior, GLIFWC, BRNRD	X	
Rehabilitation of Lake Sturgeon	RCFD, GLNPO, BRNRD, USFWS, U.S. Dept. of Interior	X	
Rehabilitation of Brook Trout	USFWS/USGS, U. S. Dept. of Interior, MI DNR, Trout Unlimited, National Park Service, and RCFD	X	
Rehabilitation of Lake Trout	MN DNR, Federal Aid for Sport Fish Restoration, WI DNR, WI funding from sale of trout and salmon stamps, MI DNR, OMNR, Provincial, RCFD, U.S. Dept. of Interior , COTFMA, KBIC	X	
Lake Trout Model Development	COTFMA/GLFC, GLFC Coordination Funds, USFWS Restoration Act, OMNR, UW-Stevens Point	X	
Ruffe and Native Fish Surveillance	USFWS/USGS-BRD and U. S. Dept. of Interior	X	
GIS Based Maps of Fish Habitat	Habitat Committee and U.S. EPA CEM	X	
Acoustics Project	GLERL/USGS-BRD and USFWS Restoration Act		X
Creel Survey at Isle Royale	MI DNR and unknown		X
Habitat Mapping	MI DNR/USGS-BRD and unknown		X
Nursery Habitats of Juvenile Lake Sturgeon	Michigan Tech Univ., GLFC, USFWS Restoration Act		X
Analysis of Plankton Samples	USGS-BRD and unknown		X

Figure 8-1. Action Summary

Project	Lead Agency/ Funding Source	Funded	Needs Funding
Caloric Density of Predators & Prey	OMNR and USFWS Restoration Act		X
Implementation of Deepwater Trawling	USGS-BRD and Dept. of Interior		X
Measuring Fish Community Productivity	GLERL/USGS-BRD and unknown		X
Implementation of Fish Community Monitoring	USGS-BRD, COTFMA, Dept. of Interior, USFWS, MI DNR, MN DNR, WI DNR, KBIC, OMNR, unknown		X
Stream Improvement Projects	Army Corps of Engineers and unknown		X
Autopsy-Based Health Profiles	USFWS and unknown		X
Appropriate Flows from Hydroelectric Facilities	State agencies and unknown		X
Brook Trout and Trout and Salmon Competition	Trout Unlimited and unknown		X

8.0 ABOUT THIS CHAPTER

Coordinated, inter-jurisdictional management of the Great Lakes fishery was facilitated by the 1955 Convention on Great Lakes Fisheries between the governments of Canada and the United States which created the Great Lakes Fishery Commission. The bilateral agreement affirmed the need for the two countries to collaborate on the protection and perpetuation of Great Lakes fish resources. The Great Lakes Fishery Commission was charged to formulate and coordinate research programs to enhance the sustained productivity of the Great Lakes, to recommend appropriate measures for enhancing the Great Lakes, to implement a sea lamprey control program, and to publish scientific and other information regarding the Great Lakes and its fishery.

The Great Lakes Fishery Commission provides the forum in which fishery agencies from each of the Great Lakes can interact and develop strategies for jointly managing resources of common concern. In 1981, a Joint Strategic Plan for Management of Great Lakes Fisheries was signed by state, federal, and provincial management agencies with jurisdiction on the Great Lakes (Great Lakes Fishery Commission 1994). The Joint Strategic Plan affirmed commitments among the various Great Lakes agencies to work together and expressed their commitment to cooperation, consensus, and strategic thinking.

Lake committees made up of state, provincial, and two inter-tribal fishery agencies are the action arm of the Joint Strategic Plan. Each lake committee is made up of one representative from each agency, with a technical committee to investigate specific fishery issues. The Lake Superior Committee is composed of representatives from the Departments of Natural Resources in Michigan, Minnesota, and Wisconsin, Ontario Ministry of Natural Resources, Great Lakes Indian Fish and Wildlife Commission, and Chippewa/Ottawa Treaty Fishery Management Authority. The Lake Superior Committee develops common Fish Community Objectives (Busiahn 1990), appropriate stocking levels, harvest targets, law enforcement capabilities, and management plans. The 1990 Fish Community Objectives for Lake Superior are currently being rewritten by the Lake Superior Committee in part to link the objectives to habitat conditions in Lake Superior and to accommodate the Binational Program for Lake Superior.

The Lake Superior Technical Committee provides the Lake Superior Committee with scientific and technical information, and is composed of representatives from the same agencies as the lake committee, as well as individuals from the U. S. Fish and Wildlife Service, Canadian Department of Fisheries and Oceans, and U. S. Geological Survey-Biological Resources Division (BRD). The Technical Committee regularly develops lakewide strategies for sampling fish populations in Lake Superior and coordinates efforts to describe the status of the Lake Superior fish community. The technical committee has written a lakewide plan for rehabilitating populations of lake trout (Hansen 1996) and a report describing the state of the Lake Superior fish community in 1992 (Hansen 1994). Subcommittees of the Technical Committee have written documents describing the status of brook trout, lake sturgeon, and walleye in Lake Superior, and have developed rehabilitation plans for each of these species (Newman and others 1999a).

In March of 1999, the Lake Superior Technical Committee was charged to serve as the link between the Lake Superior Committee and the Binational Program for Lake Superior. In that capacity, the Technical Committee chair also serves as the co-chair of the Lake Superior Work Group Aquatic Committee. The linkage of the Lake Superior Work Group and Lake Superior Committee was a logical decision since it was the lake and technical committees which have been working cooperatively to describe and manage the future fish community of Lake Superior.

Development of this Aquatic Community chapter is an extension of the work of the Lake Superior Committee and its Technical Committee completed over the last two decades. The Aquatic Committee used many of the documents created by the Lake Superior Committee and Lake Superior Technical Committee to develop this chapter. These documents include Fish Community Objectives (Busiahn 1990); the new draft of Fish Community Objectives; the rehabilitation plans for lake trout (Hansen 1996), brook trout (Newman and others 1999a), lake sturgeon, and walleye; the 1992 state of Lake Superior report (Hansen 1994); and a discussion paper on development of fish community objectives written by the Technical Committee in March 1998.

This Aquatic Community chapter does not deal with lower trophic levels in Lake Superior. Since the Lake Superior Technical Committee primarily deals with issues relating to fish, the Lake Superior Technical Committee has little information to describe phytoplankton, zooplankton, and benthos in Lake Superior. In addition, because the Aquatic Committee was formed less than a year ago, we have had little time to bring individuals with the knowledge of the lower trophic levels into the realm of the Committee and the Lake Superior Work Group.

8.1 IDENTIFICATION OF CRITICAL AND IMPORTANT HABITAT AREAS

Within the Lake Superior basin, there are both critical and important habitats defined at the species scale. The Aquatic Committee defines “critical habitat” as that which is essential for spawning and reproduction. “Important habitat” is defined as areas where juvenile and adult forms live and feed when not spawning. Critical and important habitats can occur in the same geographic area for a certain species or be separated by substantial distances. Critical and important habitats for several fish species indigenous to Lake Superior are described in Addendum 8-A.

Critical and important fish habitat is classified into five basic types in Lake Superior, each with a specific assemblage of fish species. The fish community of each habitat type overlaps to some extent, and indigenous species like lake trout, and burbot, and non-indigenous species like Pacific salmon and sea lamprey are found in each habitat type at some point in their lives. However, the fish community of each habitat type is fairly unique. The habitat types are as follows:

- **Offshore --** the open water portion of Lake Superior deeper than 80 meters which makes up over 75 percent of the total area of the lake.
- **Nearshore --** the open water portion of Lake Superior less than 80 meters deep.

- **Embayments** -- comprised of the nearshore areas that are connected to Lake Superior, but exhibit unique physical properties because they are partially protected from the physical dynamics which occur in Lake Superior. Embayments can be natural or man-made and include coastal wetlands, bays, harbors, and estuaries that are subject to lake seiche.
- **Tributaries --** all rivers and streams in the watershed that empty into Lake Superior and are not subject to seiche.
- **Inland lakes --** bodies of water spatially separated from Lake Superior, but located within the drainage basin.

The offshore area makes up the largest share of habitat in Lake Superior and contains nearly all the important and critical habitat for siscowets, humpers, chubs, and deepwater sculpin. Siscowets and humpers are actually different forms of lake trout that are found only in Lake Superior (Rahrer 1965, Burnham-Curtis and Bronte 1996). The offshore habitat of Lake Superior is comprised of about 6.3 million hectares (ha) of surface water. The fish community of the offshore habitat is relatively simple and composed of pelagic adult lean lake trout, siscowets, humpers, burbot, Pacific salmon, sea lamprey, deepwater ciscoes, lake herring, and deepwater sculpins.

The nearshore habitat is comprised of approximately 1.9 million ha of surface water. Most of the important and critical habitat for lean lake trout, lake herring, and lake whitefish is found in the nearshore habitat (Figure 8-2). The nearshore habitat has a greater assemblage of fish species than the offshore habitat and the fish community of the nearshore habitat is composed mainly of lean lake trout, siscowets, burbot, Pacific salmon, lake herring, lake whitefish, round whitefish, rainbow smelt, ninespine sticklebacks, trout-perch, pigmy whitefish, and longnose and white suckers.

Fish communities living in the embayment habitat are more complex than in the offshore and nearshore habitats because Lake Superior's embayments are warmer, more productive, and more physically diverse than the remainder of the lake. Fish living in the embayments include many of the same fish that live in the nearshore habitat, but also warm and cool water fish species such as walleye, smallmouth bass, yellow perch, rock bass, northern pike, lake sturgeon, johnny darters, emerald shiners, longnose dace, sand shiners, bullheads, and carp.

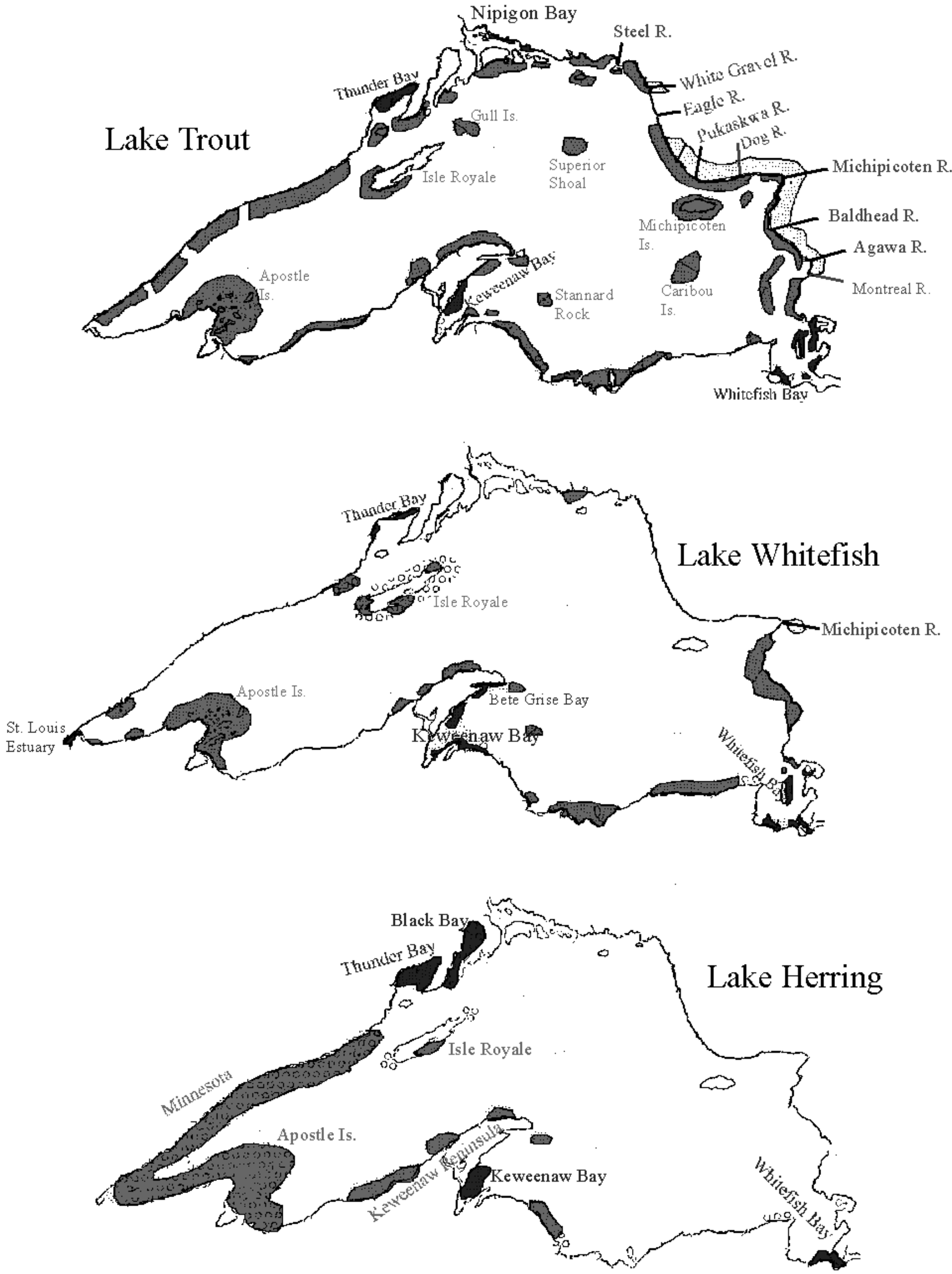

Figure 8-2. Distribution of known spawning habitat for lake trout, lake whitefish, and lake herring in Lake Superior

from Goodyear and others (1981), Coberly and Horrall (1980), and Goodier (1981)

There are over 3,300 kilometers (km) of tributaries available to Lake Superior fish. Many fish that live in the embayment, nearshore, and offshore habitat types spend part of their life in tributaries, but the fish community of tributaries includes brook trout, burbot, lake sturgeon, longnose and white suckers, redhorse suckers, Pacific salmon juveniles, mottled sculpin, bullheads, the many species of minnows, and sea lamprey. Tributaries are the critical habitat for nearly all of the species listed above. Rainbow trout and brook trout are found in more tributaries of Lake Superior than the other major fish species, while lake trout and lake whitefish are found in the fewest number of tributaries. The number of tributaries known to contain important fish species in Lake Superior is described below based on creel surveys, some published literature (Moore and Braem, 1965), and personal communications with area managers and biologists.

Table 8-1 Lake Superior Tributaries Containing Fish Species

Fish species	Minnesota	Wisconsin	Michigan	Ontario	Total
Lake trout	0	0	3	2	5
Lake sturgeon	2	3	2	6	13
Pink salmon	10	8	65	7	90
Brown trout	2	76	29	?	107
Chinook salmon	6	15	27	14	62
Coho salmon	8	59	56	8	131
Walleye	2	9	29	40	80
Brook trout	52	90	93	19	254
Rainbow trout	65	74	112	19	270

There are many inland lakes within the Lake Superior basin that exhibit a wide range of habitat conditions and contain a variety of fish communities. Habitats in these lakes vary from small, shallow winter-kill lakes to deep, cold-water lakes, and as a result of the morphometry of the lakes, fish assemblages vary from warm water to cold-water fish communities. The morphology and water chemistry of the inland lakes are dictated by the geology of the Lake Superior basin that includes Canadian Shield, sandstone, and sandy-loam shoals. Lake Nipigon is the largest of the inland lakes within the Lake Superior basin and is a significant source of the water that flows into Lake Superior.

8.1.1 Lake Superior Resources and Their Stresses

Two types of fish communities are found in Lake Superior: those that are not limited by habitat and those that are. Habitat limits can be thermal, spatial, and artificially imposed by man due to some form of degradation or manipulation to the habitat. Species that are not limited by habitat and for which there is a sufficient amount of habitat to sustain and achieve both fish community and environmental objectives include:

- All lake trout forms, lake herring, lake whitefish, chubs, and round whitefish that spawn in Lake Superior itself;
- Salmonines other than lake trout that live in the offshore, nearshore, and embayment habitat; and
- Prey species like sculpins, trout-perch, ninespine stickleback, and pigmy whitefish.

In comparison, the following fish species are limited by habitat in the Lake Superior basin and achievement of fish community or environmental objectives may not be possible under current habitat conditions.

- Lake trout stocks that spawn in rivers found in eastern Ontario waters of the lake. The Montreal River population of lake trout may be limited by habitat due to fluctuating water levels caused by a hydroelectric facility.
- The lake whitefish stock that historically spawned in the St. Louis estuary -- this stock of whitefish was extirpated over 100 years ago because of habitat destruction.
- Walleyes, lake sturgeon, Pacific salmon, brown trout, coaster brook trout, and other fish that live in Lake Superior but spawn in the tributaries, as well as tributary resident species such as brook trout, brown trout, sculpins, and cyprinids -- logging, road crossings, beaver and man-made dams, are causing (1) loss of spawning and nursery habitat (due to sedimentation) and (2) unfavorable changes in the thermal habitat.
- Yellow perch, northern pike, and smallmouth bass. These species are limited thermally, limited by depth, and limited by habitat quantity in Lake Superior.

Generally, habitat loss causes impairments in the tributary, embayment, and inland lake habitats. Most of the nearshore and offshore habitat has remained unchanged, whereas the vast majority of the embayment tributary, and inland lake habitat has borne the brunt of habitat destruction. The offshore and nearshore habitat types of Lake Superior are probably in sufficient quantity and quality to allow achievement of fish community and environmental objectives, but the tributary and embayment habitats do not have sufficient amounts of habitat remaining to allow achievement of fish community objectives for species like lake sturgeon, walleye, and brook trout.

The principal stresses to aquatic habitat in Lake Superior include:

- shoreline development in embayments and inland lakes,
- hydroelectric facilities,
- barrier dams,
- over-exploitation,
- industrial effluents,
- mining waste,
- wetland dredging,
- atmospheric deposition,
- agricultural practices,
- timber harvesting practices,

- exotic species,
- potential impacts of sea lamprey control through barriers,
- Great Lakes shipping, and
- wetland filling.

Atmospheric deposition, exotic species, and sea lamprey control practices are stresses to the aquatic community which have lakewide effects, whereas most of the other stresses have more localized effects.

The principal stresses found in each of the habitat types are as follows:

- **Offshore** -- atmospheric deposition, dumping or discharges from vessels, and exotic species.
- **Nearshore** -- atmospheric deposition, dumping or discharges from vessels, industrial effluents, exotic species, over-exploitation, and mining.
- **Embayment** -- petroleum emissions and spills, atmospheric deposition, industrial effluents, dumping or discharges from vessels, exotic species, over-exploitation, loss of wetlands, land-use practices, atmospheric deposition, urban development, sedimentation, and shoreline development.
- **Tributary** -- industrial effluents, hydroelectric facilities, barrier dams, loss of wetlands, land-use practices, exotic species, timber harvesting, mining, agricultural practices, urban development, and sedimentation.
- **Inland Lakes** -- Shoreline development, timber harvest, agriculture, contamination through septic systems or runoff, mining, atmospheric deposition, urban development, sedimentation, industrial effluents, loss of wetlands, and hydroelectric dams.

The effect of the various stresses on the aquatic community is easy to recognize. Overfishing is partly responsible for the demise of deepwater ciscoes (Lawrie and Rahrer 1973), brook trout (Newman and Dubois 1997), lake sturgeon (Slade and Auer 1997), walleye (Hoff 1996), lake trout (Hansen and others 1995a), and lake herring (Selgeby 1982) in Lake Superior from the late 1800s to the mid 1900s. Also during the same time period hydroelectric development and man-made barriers on tributaries, sedimentation of tributaries due to poor logging and land use practices, and physical destruction of stream channels contributed to the demise of brook trout, walleye, lake sturgeon, and lake trout (Lawrie and Rahrer 1973, Slade and Auer 1997, Hoff 1996, Newman and Dubois 1997). Predation by exotic sea lampreys contributed to the collapse of lake trout and whitefish populations in Lake Superior from the 1940s through the 1960s (Jensen 1976, Pycha 1980, Smith and Tibbles 1980, Coble and others 1990, Hansen and others 1995a). Logging, road crossings, and beaver and man-made dams are currently causing loss of spawning and nursery habitat in tributaries due to sedimentation and unfavorable changes in the thermal habitat. Walleye populations in Lake Superior are affected by high mercury levels, paper mill effluent, and habitat loss (Schram and others 1991).

Overfishing, hydroelectric development, logging practices, and sea lampreys are all stresses that can and are being managed. Overfishing is currently being prevented through fishery management regulations developed separately or jointly by state, provincial, and tribal agencies (Legault and others 1978, Ebener 1997, Brown and others 1999). Overfishing is currently not a pervasive problem on Lake Superior and occurs only in isolated areas on a few fish species, such as lake trout in Whitefish Bay and eastern Ontario waters. Re-licensing of hydroelectric facilities on U.S. tributaries through the Federal Energy Regulatory Commission has resulted in changing water power management from peak operations to run-of-the-river flows which are more friendly to aquatic life and fish reproduction. More stable flow regimes implemented on the Nipigon River in the 1990s have helped increase reproduction of brook trout. Present day logging practices can be regulated to protect aquatic life. These practices are much less stressful to aquatic life than historic methods. Sea lamprey populations have been successfully suppressed throughout most of Lake Superior because of integrated control using chemicals, barrier dams, and sterile-male releases.

Other stresses to the aquatic community of Lake Superior are much less easy to recognize or manage. It appears that chemical contaminants in fish flesh have not limited the ability of Lake Superior fish to reproduce, although it is uncertain if reproduction would be better if the chemical contaminants were in lower concentrations or absent. Some of the chemicals being deposited in Lake Superior through atmospheric deposition originate outside of the Lake Superior basin, including outside North America, making it impossible to address management of these chemicals in the Aquatic Community LaMP. The presence of chlordane in siscowet trout from Lake Superior is an example of a chemical that originates outside the Lake Superior basin, yet the chemical is in sufficient quantity in siscowets that consumption advisories have been issued by the state of Michigan. Michigan closed its state-licensed commercial fishery for siscowets in the early 1990s due to chlordane contamination of the fish. In addition, shoreline development on inland lakes typically results in the loss of aquatic vegetation which is important to survival and reproduction of some fish species, such as yellow perch and northern pike, however, the direct, measurable effects of shoreline development are not as recognizable. Land use practices and urban development alter drainage patterns and increase surface water run-off, but the effects on the aquatic community are difficult to assess and understand.

The effect of exotic species other than sea lampreys on the aquatic community remain unknown and exotic species are difficult to manage. Rainbow smelt have provided valuable commercial and sport fisheries on Lake Superior since the 1930s, and have been the primary food source for many of the predatory fish in Lake Superior (Legault and other 1978, Conner and others 1993). Conversely, when rainbow smelt enter a Great Lake, indigenous fish such as lake herring and whitefish initially decline in abundance, although there has been no direct measure of the effect of smelt on these fish species in Lake Superior (Selgeby and others 1994a). A negative effect of the Eurasian ruffe on the Lake Superior fish community has not currently been found, although ruffe have become the most abundant fish species in the estuaries of some tributaries to western U.S. waters of Lake Superior (Hoff and others 1998). Pacific salmon also provide valuable sport and limited commercial fisheries on Lake Superior, but they may also negatively interact with indigenous brook trout in some tributaries (Newman and others 1999a). Implementing changes in the stocking rates of hatchery-reared Pacific salmon typically causes substantial political problems for fishery agencies, and since most Pacific salmon now living in Lake Superior are the product of natural reproduction, there are few options available for managing their populations. The exotic zooplankton *Bythotrephes* is very abundant in early summer in Lake Superior and fish regularly eat *Bythotrephes*. However, the effect of *Bythotrephe* on the aquatic community is unknown. The use of chemicals and barrier dams to control sea lamprey, although good at protecting lake trout and whitefish, present a difficult balancing act to managers because these control tools also have potential negative effects on lake sturgeon migration up tributaries and survival of recently hatched lake sturgeon in tributaries. Sea lamprey continue to kill a substantial number of lake trout in Lake Superior every year (Hansen and others 1994, Weeks 1997).

8.1.2 Inland Lake Aquatic Resources and Their Stresses

This discussion is organized by state and province.

Minnesota

Minnesota's portion of the Lake Superior watershed contains many inland lakes. These areas are extremely important for both recreation and tourism. Much of the aquatic resource in Minnesota is in very good condition. High quality pristine areas in the watershed include portions of the Boundary Waters Canoe Area, natural heritage lake trout lakes that are supported only by wild populations, state parks, and state and federal forests.

The Minnesota watershed, however, is in general and in a few specific areas experiencing increased stress from a variety of sources. The major stresses include logging, iron ore mining, increased construction of roadways, increased development of both riparian stream and lake shoreline areas, and increased exploitation on the fisheries resource. There are ongoing discussions with the timber industry on implementation of best management practices, specifically requiring increased protection of the riparian zone along streams, lakes, and wetlands. The Minnesota Division of Forestry is presently working on a new policy for timber harvest in the Lake Superior watershed. Iron ore mining is an important industry in northeast Minnesota and in general has made efforts to improve water quality near mining sites, but there are still areas that need attention. With the renewed interest in experiencing "wilderness" and the changing demographics of our society there is a major development boom in Minnesota's portion of the Lake Superior watershed that includes expansion of roads, businesses, cabins/homes, and general shoreline development.

Lake trout, in the natural heritage lakes, and other native species are especially affected by the above stresses because of their need for undisturbed shoreline and native aquatic vegetation for natural reproduction. Many of the other stresses in the watershed are being addressed through a variety of policy and regulatory changes. The Binational Program will provide an important tool to assist in implementing the required changes.

Wisconsin

The soft water seepage lakes are most commonly found in the Wisconsin Lake Superior basin. These lakes are typically clear, slightly acid, and relatively infertile. The principal fishery resources pursued by anglers in the Wisconsin basin include muskellunge, northern pike, walleye, largemouth and smallmouth bass, and panfish.

Lakes within the Wisconsin Lake Superior basin are continually being stressed as an increasing number of people purchase shoreline properties. Shoreline development has resulted in a reduction of aquatic habitat and in some cases a reduction in water quality. Management actions to improve water quality include acquisition of remaining undeveloped shoreline near fish spawning areas and wildlife marshes, and improvement in sewage treatment facilities.

Michigan

The MI DNR, U.S. Forest Service, U.S. Fish and Wildlife Service, Bay Mills Indian Community, and Keweenaw Bay Indian Community have assessed many of the 200 to 300 lakes in the Lake Superior drainage of Michigan. Most of these lakes support a cold or cool water fishery. The cold-water lakes have brook trout or rainbow trout as the dominant predator, while the cool-water lakes have walleye, northern pike, or perch as the dominant predator. A few lakes are characterized as warm-water and have a largemouth bass/bluegill fish community. A compliment of various prey species also exists in these lakes, dominated by minnows (cyprinids) and suckers (catostomids).

In general, Michigan inland lakes within the Lake Superior basin receive minimal fishing pressure because of the sparse human population in their region, and their remote locations. A few lakes are storage reservoirs used for hydroelectric power; associated lake level fluctuations negatively impact those fisheries. These lakes include: Gogebic, Prickett, Bond Falls, Victoria, Silver, McClure, and Autrain.

The Michigan Department of Environmental Quality and the Great Lakes Indian Fish and Wildlife Commission have instituted a general mercury advisory for fish existing within all lakes, stipulating that smaller and leaner fish should be eaten. Specific advisories exist for the following lakes: Siskiwit, Gogebic, Bond Falls Flowage, Perch, Langford, Clearwater, Lindsley, Marion, Torch, Portage, Parent, Lake Independence, Cisco Chain, Deer, and Autrain. All of the above lakes have fish advisories for mercury, while Portage, Siskiwit, and Torch lakes also have advisories related to PCB contamination.

Currently, there are two Areas of Concern (AOCs) identified by the International Joint Commission within Michigan's Lake Superior basin: Torch Lake in Houghton County and Deer Lake in Marquette County. In the Torch Lake AOC, the impaired beneficial uses identified include restrictions on fish and wildlife consumption, fish tumors or other deformities, and degradation of benthos. With a review currently in process, this list is undergoing significant revision. For instance, sauger, the fish species most heavily afflicted with tumors and anomalous growths, is no longer present within the AOC. Consequently, the Fish Consumption Advisory was lifted in 1989. In 1998, however, PCBs were detected in samples, and a Fish Consumption Advisory was reinstated for women and children. Deer Lake environmental concerns include elevated mercury levels in fish. The Michigan Department of Environmental Quality has been working to address and remediate these concerns for several years. Their efforts have been supported by the Deer Lake PAC since 1997. The AOC includes the Carp River watershed, Deer Lake, and the Carp River downstream about twenty miles to Lake Superior in Marquette.

Ontario

Ontario's portion of the Lake Superior watershed contains numerous inland lakes supporting lake trout, brook trout, walleye, and northern pike fisheries. Some of the lakes, particularly in the Thunder Bay and Sault Ste. Marie areas, are experiencing stress due to the effects of shoreline development. However, the majority of the lakes are undeveloped and the shorelines are managed as public lands. Current Ontario government policy prohibits development on lake trout lakes where all of the shoreline is public land, and limits development on patent lands on lake trout lakes based on the late summer hypolimnetic dissolved oxygen level.

More widespread stresses to Ontario inland lakes are associated with logging activity and exploitation. Ontario's Timber Management Guidelines for the Protection of Fish Habitat have been used since 1988 to minimize the effects of crown land logging operations on inland lakes and streams. A large, ongoing research project was initiated in 1990 to experimentally evaluate the effects of logging on boreal forest lakes and streams. The results of this project will help in the development of more scientifically-based guidelines to ensure the protection of fish habitat. With regard to exploitation on Ontario's inland lakes, standardized rapid assessment protocols have been developed in order to identify stressed populations which may require management intervention and to facilitate the development of management support models. These protocols include the spring littoral index netting, fall walleye index netting, and nearshore community index netting. A modified version of the trap net, based nearshore community index netting, has recently been used to assess walleye populations in the Georgian Bay area of Lake Huron and may prove to be a valuable assessment tool for the assessment of sensitive populations in embayments on Lake Superior.

Lake Nipigon is the largest inland lake in Ontario's portion of the Lake Superior watershed; with a surface area of 448,060 ha it is approximately one quarter the size of Lake Ontario. Lake Nipigon supports trophy sports fisheries for brook trout and lake trout as well as commercial fisheries for whitefish, lake trout, walleye, and more recently rainbow smelt. Stresses acting on the fish community of Lake Nipigon include exploitation, water level fluctuations, and the introduction of the non-indigenous rainbow smelt. Declines in Lake Nipigon walleye stocks in the early 1980s, attributed primarily to over-fishing, have led to angling closures and reduced commercial walleye quotas. Recovery of the walleye stocks in Ombabika Bay is being monitored on an ongoing basis. Rainbow smelt were first discovered in Lake Nipigon in the early 1980s and smelt numbers have increased dramatically since. It is unknown, however, what the long-term impacts of smelt will be on the Lake Nipigon fish community.

The level of Lake Nipigon is controlled by hydroelectric dams on the Nipigon River and by the diversion of water from the Ogoki River into Ombabika Bay. Winter draw-downs have impacted brook trout reproduction by de-watering brook trout spawning shoals. The past impact on other fall spawning species is unknown. A recent water level agreement on the Nipigon system is expected to reduce water level impacts on Lake Nipigon as well as on the Nipigon River.

The Lake Nipigon Fisheries Assessment Unit (LNFAU) was established by the Ontario Ministry of Natural Resources around 1980 in order to establish long term data sets on the Lake Nipigon fish community. Current LNFAU projects include fish community index netting, fall walleye index netting, commercial catch sampling, smelt index netting, and lake trout index netting. More recently the Kitchi-gaa-ming Field Fisheries Unit of the Anishnawbec/Ontario Fisheries Resource Center (A/OFRC) has also been conducting fisheries assessment work on Lake Nipigon. The Lake Nipigon Fish Community Index Netting project is currently undertaken as a partnership between LNFAU and A/OFRC.

8.1.3 Tributaries and Their Stresses

Minnesota

Minnesota tributaries to Lake Superior are generally very harsh environments for salmonine fish to inhabit in comparison to tributaries in other jurisdictions. Nearly all Minnesota tributaries have natural barriers a short distance upstream from Lake Superior. These barriers limit movement of anadromous fish within tributaries and reduce juvenile salmonine habitat. Minnesota tributaries have very little groundwater intrusion and stream flows are controlled mainly by precipitation. The largest Minnesota tributary to Lake Superior is the St. Louis River, which forms the boundary between Minnesota and Wisconsin. The St. Louis River is an AOC and progress is being made to alleviate stresses to the river. Some major stressor concerns and their related species include lake sturgeon in the St. Louis River, anadromous species such as brook trout, and wild Pacific salmon in all tributary streams.

Wisconsin

Wisconsin has many high quality, spring-fed trout streams which provide extensive recreational fishing opportunities. Some streams have small coastal estuaries, which provide habitat for fish and wildlife species. Most tributaries were impacted by a complete forest cut-over in the middle 1800s, extensive fires, and the cumulative watershed damage caused by man’s activities (e.g. agriculture). Resulting higher peak flood flows increased channel water velocities, which displaced the remaining woody cover, eroded stream banks, straightened channels and ultimately sorted bottom substrates. Although watershed health has generally improved, the channel damage caused during this time period is still not healed. Management actions include land acquisition, beaver control, stream habitat improvement in critical areas, and fishery regulations.

Michigan

According to an unpublished U. S. Fish and Wildlife Service Sea Lamprey Control stream database, there are 420 Michigan tributaries to Lake Superior. These include the Montreal River, a boundary stream shared with Wisconsin. Most of these streams are small, having a discharge less than 0.5 m^3/sec. The discharge depends mostly on surface runoff. These surface-runoff streams typically experience wide fluctuations in physical and chemical parameters. In Big Garlic River in Marquette County, Michigan, discharge ranged from 0.3 to 3.3 m^3/sec.

Discharge rates are even higher during spring runoff. During these periods, temperatures ranged from 0 to 21° C, conductivity ranged from 40 to 124 micro-mhos, total alkalinity ranged from 14 to 62 ppm, and total hardness ranged from 20 to 66 ppm (Zimmerman 1968). Eighty-one of the 420 streams in the database did not have a name, likely because they were extremely small and had intermittent discharge. These fluctuations in stream parameters influence the fish community in a number of ways. Increased discharge in the spring due to melting snow and rain provides improved access to tributaries by spring-spawning anadromous species such as rainbow trout and suckers. However, stream resident fish and juveniles of anadromous fish that require an extended nursery period are adversely affected by the fluctuating conditions. Reduced discharge and temperature extremes during summer, fall, and winter reduce available habitat (e.g. anchor ice) and lead to increased mortality in the tributary and the lake. Shrinking habitat forces anadromous juveniles to migrate into Lake Superior at less than optimum size and age.

Ontario

Ontario tributaries to Lake Superior support a diverse group of fisheries including walleye, northern pike, rainbow trout, coho and chinook salmon, lake trout, lake sturgeon and brook trout. Stresses to Ontario tributaries include hydroelectric development and shoreline development. Hydroelectric development has impacted a number of Lake Superior tributary watersheds including the Kaministiquia, Nipigon, Pic, Michipicoten and Dog rivers. A water management agreement was developed in 1990s for the Nipigon watershed which balances the needs of all stakeholders on the Nipigon River and Lake Nipigon with the protection of fish habitat. This agreement is expected to serve as a model for other tributaries in Ontario with hydroelectric development as hydroelectric leases are re-negotiated.

Shoreline development has impacted fish habitat in tributaries in localized areas such as Thunder Bay and Sault Ste. Marie, Ontario. More widespread stresses are associated with water crossings. Both the trans-Canada highway and railway are close to the north shore of Lake Superior and cross the majority of tributaries. Many of the crossings are sub-standard by current standards and have resulted in barriers to migration of anadromous fish, habitat fragmentation and severe erosion problems in some cases. Improvements to some of these crossings have been undertaken as opportunities have arisen. Tail-water controls have been used to improve fish passage at perched or inclined culverts. Flood conditions frequently cause washouts and replacement culverts are sized and installed to facilitate fish passage. Recently the Ontario Ministry of Natural Resources has taken a proactive role in ensuring that natural channel design and 'soft' engineering approaches are used in the design of replacement water crossings. It is anticipated that this approach will reduce the frequency of washouts as well as facilitating fish passage.

A standardized stream assessment protocol has been developed by the Ontario Ministry of Natural Resources in order to evaluate and compare stream habitats and the status of fish populations in the streams. Using this method, efforts are ongoing to establish a database of baseline habitat and population information on Lake Superior tributary streams in order to identify streams in need of harvest controls or habitat rehabilitation. In addition, the standardized assessment protocol will facilitate monitoring of the effects of such management actions.

8.1.4 Embayments and Their Stresses

Besides the tributaries to Lake Superior, a substantial amount of habitat destruction has taken place in the embayment habitat. Most of the AOCs on Lake Superior are located in embayments, particularly in Canada. The AOCs in the embayment habitat of Canada are located in Nipigon Bay, Jackfish Bay, Thunder Bay, and Peninsula Harbour.

Nipigon Bay is the most northerly area of Lake Superior and receives most of its drainage from a watershed underlain by the Canadian Shield. Environmental concerns in Nipigon Bay center around water quality issues, degraded fish populations, and impaired natural watercourses. In 1995, the Nipigon AOC completed remedial strategies for ecosystem restoration, most of which have been implemented. Actions taken include reducing water level fluctuations, completion of secondary treatment at the Norampac Inc. paper mill, and cleanup and rehabilitation of nearshore and tributary habitat. All actions associated with rehabilitation of native brook trout, walleye and lake trout stocks in the Nipigon AOC have been implemented or completed. A reference for this AOC is the Nipigon Bay Remedial Action Plan, Stage 2: Remedial Strategies for Ecosystem Restoration (1995).

The Jackfish Bay AOC is located on the north shore of Lake Superior, approximately 250 km northeast of Thunder Bay, ON. The AOC consists of a 14 km stretch of Blackbird Creek between the Kimberly-Clark pulp mill and Jackfish Bay including Lake ‘A’, Moberly Lake, and Jackfish Bay. The town of Terrace Bay is the closest community west of the AOC. Jackfish Bay and Blackbird Creek have been impacted by effluent from the pulp and paper industry, resulting in contaminated sediments and degradation of fish and wildlife habitat. Process changes and the installation of secondary treatment at the Kimberly-Clark mill have substantially improved effluent quality, resulting in environmental improvements. It is expected that previously deposited organic sediments will degrade over time and the Remedial Action Plan recommends natural recovery as the preferred option in the 1998 Stage 2 report on remedial strategies for ecosystem restoration. Natural rehabilitation of aquatic communities will continue to be monitored in the Jackfish AOC. A reference on this AOC is the Jackfish Bay Remedial Action Plan, Stage 2: Remedial Strategies for Ecosystem Restoration (1998).

The Thunder Bay AOC fans out from the city of Thunder Bay, ON, extending for about 28 km along the shoreline and up to nine km offshore. The AOC occupies the southwest corner of Thunder Bay proper. The greatest impacts on the area have resulted from industrial and urban development along the Thunder Bay waterfront and adjoining tributaries. Dredging, waste disposal, channelization, and the release of a number of pollutants have eliminated a significant portion of quality habitat along the waterfront. The consequences have included a loss of species abundance and diversity, reduced recreational opportunities, and a decline in the aesthetic value of the area. Impacts resulting form the release of process effluent into the Kaministiquia River and Lake Superior have been significantly reduced in recent years because of improved effluent treatment and changes in industrial processes; however, the ecosystem remains impaired in a number of ways. Some areas support benthic communities reflective of organic enrichment, contaminated sediments, and habitat loss from dredging activities. Dredging restrictions are still in effect because of sediment contamination in the harbour, particularly health hazards for water based recreational activities. A reference for this AOC is the Thunder Bay Remedial Action Plan, Stage 2: Remedial Strategies for Ecosystem Restoration (1999).

Peninsula Harbour is located on the northeastern shore of Lake Superior approximately 290 km east of the city of Thunder Bay, ON. The AOC is roughly bounded by the watershed of the harbour and Pebble Beach, and extends outward approximately 4 km from the Peninsula in to Lake Superior. The area has problems associated with degraded fish and benthic communities and high levels of toxic contaminants in fish and bottom sediments. The preferred remediation option currently under consideration is to remove mercury contaminated sediments and isolate them in a Confined Disposal Facility. Mercury levels in lake trout have stabilized at a mean value of 0.35 mg/kg from 1984 to 1996 and are not significantly different from lake trout sampled at other locations along the north shore of Lake Superior. A reference for this AOC is the Peninsula Harbour Remedial Action Plan, Stage 2: Remedial Strategies for Ecosystem Restoration (1999).

8.2 ACTION PLANS

Most of the action plans listed in the Aquatic Community LaMP are intended to gather information on specific aquatic resources rather than fix problems with the ecosystem. The gathering of basic biological and ecological information must occur first in order to understand the linkages between the aquatic community and habitat. Restoration of the Lake Superior ecosystem can only occur once we understand the linkages between habitat and the aquatic community structure and function. The Aquatic Committee views the lack of information to be as much an impediment to restoring the health of the aquatic community as the actual destruction that has been inflicted on the ecosystem. Kelso and Hartig (1995) described various projects and methods being implemented in the Great Lakes basin to modify habitat to benefit the ecosystem. They stated that these projects would provide the foundation for selecting and evaluating habitat modification and conservation actions. Unfortunately, many of those projects were either incomplete or had not been started by 1995. As a result, they provide little assistance with development of strategies for restoring the aquatic ecosystem of Lake Superior.

Nearly all of the action plans and strategies described below are based on the fish community objectives (Busiahn 1990), rehabilitation plans for lake trout (Hansen 1996), brook trout (Newman and others 1999a), walleye, and lake sturgeon, and the state of the lake report for Lake Superior (Hansen 1994). All of these plans were written by either the Lake Superior Technical Committee and its subcommittees or the Lake Superior Committee itself. The first four of the action plans, or projects, have been given the highest priority for funding by the Aquatic Committee. These projects are aimed at increasing our knowledge of predator-prey interactions and linking fish community dynamics to habitat.

8.2.1 Acoustics Project

The goal of this project is to develop a standardized lakewide monitoring program to evaluate the status of the pelagic fish community of Lake Superior. Objectives of the project are as follows:

1. To develop species-specific acoustic size-length relationships for pelagic prey fishes in Lake Superior.
2. To quantify species-specific spatial distribution patterns with respect to environmental conditions such as water temperature, bathymetric depth, water column depth, etc.
3. To develop statistical models for remote species identification of fishes with estimates of variance using information from objectives 1 and 2 and from trawling.
4. To develop and implement a sampling design to quantify and assess pelagic prey fish abundance and biomass.
5. To attempt to develop a correction factor for observed differences in the species-species abundance and biomass estimates between traditional bottom trawls and acoustic surveys.

The product of this work will be a strategy for conducting long-term acoustic work to estimate the biomass of the pelagic fish community of Lake Superior.

Acoustics sampling involves sending an electronic signal down through the water column of a lake from a vessel as that vessel moves along a straight line transect. The strength and shape of the returning signal to the vessel can be used to estimate fish species composition in the water column and the size of the fish. The Lake Superior Technical Committee and Lake Superior Work Group have developed indicators for the offshore and nearshore aquatic communities that include trends in abundance of key aquatic species like lake herring, exotic species, and predators to meet both ecosystem and fishery management objectives. Acoustic sampling must play an important role in estimating and monitoring the abundance of these key aquatic organisms.

The acoustics project will cost $739,00 (U.S.) and will be divided into two projects. The first is a 2-year project that addresses objectives 1 through 3 above at a cost of $139,000 (U.S.). The second project is a 4-year study that addresses objectives 4 and 5 above at a cost of $600,000 (U.S.).

8.2.2 Habitat Mapping

The goal of this project is to identify and quantify critical habitat for key fish species that are both indicators of ecosystem health and fish community stability. This project involves using remote sensing and advanced global positioning systems to describe the distribution and quantity of Lake Superior bottom substrates. Surveys would be conducted in areas that are critical to reproduction and rearing of fish indigenous to Lake Superior, such as lake trout, especially in areas where habitat has been destroyed or altered. These surveys should include those areas that are not already protected. The current draft of fish community objectives for Lake Superior and the Binational Program both call for quantification of fish habitat and identification of its distribution within the lake. Important lake trout spawning habitat has already been mapped in portions of Minnesota waters of Lake Superior. Whitefish spawning habitat has also been mapped in lower Whitefish Bay. We expect this project to cost about $100,000 annually and to last until all of the important areas have been mapped.

8.2.3 Rehabilitation of Lake Sturgeon

The goal of this project is to determine the current population status and abundance of lake sturgeon in historic spawning streams and to quantify sturgeon spawning habitat in those streams. Lake sturgeon were historically very abundant in the nearshore and tributary habitats of Lake Superior, but a combination of habitat destruction, hydroelectric development, and over-fishing resulted in the lakewide collapse of the populations early in the twentieth century. The current lake sturgeon rehabilitation plan gives this work high priority for future research. This project will cost about $20,000 per stream per year, with at least two streams per year being studied. These costs include personnel and radio tagging equipment. This project could last for 3 to 5 years.

8.2.4 GIS-Based Maps of Fish Habitat

This project involves adding data on fish habitat to the existing Habitat Committee project to develop Geographic Information System (GIS)-based maps of habitat in the Lake Superior basin. These data would include the attributes associated with each stream listed in the Lake Superior Technical Committee Discussion Paper. The goal would be to visualize fish habitat in Lake Superior by identifying, quantifying, and illustrating that habitat on GIS maps. The cost of this project is unknown and will be based upon the ease of incorporating the information into the existing databases.

8.3 OTHER ACTION PLANS

Besides the four high-priority action plans listed above, there are many more projects identified by the Aquatic Committee that need to be funded. These projects were identified by either the Aquatic Committee or were recommended in the lake trout, brook trout, lake sturgeon, and walleye rehabilitation plans. These projects are listed below in no particular order of priority. They have no time-lines and only a few of the projects have a suggested annual budget.

1. Describe the nursery habitats, habitat requirements, and seasonal distribution of juvenile lake sturgeon in tributaries to Lake Superior where sturgeon are currently known to spawn.
2. Measure fish community productivity in tributaries and measure the contribution of tributaries to both fish production and productivity of Lake Superior; $50,000 (U.S.) annually.
3. Implement bottom trawling to waters greater than 300 feet deep in Lake Superior; $25,000 (U.S.) annually.
4. Implement fish community monitoring in tributaries, embayments, and nearshore habitat less than 45 feet deep to gather background data prior to invasion of new exotic species to Lake Superior; $75,000 (U.S.) annually.
5. Analyze U. S. Geological Survey - BRD plankton collections made around Lake Superior over the last decade; $25,000 (U.S.) annually.

6. Conduct stream improvement projects to reduce sand loading on brook trout streams; $40,000 (U.S.) annually per stream.
7. Determine the usefulness of autopsy-based health and condition profiles for juvenile lake trout.
8. Determine the caloric densities of predators and their prey throughout the water column of Lake Superior for use in bioenergetics models; $50,000 (U.S.) annually for three years.
9. Determine the appropriate spring flows that enhance recruitment of brook trout, walleye, and lake sturgeon on tributaries with hydroelectric facilities.
10. Measure the competitive relationship between coaster brook trout and naturalized anadromous salmonines and their hybrids in spawning and nursery habitats, and in Lake Superior.

8.4 MONITORING PROGRAMS

A significant advantage of integrating the Lake Superior Committee with the Lake Superior Work Group is that the agencies represented on the Lake Committee have a substantial number of monitoring programs already in place for evaluating aquatic ecosystem health and measuring the response of the aquatic ecosystem to management actions. The management agencies have already committed a significant amount of money into various research and assessment projects. Some of these projects have the long-term commitment necessary for measuring management actions and understanding community dynamics. For each of the principal monitoring projects we describe the following (if available): (1) who is conducting the study; (2) what are the goals and objectives of the study; (3) what general methods are being used; (4) what are some results; (5) who are the contact people; and (6) what is the primary reference for the study. These monitoring projects are organized by the five basic habitat types in Lake Superior.

8.4.1 Offshore Habitat

Deepwater predator surveys - This is a cooperative project developed by the Lake Superior Technical Committee and implemented by nearly every agency with representation on, or involvement with, the committee. Preliminary bioenergetics analyses conducted in western Lake Superior in the early 1990s indicated that siscowets dominated the predator fish population in that portion of the lake (M. Ebener, COTFMA, personal communication). To confirm this and determine if a similar domination occurred lakewide, member agencies of the Lake Superior Technical Committee conducted a lakewide assessment in June 1996 and August-September 1997 to determine the relative abundance and biology of predator fish, especially siscowets, at depth strata from inshore as shallow as 60 feet to offshore depths that at some stations exceeded 600 feet.

Graded-mesh gill nets were fished overnight on the bottom at 60-foot depth intervals in 1996 and at 120-foot depth intervals in 1997. The nets were 6 feet deep and 2,700 feet long and were made up of 300-foot panels of 2.0-, 2.5-, 3.0-, 3.5-, 4.0-, 4.5-, 5.0-, 5.5-, and 6.0-inch extension-measure multifilament nylon or monofilament mesh. Fish captured in each mesh in each net were identified, measured, weighed, sex and maturity determined, number and stage of sea lamprey attack marks recorded, and scales or otoliths collected for age analysis. Otoliths were collected from all siscowets, burbot, and leans 23 inches and longer, and scales collected from leans less than 23 inches and all other fishes. Fin clips were recorded for all salmonines and stomachs were collected from all salmonines and burbot for diet analysis.

This assessment will be repeated in 2000 or expanded by member agencies in future years, but the time frame between sampling years has not yet been determined. These data have not yet been published. The contact persons for the deepwater predator survey are listed below.

Don Schreiner	Minnesota Department of Natural Resources (MN DNR)
Stephen Schram	Wisconsin Department of Natural Resources (WI DNR)
Owen Gorman	U. S. Geological Survey - BRD
Mike Gallinat	Red Cliff Fisheries Department
William Mattes	Great Lakes Indian Fish and Wildlife Commission
Michael Donofrio	Keweenaw Bay Indian Community
Shawn Sitar	Michigan Department of Natural Resources (MI DNR)
Mark Ebener	Chippewa/Ottawa Treaty Fishery Management Authority
Bryan Henderson	Ontario Ministry of Natural Resources

8.4.2 Nearshore Habitat

Fish Community Surveys - The U.S. Geological Survey- BRD has conducted surveys of fish populations and communities in U.S. and Canadian waters of the lake. The objective of this continuing assessment study is to provide annual estimates of recruitment, relative abundance, biomass, age structure, and size structure of important prey fishes such as lake herring, rainbow smelt, slimy sculpin, spoonhead sculpin, deepwater sculpin, and ninespine stickleback. Species such as lake herring, rainbow smelt, slimy sculpin, spoonhead sculpin, deepwater sculpin, and ninespine stickleback are ecologically important because they are common prey for lake trout and other salmonines (Conner and others 1993, Selgeby and others 1994b). Lake herring, rainbow smelt, slimy sculpin, spoonhead sculpin, deepwater sculpin, nine-spine stickleback, and other prey species require annual monitoring because they are short-lived and experience large annual variations in abundance. In these surveys, bottom trawls with a 11.7-m headrope and 12.7-mm stretched mesh cod end are towed at a speed of 4.3 km/h across contours beginning at 15 m and ending after reaching the maximum depth obtainable within 1 hour. These surveys were conducted annually in the spring at 43 to 53 locations in U.S. waters during 1978 to 1999, and at 33 to 35 locations in Ontario waters during 1988 to 1999.

The annual surveys showed that recruitment, which was measured at age 1, varied by a factor of 3,000 for lake herring. In contrast, recruitment of rainbow smelt varied by a factor of only 4 in recent years, and most other species showed similar variations in recruitment. In decreasing order, lake herring, lake whitefish, rainbow smelt, ninespine stickleback, trout-perch, and slimy sculpin composed most of the biomass in U.S. waters. In recent years, biomass was greater than the long-term mean for lake whitefish, and lower than the mean for trout-perch, rainbow smelt, lake herring, slimy sculpin, and ninespine stickleback. Prey abundance and biomass data are being used along with other data to model energy flow through the ecosystem. Those models have resulted in predictions of population changes after management strategies are implemented. The primary contacts for the fish community survey are Owen Gorman or Michael Hoff of the U.S. Geological Survey- BRD in Ashland, Wisconsin. The primary reference for this study can be found in Selgeby and others (1994b) and Hoff and Bronte (1998).

Spring lake trout assessment fishery - An annual spring assessment was initiated in Michigan and Wisconsin waters in 1959 to assess lean lake trout relative abundance, contribution of hatchery lake trout, sea lamprey wounding, and various lean lake trout biological parameters (Pycha and King 1975). Spring surveys are now conducted annually from mid-April through early June throughout the U. S. and Canadian waters of Lake Superior within the nearshore habitat. The goal of the assessment fishery is to monitor the abundance of wild and hatchery lean lake trout for the purpose of understanding both the dynamics of the populations and the potential impacts of lamprey and fishing activities on the populations. Specific objectives are to gather biological and relative abundance data from most of the stocks in Lake Superior. Minnesota began the assessment fishery in the mid 1960s, while in Ontario, the assessment fishery did not begin until 1997.

Nylon multifilament or monofilament gill nets of 4 ½ inch stretched mesh, 210/2 twine diameter, and 1.8 meters high are used to capture lake trout for the study. Nets are set in roughly the same sample location every year depending upon the agency conducting the survey in waters of 60 to 240 feet deep and lifted after three nights. Total length and weight are determined for each fish, and each fish is examined for the presence of fin clips and sea lamprey marks. Stomach samples are collected from 100 lean and 100 siscowet lake trout in each management unit. A scale or otolith is taken from the fish in order to determine age. The total number of wild and hatchery lean lake trout is recorded for each gang of nets lifted.

The results from this study serve many purposes. Biological and relative abundance information is used to develop models of lake trout populations for predicting total allowable catches, impacts of sea lamprey control actions, and fishery management actions. The relative abundance data have been used to evaluate fish community goals for lake trout in Lake Superior and to evaluate progress towards lake trout rehabilitation. The long-term relative abundance data can be used to measure the health of the Lake Superior nearshore habitat for the Binational Program on Lake Superior.

The primary contacts for the spring lake trout assessment fishery are:

Don Schreiner	Minnesota Department of Natural Resources (MN DNR)
Stephen Schram	Wisconsin Department of Natural Resources (WI DNR)
Shawn Sitar	Michigan Department of Natural Resources (MI DNR)
Mike Gallinat	Red Cliff Fisheries Department
Michael Donofrio	Keweenaw Bay Indian Community
Mike Petzold	Ontario Ministry of Natural Resources

Ken Gebhardt	Bay Mills Indian Community
Mark Ebener	Chippewa/Ottawa Treaty Fishery Management Authority

The results of this study can be found in Pycha and King (1975), Peck and Schorfhaar (1991 and 1994), Hansen and others (1995a), and Hansen and others (1995b).

Summer lake trout gill net survey - Lake trout less than 17 inches long are not common in the sport harvest and generally are not legal in the commercial harvest. Thus, they are considered pre-recruits to these fisheries. Knowledge of the status of these pre-recruit fish would provide some insights regarding management of these fish when they recruit to fishable size in future years. The status of pre-recruit lean and siscowet lake trout less than 17 inches total length are assessed throughout U.S. waters of Lake Superior from Grand Portage, Minnesota to Grand Marais, Michigan. This study has been ongoing since 1970 and is conducted every year.

Multifilament nylon or monofilament graded-mesh gill net of 1.5 to 3.5-inch stretch-measure mesh in ¼ or ½ inch increments are used to capture pre-recruit lake trout. Gangs of these nets are fished on the bottom overnight for approximately 24 hours at depths of 90 to 250 feet from late July through August each year. Data recorded for each fish captured in each mesh size in each gill net gang includes species and total length for all fish; a structure for aging is collected from each lean and siscowet lake trout, other salmonines, burbot, and subsamples of coregonines, along with corresponding fin clip, sea lamprey marks, sex, and maturity data. Otoliths are the structure taken from all siscowets and leans larger than 23 inches long and scales are taken from all other species sampled. Stomachs are collected from a subsample of leans and siscowets in each management area.

Contact persons for the summer lake trout gill net survey are:

Shawn Sitar	MI DNR
Don Schreiner	MN DNR
Stephen Schram	WI DNR
Mike Gallinat	Red Cliff Fisheries Department

Results of this assessment have been documented in Peck and Schorfhaar (1991 and 1994).

Diet Summaries - The objective of this study is to provide long-term trend information on the food eaten by predatory fish in Lake Superior. This is a cooperative effort that began in 1992 and involves all members and agencies that participate on the Lake Superior Technical Committee. Stomachs are collected from all predatory fish, but primarily lean and siscowet lake trout, caught during routine spring lake trout assessment surveys throughout the U. S. and Canadian nearshore waters of Lake Superior. The objective is to collect stomachs from 20 lean and 20 siscowet trout each season in each of the following size classes: < 200 mm, 200-399 mm, 400-599 mm, 600-799 mm, and > 800 mm.

Stomachs are removed intact, placed in individually marked plastic bags, and typically frozen for later analysis. Stomachs are dissected and food items removed, categorized, enumerated, and weighed. Fish identified during dissection are placed in one of the following food categories: rainbow smelt, coregonines, (*Coregonus* spp.), burbot, sculpins (*Cottus* sp.), sticklebacks, salmonines (trout and salmon), other fish, *Mysis*, amphipods, and terrestrial insects. Data are described as percent weight composition and percent frequency of occurrence by season, spatial unit, and size class of predator.

Data analysis has revealed that rainbow smelt are the principal dietary supplement for lean lake trout in the spring. The agencies have also determined that siscowet lake trout have a more diverse diet than lean lake trout and coregonines compose a higher percentage of the siscowet diet.

The primary contact for this project is Chuck Bronte of the U. S. Geological Survey - BRD. The primary literature reference for this project is Conner and others (1993).

Angler Creel Surveys - The Michigan, Wisconsin, and Minnesota Departments of Natural Resources, and Ontario Ministry of Natural Resources conduct on-site direct-contact angler creel surveys in portions of Lake Superior to estimate angler harvests. In Michigan, the survey is conducted at specific ports every year from Black River Harbor to Munising. Minnesota divides its shoreline into two areas and creates two clusters of sample sites in each area where clerks contact sport anglers. These surveys estimate angling effort in hours fished and harvest in number of each species caught and kept. Survey clerks collect various biological data from a sample of harvested fish. An angler survey was conducted in Lake Superior waters of Isle Royale in 1998 through a cooperative effort by Isle Royale National Park, MI DNR, Grand Portage Band of Chippewa, and Keweenaw Bay Indian Community. This survey estimated effort and harvest, but also estimated the number caught and released. In 1990, charter boat fisheries operating in Michigan waters were required to provide the MI DNR with reports of sportfish harvest for each month fished. Michigan began their survey in 1984, while other agencies have been conducting creel surveys for somewhat longer than Michigan.

Contact persons for the angler creel surveys are Don Schreiner of the MN DNR, Stephen Schram of the WI DNR, and Gerald Rakoczy of the MI DNR. Results of these surveys are in Peck (1992), Lockwood and others (1999).

Lake trout spawning substrate study - An inter-agency project to electronically map and describe the bottom substrates in Minnesota waters of Lake Superior that may be important as lake trout spawning sites was completed in 1999. Acoustics signals were used to identify and classify habitat on the lake bottom along most of the Minnesota shoreline of Lake Superior at depths less than 100 feet. Funding for the study came from LTV Steel Company.

Survey data were collected with an echosounder, RoxAnn signal processor, global positioning system, and computer. Transects of 200 ft. wide were made perpendicular and parallel to shore. A statistical technique was developed to place precise statistical boundaries around the signals that were returned from the lake bottom to the RoxAnn. The equipment allowed the researchers to produce estimates of the amount of very good, good, and poor lake trout spawning habitat based on depth and amount of large rocky substrate.

The contacts for information from this study are Dr. Carl Richards of Minnesota Sea Grant in Duluth, Minnesota and Don Schreiner of the MN DNR. Results of the study have been published and can be found in Richard and others (1999). A series of digital and hard maps of bottom substrates and their quantity is available on CD-ROM.

Lake Trout Population Models - In 1998, the Lake Superior Technical Committee began a process to develop a lake-wide lake trout population model for Lake Superior. Various agencies and individuals in the Lake Superior basin were involved in development of models of lake trout populations, and while the tasks by themselves were useful, they were also isolated. The Technical Committee sought to coordinate these separate tasks to produce a management tool that could be applied throughout Lake Superior. This tool would also be valuable to managers and the Great Lakes Fishery Commission. The goal of the modeling task is to evaluate fish community objectives, sea lamprey control, and sustainability of the fish community on a lake-wide basis.

The task involves inviting technical staff from all management agencies and researchers in current modeling tasks to a series of workshops over three to five years. In addition to the workshops, the Technical Committee is soliciting the efforts of various researchers and helping them apply for grants to aid in development of the model. As of January 2000, there are three ongoing research projects that will be used to help build the population model. One project involves evaluating compensatory growth mechanisms in lake trout in Lake Superior. Another project will evaluate the appropriate spatial scales for modeling lake trout in Lake Superior and will assist with data consolidation. The last project involves constructing stock assessment models and a projection model for evaluating management strategies.

The primary contact for this project is Mark Ebener of the Chippewa/Ottawa Treaty Fishery Management Authority. No results have been published from this project, but a document titled "Minutes from the Lake Trout Model Development Workshop, Workshop 1 - Scoping Session" is available from Mark Ebener or Gavin Christie of the Great Lakes Fishery Commission.

KITES - National Science Foundation, Sea Grant, and University of Minnesota at Duluth have funded a project titled "**K**eweenaw **I**nterdisciplinary **T**ransport **E**xperiment in Lake **S**uperior." This goal of the project is to understand how storms influence biological, geological, and chemical material and biota along the Keweenaw Peninsula, and how the Keweenaw current produces differences in composition and productivity of nearshore and offshore plankton communities. A coastal jet exists along the west shore of the Keweenaw Peninsula, producing water speeds of up to 7 cm per second along the peninsula. The Ontonagon River empties into the current with the result that the river contributes 25 percent of all river-borne sediments to U.S. waters of Lake Superior. The KITES project has 13 researchers involved from seven agencies assessing three major study sites located along the west side of the peninsula. Data are being collected from buoy moorings, boats, and satellite images. Sampling started in May of 1998.

The primary contact for this study is Dr. Elise Ralph of the University of Minnesota, Duluth, Minnesota. No results have been published from this study.

8.4.3 Embayments

Chequamegon Bay Fish Community Survey - It is important to monitor the status and trends of populations of walleye, yellow perch, and other species in the embayments of Lake Superior because those areas have sustained the greatest amount of environmental damage (Lake Superior Work Group 1995). The structure and stability of the summer fish communities of Chequamegon Bay, Wisconsin have been studied and analyzed from data collected during 1973-1996 with bottom trawls at 39 stations. The study continues to be conducted annually.

Fish were sampled annually from mid-July to early August by taking one 10-minute bottom trawl tow at each station. The locations of the stations were permanently established in the first year and were sampled by randomly selecting coordinates within ten, 1.83-m depth strata. The proportion of stations in each stratum was equal to the proportion of the stratum area to that of the bay.

Fifty-three fish species were collected during the study, but relative abundance of 20 species described most of the internal variability of the data for all species. Abundance data for the 20 species showed that two communities existed in the bay; one inhabited shallow water up to 3.0 m deep while the other inhabited water greater than 3.0 m deep. The deep-water community, whose variation was best described by eight species, underwent three periods of change in abundance: 1973 to 1978, 1979 to 1988, and 1989 to 1996. In contrast, the shallow-water community was stable through the 24 years studied. Dynamics of the deep-water community were greatly affected by changes in stocking rates of lake trout and splake, and by rehabilitation of lake herring and lake whitefish populations. Information on the existence, structure, stability, and habitats used by fish communities in the bay will be useful for assessing changes in those communities that result from further changes in the bay or lake ecosystems.

The primary contact for this study is Michael Hoff of the U. S. Geological Survey - BRD. The primary literature for this study is Hoff and Bronte (1999).

Lake Sturgeon Surveys - Lake sturgeon are assessed each year in Chequamegon Bay, Wisconsin, using large mesh gill nets. Information on movements, age, growth, and relative abundance is used to develop effective management strategies. A stocking program in the St. Louis River is being evaluated by sampling during the spring lake trout survey and the summer graded mesh assessment in Lake Superior itself.

The primary contact for this survey is Stephen Schram of the WI DNR. A scientific publication of interest is Schram and others (1999).

Upper St. Mary's Fish Community Survey - In 1991, the Chippewa/Ottawa Treaty Fishery Management Authority initiated a series of surveys in the upper St. Mary's River area of

Whitefish Bay with the goal of establishing a walleye fishery and determining management strategies for harvesting walleye from the area. The primary objectives of the study are to monitor trends in abundance of the fish community, to collect biological information from selected species, to determine population characteristics of selected species, and to evaluate the walleye stocking program. Walleye fry, spring fingerlings, and fall fingerlings have been stocked in the area every year since 1989. The study and walleye stocking have been conducted annually through 1999.

Drop nets, beach seines, bottom trawls, and electrofishing gear are used to capture fish for the study. Drop nets are fished in Waishkey Bay during early July to monitor abundance of adult yellow perch, walleye, northern pike, pumpkinseed, rock bass, smallmouth bass, bullheads species, redhorse suckers, and white suckers. Day- and night-time beach seines are used to capture and assess age-0 and age-1 walleye and whitefish abundance, as well as the abundance of the fish community in the littoral area from May through early October. Bottom trawls are made at randomly selected sites using either a 16-foot otter trawl or a 4-foot beam trawl from May through September. Two ten minute trawl tows are made perpendicular to shore in waters of 10 to 60 feet deep at each site, and the total number and weight of each species caught are recorded for each trawl tow. Night-time electrofishing surveys are conducted during mid-September of each year to assess abundance of age-0 walleyes and monitor abundance of other important fish species. Biological data are collected from all walleyes, yellow perch, northern pike, smallmouth bass, and trout and salmon caught during all surveys, and the number of each fish species caught in each survey are also recorded.

The primary contacts for the study are Ken Gebhardt of the Bay Mills Indian Community and Mark Ebener of the Chippewa/Ottawa Treaty Fishery Management Authority. No scientific publications have been written from the study, but annual reports summarizing the study are available from Ken Gebhardt or Mark Ebener.

8.4.4 Tributaries

Abundance of Anadromous Adults - The number of anadromous adult salmonids ascending several tributaries are estimated by the MN DNR and WI DNR. Anadromous adult salmonids ascending the French River in Minnesota are captured in a weir, while the number of adult salmonids are counted at the observation window at the Brule River, Wisconsin, sea lamprey barrier/fishway. The window on the Brule River fishway allows salmonids to be measured and identified to species prior to moving upstream.

The primary contacts for this study are Don Schreiner of the MN DNR and Stephen Schram of the WI DNR. A publication of interest on this study is Schreiner (1995).

McIntyre River Rainbow Trout Population Assessment - The goal of this is study is to better understand rainbow trout population dynamics in the McIntyre River and to determine the status of an individual stock of rainbow trout in a heavily exploited system. The specific objective is to monitor total numbers of adult rainbow trout migrating upstream to spawn. The study began in 1999 and is ongoing.

In May 1999, a resistivity fish counter (Aquatic Ltd, Logie Counter 2100C) was installed at the upper end of the fish ladder at Lake Tamblyn on the McIntyre River. This device detects the passage of fish across an array of three electrodes. When a fish passes over the three electrodes, a change in resistance occurs because the fish is more conductive than the water it displaces. This change of resistance is recorded and analyzed by the counter using a firmwave algorithm to determine if it fits a typical fish pattern. Should the counter assess that a fish has passed over the array based on this comparison, the time, direction of travel and peak signal size of the fish event is recorded and stored for downloading and analysis.

Data from the April to June 1999 migration period indicates that a total of 414 fish were assessed to have passed over the counter in an upstream direction. Of these, 53% were correctly assigned as upstream migrants, while 47% were recorded as events with "trace signature" subsequently proven to be fish generated events. Peak migration of 115 fish (28% of total run) occurred on May 1, 1999. Current data suggests a population that may be dominated by spawners in the 2-4 lb. classes with fewer than 11% of the run being composed of fish greater than 5 lb.

The primary contact for this study is Ken Cullis of the Ontario Ministry of Natural Resources. A reference for this study is report summarizing the 1999 results that is available from Mr. Cullis.

Juvenile Lake Sturgeon Studies on the Bad River - The Bad River, Wisconsin, is one of only two U.S. tributaries to Lake Superior that support a self-sustaining population of lake sturgeon. A cooperative study of juvenile lake sturgeon in the Bad River was started in 1994. The objective of the project is to obtain information on juvenile sturgeon inhabiting the Bad River. Information on distribution, movement, biological characteristics, and habitat condition is collected from juvenile sturgeon. The project began in 1994 and continued through 1999.

Data collection procedures involved setting two gill nets approximately 200 yards east and west of the mouth of the Bad River. Nets were set and lifted three days each week from June through July and information on water temperature, bottom type and depth is recorded for each set. The number of each fish species caught is recorded for each net lifted. Sturgeon are identified with a unique tag number, total length, fork length, girth, and weight were recorded and the fish are released. Length, weight, and age data are also taken on game species such as walleye, northern pike, smallmouth bass, trout, and salmon. For sturgeon killed during netting operations, sex is determined from gonads, pectoral fins are collected for aging, and stomachs are collected to determine diet.

In 1999, Ashland Fishery Resources Office, Bad River Natural Resources Department, and Red Cliff Tribal Fish Hatchery developed and initiated a plan to utilize multiple capture, egg collection, and rearing methods for Bad River lake sturgeon. The purpose was to determine the feasibility of the Bad River serving as an egg source to augment the Bad River population and to assist rehabilitation efforts in Lake Superior. Eggs were successfully collected and hatched, but no fingerlings were produced. The project is ongoing.

Lake sturgeon larval drift and juvenile distribution in the summer has also been studied on the Bad River. This assessment occurs periodically when agency personnel and funds are available. Objectives include determination of the timing and extent of downstream drift of larval sturgeon, and determination of the duration of residency and habitat utilized by young-of-the-year lake sturgeon. Information on early life history of lake sturgeon is necessary to aid fishery agencies with critical habitat management and rehabilitation efforts.

The primary contacts for this study are Bill Mattes of the Great Lakes Indian Fish and Wildlife Commission, Henry Quinlan of the U. S. Fish and Wildlife Service, Rick Huber of the Bad River Natural Resources Department, and Greg Fischer of the Red Cliff Fish Hatchery. There have been no scientific papers written from this study.

Brook trout Rehabilitation Projects **-** Historically, brook trout were very abundant in Lake Superior tributaries and areas of the lake near the tributaries, but these populations were severely depressed during the late 1800s and early 1900s. In the early 1990's, a coordinated multi-agency effort began to rehabilitate brook trout populations in Lake Superior. The Lake Superior Committee established the Brook Trout Subcommittee under the auspices of the Lake Superior Technical Committee. The subcommittee completed "Status of brook trout in Lake Superior" in 1997, and in 1999, the Lake Superior Committee adopted the "Rehabilitation plan for brook trout in Lake Superior."

Fishery agencies have several ongoing projects to study brook trout in the Lake Superior basin. MN DNR conducts a study of brook trout in Lake Superior and north shore tributaries to investigate the status of the populations. Study objectives include identification of remnant populations, population structure below and above barriers, and genetic analysis. The U.S. Fish and Wildlife Service has led cooperative surveys to assess abundance, distribution, movement, habitat use, and life history of brook trout at Isle Royale National Park, Michigan since 1993. A marking study was developed by the Red Cliff Tribal Hatchery and U.S. Fish and Wildlife Service in 1997 to determine the effectiveness and longevity of marking various life stages of Lake Superior strain brook trout utilizing oxytetracycline and temperature fluctuation in both hatchery and lake environments. Radio telemetry tracking was conducted to measure the movements, ranges, habitat use patterns, and spawning behavior of reintroduced Lake Nipigon brook trout at Grand Portage, Minnesota and wild brook trout at Isle Royale, Michigan. In the spring of 1999, as a cooperative effort between the Ontario Lake Superior Management Unit and the Centre for Northern Forest Ecosystem Research placed radio transmitters into the body cavity of 40 brook trout captured in the Nipigon Bay area. The study is designed to quantify habitat use by brook trout and identify locations with suitable habitat.

Most fishery management agencies have collected and continue to collect brook trout tissue samples for genetic analysis. The objective of a Lake Superior genetics study was to survey genetic variation among populations sampled from tributary streams, especially those with remnant populations, or those reported to have had them in the past. Analysis of Lake Superior brook trout populations using microsatellite DNA was initiated in 1998. The goal of the study is to analyze allele variation among single and multi-locus microsatellite DNA characters of Lake

Superior brook trout populations with an emphasis on populations with anadromous life history variants. A report has been completed on the project.

Contact persons regarding brook trout rehabilitation in Lake Superior include;

Henry Quinlan and Lee Newman	U. S. Fish and Wildlife Service
Don Schreiner	Minnesota Dept. of Natural Resources
Ken Cullis	Ontario Ministry of Natural Resources
Greg Fischer	Red Cliff Tribal Fish Hatchery
Mike Donofrio	Keweenaw Bay Indian Community
Mary Curtis	U. S. Geological Survey - BRD

References on brook trout in Lake Superior and the rehabilitation process include Slade (1994), Burnham-Curtis (1996), Newman and Johnson (1996), Newman and Dubois (1997), Tillma and others (1999), Newman and others (1999a and 1999b), Quinlan (1999), and Quinlan and others (1999).

Surveys of Ruffe and Native Fishes - The objective of this study is to measure the relative abundance of the non-indigenous ruffe and other fishes in four south shore tributaries of Lake Superior in order to monitor long-term changes in these fish communities. These tributaries are the Amnicon, Iron, and Flag rivers in Wisconsin, and the Ontonagon River in Michigan. In 1993, the U. S. Fish and Wildlife Service expanded its efforts to monitor abundance of ruffe relative to native fish abundance in ten south shore tributaries to western Lake Superior. These tributaries include the Amnicon, Brule, Iron, Flag, Sand, and Sioux rivers in Wisconsin, and the Black, Mineral, Potato, and Ontonagon rivers in Michigan. The study on the ten tributaries was stopped in 1997 in favor of continuing the study on the original four tributaries. The study has been conducted annually from 1988 through 1999 on the four tributaries, and will continue in the future.

Ruffe abundance increased every year and by 1991, they had become the most abundant species captured in trawl tows. As the abundance of ruffe in the St. Louis Estuary increased, apparent declines in abundance of several native species were noted. A recent statistical analysis, however, has not been able to establish a connection with ruffe. Ruffe were reported at locations outside of the St. Louis Estuary as early as 1988. Results of the study indicated abundant ruffe populations with both fluctuating ruffe and native fish populations in the ten study streams.

The primary contacts this study are Gary Czypinski of the U.S. Fish and Wildlife Service or Mike Hoff of the U. S. Geological Survey - BRD. The primary reference for this study is Hoff and others (1998).

Surveillance For Ruffe - The goal of this study is to locate new populations of ruffe and describe their age and/or size composition. Secondary objectives are to describe the fish community at each location surveyed, and to monitor interior range locations where ruffe had been previously collected to detect increases in ruffe abundance. These objectives address the needs of the Ruffe Control Program by defining the range of ruffe and detecting reproducing populations on the periphery of the range. The findings of this program also assist in monitoring the results of the voluntary ballast water management plan implemented by the Great Lakes maritime industry. Formal surveillance began in 1992 and continued through 1999.

Cooperating agencies in the 1999 surveillance effort included the U. S. Fish and Wildlife Service Ashland, Alpena, and Lower Lakes Fishery Resource Offices, and the Ontario Ministry of Natural Resources. Cooperation from agency partners and the public has expanded the coverage and frequency of ruffe surveillance activity and contributes significantly to its effectiveness. With the Duluth/Superior Harbor as the origin, the detected ruffe range extends to Thunder Bay, Ontario, Canada on the north shore of Lake Superior, the Ontonagon River, Michigan, on the south shore of Lake Superior, and the Thunder Bay River, Michigan, on Lake Huron.

The primary contact for this study is Gary Czypinski of the U. S. Fish and Wildlife Service. Several internal reports are written every year and can be obtained from Mr. Czypinski..

Sea Lamprey Index Surveys - This is an ongoing cooperative project involving the Great Lakes Indian Fish and Wildlife Commission, Wisconsin Dept. of Natural Resources, National Park Service, and the U. S. Fish and Wildlife Service Sea Lamprey Management Program. The goal of the project is to monitor relative and absolute abundance of adult sea lampreys in 13 tributaries to Lake Superior during May to early July. The specific objectives of the project are: to estimate the number of sea lampreys spawning in each tributary, monitor the upstream spawning movements of sea lampreys, and to collect biological data on sex, length, and weight of adult spawning sea lamprey. This project has been taking place every year from 1986 through 1999.

Data collection procedures involve using portable assessment traps or fyke nets to capture adult sea lampreys in the Amnicon, Middle, Brule, Bad, Ontonagon, Firesteel, Misery, Silver, Huron, Big Garlic, Rock, Miners, and Tahquamenon rivers at least three times per week. Dead lamprey are measured to the nearest millimeter, weighed to the nearest gram, and their sex is determined. Live lampreys are transported downstream, marked by clipping one or both dorsal fins according to a marking schedule, and then released back into the river. A different combination of clips is used to identify week of capture and release. The number of live and dead marked and unmarked lamprey captured each sampling day is counted, along with the number of other fish species in the traps or nets. Other exotic species such as ruffe and goby if captured, are counted, sexed, and destroyed. Various environmental conditions are recorded each time the traps or nets are emptied, including water and air temperature, as well as subjective evaluations of river condition and river flow.

The primary contacts for this study are Katherine Mullett of the U. S. Fish and Wildlife Service Sea Lamprey Management Program and Bill Mattes of the Great Lakes Indian Fish and Wildlife Commission. Numerous annual reports summarizing the sea lamprey catches can be found in the annual minutes of the Lake Superior Committee Meeting, from the U.S. Fish and Wildlife Service Sea Lamprey Control Program, or Bill Mattes.

Stream Surveys - This in an ongoing, cooperative project to develop an index of the relative condition of each watershed in Michigan's Lake Superior basin. The objectives include assessing the fish, invertebrates, and habitat which exists in each watershed once every five years.

Most of the streams are surveyed utilizing a Michigan Dept. of Environmental Quality protocol known as Great Lakes and Environmental Assessment Section Procedure #51 (GLEAS 51). GLEAS 51 consists of three parts, including evaluation of the macroinvertebrate community, fish community, and habitat quality. Fish, macroinvertebrate, and habitat quality is scored and compared to reference streams when determining their status. Representative sites of usually more than one station, spaced at least one mile away from another station, selected on each stream, and identified and marked for future reference in each watershed. The fishery surveys are conducted in late September or October. Fish are usually collected using a 12 volt backpack electrofishing device. A minimum of 100 fish are collected from each site. All salmonine species are identified to species, measured to the nearest millimeter and released. All other species are identified to species, enumerated, and released. Warm-water fish communities are evaluated using a rating system, whereas cold-water streams are not ranked but are determined to be meeting standards if at least 1% of the community is comprised of salmonines.

A habitat assessment developed by the MDEQ is used at each site and includes evaluations of nine parameters: (1) bottom substrate, (2) stream embeddedness or the degree to which boulders, rubble, logs, or gravel in run or riffle areas are surrounded or covered by fine sediments, (3) stream velocity versus depth, (4) flow stability, (5) bottom deposition, (6) habitat diversity, defined as the number of pools, riffles, runs, and bends, (7) bank stability, (8) bank vegetative stability, and (9) stream side cover. Each habitat parameter is given a relative numeric value for comparison to other Michigan streams. All of the parameter values are summarized for each site and assigned a relative habitat assessment value of excellent, good, fair, or poor. Macroinvertebrate samples are also collected at all sites using various techniques to obtain a representative sample. A total of 64 tributaries have been surveyed since 1991 and should be surveyed every five years.

The primary contacts for this study are William Taft of Michigan Department of Environmental Quality, Ed Baker of the MI DNR, and Mike Donofrio of the Keweenaw Bay Indian Community in L'Anse, Michigan.

8.4.5 Inland Lakes

Coldwater Lakes Ecosystem Monitoring - This project was initiated in Ontario in 1990 to experimentally evaluate the effects of logging on lake ecosystems, and to provide information about the effectiveness of shoreline buffer strips in preventing those effects. This project is part of a larger integrated program that also addresses timber management effects on cool-water lakes and cold-water streams in Ontario.

The research is based on detailed monitoring of the ecological responses to commercial timber harvest operations, of a small group of headwater lakes and their drainage basins. The study lakes are located 70 km northwest of Atikokan, Ontario and support populations of lake trout, common white sucker, minnows and hundreds of other aquatic plants and animal species. As part of the experiment, two lakes have been clear-cut to the shoreline and one lake retains a buffer of standing timber along the shoreline as described in the Timber Management Guidelines for the Protection of Fish Habitat. To detect ecosystem responses to timber harvest, five years of intensive, pre-harvest monitoring will be followed by five to seven years of post-harvest data collection. Parameters being monitored include meteorology, hydrology, sedimentation, lake Hydrodynamics, water temperature, oxygen levels, water chemistry, phytoplankton and zooplankton populations, aquatic insect communities, fish populations, and watershed characteristics.

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ADDENDUM 8-A - HABITAT REQUIREMENTS FOR LAKE TROUT, WHITEFISH, LAKE HERRING, AND WALLEYE

LAKE TROUT

Life stage	Habitat requirement	Source[1]
Egg	dissolved oxygen levels > 6 mg/l	FHD
	clean, large, rocky substrate composed of cobble and boulders	Marsden & Krueger (1991), Marsden and others (1995)
	interstices 20-120 cm	Kelso and others (1995), Marsden and others (1995)
	water depth of 0.5-4.5 m	Kelso and others (1995)
Juvenile	hatching time April through early July	Peck (1982), Bronte and others (1995)
	sand substrate for age-0 lake trout	Peck (1982), Bronte and others (1995)
	age-0 found in 4-60 m	Peck (1982), Bronte and others (1995)
	< 20 m of water through July	Bronte and others (1995)
	< 10 m of water through July	Peck (1982)
	prefer deep water	FHD
	Mysis important food source	FHD, Bronte and others (1995)
	invertebrates and small fish primary food	FHD
	preferred temperature 11.7°C for yearlings	FHD
	preferred temperatures < 15°C for age-0	Peck (1982)
	upper lethal temperature 23.5oC	FHD
Non-spawning adult	distributed throughout waters < 92 m deep	FHD
	older lean lake trout become pelagic	FHD
	siscowets distributed throughout waters > 55 m deep	
	most lake trout have home range of about 80 km	FHD
	siscowets spend most of time in waters < 4.5°C	FHD
	deepwater ciscoes, sculpins, and terrestrial insects important prey items	
	feed almost exclusively on fish	
	humpers found on reefs near Isle Royale, Caribou Is., and Superior Shoal	FHD
	preferred water temperature 4-18°C	FHD
	usually solitary except during spawning season	FHD

Lake Trout continued

Life stage	Habitat requirement	Source[1]
	dissolved oxygen concentrations > 6 mg/l	FHD
	humpers spawn August-September near tops of reefs as shallow as 18 m	FHD
	adult lean trout return to same spawning site in successive seasons	FHD
Spawning adult	siscowets likely spawn June through November	FHD
	lean trout spawn late September through early November	FHD
	most lean trout spawning occurs mid to late October	FHD
	siscowet spawn in waters > 90 m deep	FHD
	most spawning in lakes, but some in streams	FHD
	lean trout spawning occurs in waters of 0.5-37 m deep	FHD
	critical spawning temperature various from 4.5-14^{o}C	FHD

Lake Whitefish

Life stage	Habitat requirement	Source[1]
Egg	eggs hatch from March to May	FHD
	incubation period of 120-140 days at 0.5-1.7^{o}C	FHD
Juvenile	age-0 fish associated with the 17^{o}C isotherm	FHD
Non-spawning adult	distributed from inshore area out to waters < 55 m deep	FHD
	primarily bottom feeder	FHD
	most fish live within a 40 km home range	FHD
	travel in schools	FHD
	feeding usually occurs in soft bottom areas	

Lake Whitefish continued

Life stage	Habitat requirement	Source[1]
Spawning adult	spawn on sand, gravel, and rock in water of 2-23 m deep	FHD
	most spawning takes place during November to early December	FHD
	spawning occurs at temperatures of 0.5-5.5°C	FHD

Lake Herring

Life stage	Habitat requirement	Source[1]
Egg	incubation takes 111-125 days at 3.3-2.4°C	FHD
Juvenile	algae, small copepods, and cladocerans first food of larva	FHD
	predominately plankton feeders, but also feed on smelt and other fish	FHD, Link and others (1995), Hoff and others (1997)
	important food of lean lake trout	FHD
Non-spawning adult	predominately plankton feeders, but also feed on smelt	Link and others (1995), Hoff and others (1997)
	important prey item of lean lake trout	FHD
	dissolved oxygen > 3-4 ppm	FHD
	prefer temperatures < 15-17°C	FHD
	mainly pelagic	
	strong schooling behavior	FHD
Spawning adult	spawn in late fall, typically late November through December	
	spawn at temperatures of 1-5°C	FHD
	spawning occurs in shoal areas as well as in water of 43-46 m deep	FHD
	spawning occurs over most types of substrates	FHD
	spawning takes place some distance from the bottom, as far as 14 m from the surface of the water	

Walleye

Life stage	Habitat requirement	Source[1]
Egg	incubation 14-21 days at 8-15°C	FHD
	optimum temperatures were 6-12°C for fertilization & 9-15°C for incubation	FHD
	survival best on clean gravel and rubble substrate of 2.5-15 cm diameter	FHD
	survival good on mats of vegetation with adequate water circulation	FHD
	poor survival on soft muck and detritus	FHD
	dissolved oxygen > 5 mg/l	FHD
	temperatures < 19°C	FHD
Larva	fry eat zooplankton and insects and start to eat fish at 1.5-2.5 cm long	FHD
	optimal temperature for growth of age-0 fish is 19-25°C	FHD
	optimum temperature for fry survival is 15-21°C	FHD
	fry become benthic at 20-35 mm long, and inhabit water of 0.3-1.2 m deep	FHD
	found in deep or turbid water, or in near substrate and under any cover in day	FHD
	no growth at < 12°C or > 29°C	FHD
	upper lethal temperature 31-33°C	FHD
	dissolved oxygen > 5 mg/l	FHD
Non-spawning adult	fish live in shallow water where have sufficient shelter or turbidity to shield eyes	FHD
	optimum range for dissolved solids 40-80 mg/l	FHD
	consume smelt, shiners, and small herring	FHD
	preferred temperature is 22-23°C	FHD
	upper lethal temperature limit is 33-34°C	FHD
	crepuscular or nocturnal feeding habits	FHD
	dissolved oxygen > 3 mg/l, preferred is > 6 mg/l, lethal is 1 mg/l	FHD
	pH of 6-9	FHD
	tolerant of relatively large amounts of suspended and dissolved organic solids	FHD
	no growth at temperatures < 12°C	FHD
Spawning adult	move long distances after spawning	Schram and others (1992)
	do not spawn at pH < 4	FHD
	spawn in clean, hard substrate mainly, but also sand, vegetation, and sticks	FHD
	spawning occurs at 5-11°C	FHD
	do home to spawning areas	FHD
	spawn in rivers	FHD

[1]FHD = Fish Habitat Database created by the Habitat Advisory Board of the Great Lakes Fishery Commission.