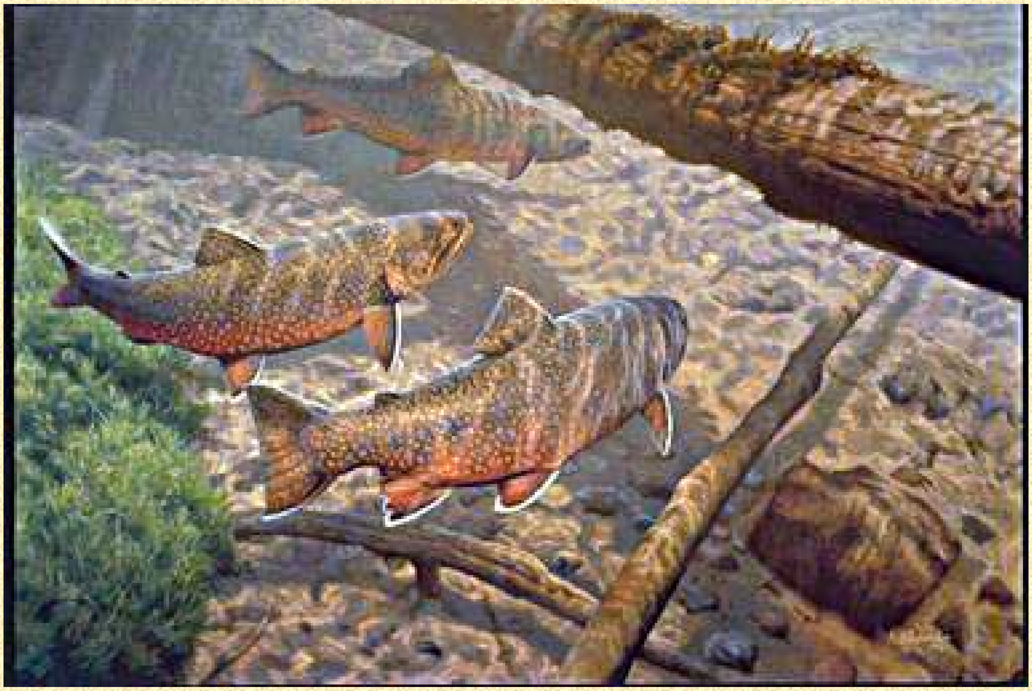
# STATUS OF BROOK TROUT IN LAKE SUPERIOR



prepared for the
**Lake Superior Technical Committee**
by

**The Brook Trout Subcommittee**

---

**Edited by:**

Lee E. Newman

U.S. Fish and Wildlife Service
Ashland Fishery Resources Office
2800 Lake Shore Drive East, Suite B.
Ashland, WI.

Robert B. Dubois

Wisconsin Department of Natural Resources
Bureau of Research
6250 South Ranger Road
P.O. Box 125
Brule, WI.

**March, 1996**

---

## TABLE OF CONTENTS

---

## INTRODUCTION

Fish-community objectives were established for Lake Superior (Busiahn 1990) in response to A Joint Strategic Plan for Management of Great Lakes Fisheries (Great Lakes Fishery Commission 1980). In part, the fish community objectives set goals to; "re-establish depleted stocks of native species such as the lake sturgeon, brook trout and walleye."

In 1993, the Lake Superior Technical Committee (LSTC) created a subcommittee on brook trout (*Salvelinus fontinalis)* in Lake Superior (Appendices1, and 2). One specific charge to the Brook Trout

Subcommittee was to prepare a report on the status of brook trout stocks in Lake Superior. This report is submitted in response to that charge.

## HISTORY

Early European settlers to the Lake Superior area called the large form of Lake Superior native brook trout a "coaster" because of its preference for shoreline habitat in the lake. In this report, we employ the definition of coaster used by Becker (1983) as "any brook trout that spends part of its life in Lake Superior". In the past decade, advances in fisheries technology have provided new insights in understanding the importance of unique fish stocks at the population level. While the coaster has still not been described by genetic analysis, biologists now appreciate that the Lake Superior coaster population (s) may be unique and comprise an "evolutionarily significant unit(s)" (Behnke 1994) and, as such, require consideration as a discrete group.

By the early 1900's, coaster stocks in Lake Superior were reduced to scattered, small remnants (Hansen 1994). Since then, they have received limited attention from fisheries managers. The coaster has never been described as a separate species or subspecies of brook trout. To date, no studies have been published that specifically describe the morphology, life cycle, population structure, mortality rates, or genetics of the Lake Superior coaster.

Information specific to the Lake Superior coaster must be derived from a small number of studies on surviving populations such as those of the Nipigon River and Isle Royale, and by gathering anecdotal information from historic newspapers, journals, and writings of early residents of the region. Reliable information specifically applying to coaster brook trout is limited.

### Historical Distribution

Brook trout and lake trout (*Salvelinus namaycush)* are known to be the two indigenous trout species to inhabit Lake Superior. However, the writings of early explorers and traders do not appear to differentiate between the species (Goodier 1981; Wilson 1990).

The first written record of lake-dwelling brook trout is found in Louis Agassiz's writings of his trip along Superior's north coast in 1848 (Wilson 1990). The Canadian Government Overseer for Fisheries on Lake Superior noted speckled trout (a commonly used name for brook trout) as being present in great numbers in the creeks and large rivers of Superior's north shore in his report of 1860 (Goodier 1981). By these dates however, fur trading settlements had probably been incidentally netting coaster brook trout along with lake trout, whitefish (*Coregonus clupeaformis)*, and herring (*Coregonus artedi)* to supplement winter food supplies for over 100 years. Native indigenous peoples undoubtedly utilized brook trout from their earliest habitation of the region as well.

In eastern Lake Superior the St. Mary's Rapids was a destination fishery for many anglers. From this hub of Great Lakes travel, gentlemen anglers hired boats and guides to explore the fishing opportunities provided by Superior's nearshore waters and many tributaries. Early writings of brook trout occurrence along Ontario's shore include the recorded travels of R. B. Roosevelt (1865). Roosevelt found brook trout to be abundant in the St. Mary's Rapids and up the coast from Gros Cap, including the Chippewa, Batchewana, Agawa and Nipigon Rivers. The total number of Ontario streams that once supported spawning populations of coaster brook trout probably exceeded the 45 documented for this report.

At least 25 rivers in Michigan are known to have supported runs of spawning coasters, as are 12 in Wisconsin and 9 in Minnesota.

The actual number of original spawning streams will never be known, however, most tributaries emptying into Lake Superior probably supported spawning populations. Shiras (1935) stated that prior to 1890, brook trout inhabited all the nearshore waters of Lake Superior for more than 1,000 miles. Exceptions to this were locations with pure sand beaches or steep, wave-washed cliffs. The fish preferred more sheltered waters. Every stream with cool temperatures supported resident trout and in the fall spawning coasters from the lake. Lake-dwelling coasters were generally found within 50 feet of the shore, or about islets and shoals close to shore.

This contention is supported by regional examples such as an article from the 13 June 1877 issue of the Bayfield County (WI) Press which states:

"The brook trout fishing in the vicinity of Bayfield (Wisconsin) can scarcely be equaled in any part of the world. There are not less than 50 trout streams of easy access from Bayfield, for both ladies and gentlemen; and the rock fishing for brook trout all along the shore, which is shielded by the Islands, affords the grandest sport that the disciples of Walton can find."

Waters (1987) suggested that historically, brook trout were probably present below the first barrier in all streams along Lake Superior's north shore. While commercial fisheries targeting coaster brook trout were known to exist around Isle Royale (Stan Sivertson, Duluth, MN, pers. commun.), in Wisconsin's Bois Brule River (O'Donnell 1944), and in the Nipigon River (Wilson 1990), early records of brook trout in commercial catches can't be determined as the trout catch was not separated by species. A reasonable assumption may be that many hundreds of barrels of these fish were sent to commercial markets (Roosevelt 1865; Wilson 1990).

During the late nineteenth century, sportsmen from all over North America were traveling to Lake Superior to fish for brook trout (Roosevelt 1865). Tales of abundant large trout drew more and more anglers to the many north shore rivers, and particularly the Nipigon.

The south shore of Superior from Sault Ste. Marie, Michigan west also supported coaster brook trout populations in association with many spawning streams. Sports magazines extolled the abundance of brook trout along this shoreline both in the lake and its coastal rivers (Opel 1986) with Wisconsin's Bois Brule (O'Donnell 1944), and Michigan's Salmon Trout often cited as the greatest fisheries.

Anecdotal comments by early reporters clearly indicated robust populations. Roosevelt (1985) stated that the finest brook trout fishing in the world was to be had in Lake Superior, with the same abundance of trout, averaging above two pounds, to be found nowhere else.

While it is likely that there is much truth in early accounts of coaster catches, it is also likely that the original fisheries were concentrated on stocks that were highly vulnerable because they occupied a very narrow band of Lake Superior shoreline habitat and specific, small spawning habitats in streams. Their high vulnerability to harvest in the lake and streams (Shiras 1935) coupled with their value as a sport and food fish suggest a likelihood of rapid depletion.

### The Twentieth Century to the Present

The exploitation of coaster stocks and demands on their habitat accelerated in the twentieth century. Settlement and industrial establishment in the early twentieth century had a local and lakewide effect on brook trout (Hansen 1994). The opening of the Lake Superior watershed by road, rail, and water removed protection by isolation. Hydroelectric dams, road and railway construction, logging, mining, commercial and sportfishing, all probably contributed to the decline. In some areas, sea lamprey (*Petromyzon marinus)* predation, which peaked in the late 1950's (Curtis 1990) and the introduction of Pacific salmon and rainbow trout (*Onchoryhychus mykiss*) and brown trout (*Salmo trutta)* were additional stressors that probably effected coaster abundance and distribution.

More and more anglers sought fishing opportunities by boat along the Lake Superior shore or by vehicle to once remote streams. The exploitation of these fisheries improved the documentation of coaster presence around the lake; however, that documentation was dominated by reports of declining numbers of fish or extirpated populations (Halpern and Schreiner 1992; Wilson 1991; and Goodier 1982).

Shiras (1935) reported that coasters were taken by anglers in great numbers as they gathered at the mouths of streams or lay in pools in the lower reaches. Shiras suggested that this practice and the setting of gillnets along the shore eventually extirpated lake dwelling brook trout in U.S. waters.

By 1950, viable coaster populations were reduced to the few remnants that exist today (Hansen 1994).

## CURRENT POPULATION STATUS

Description of current populations of coasters in Lake Superior is complicated by the lack of definitive knowledge of the origin of existing populations. Any individual coaster, or any coaster population could be derived from a native coaster stock, an introduced hatchery stock or from incidental downstream movement of a native headwater (non-migratory) stock. Ongoing studies of coaster brook trout genetics may clarify the genetic origin of some existing stocks.

Brook trout in Ontario waters were still common in the early part of the century. Anglers gathered at the larger accessible rivers such as the Nipigon, or fished the coastal bays and inlets in the spring and fall. Early records of coaster fisheries are related to the development of charter fishing in the 1930's, as expanding operators ventured further along the coast.

Interviews with elderly residents of Ontario coastal communities also produced valuable information. Much of what is known about coaster fisheries, in the last 20 years, is focused on the few remnant fisheries, in western Lake Superior, where some fish are still caught. The most recent records (1994-1995) of fisheries for coasters come from the western Lake Superior locations; the Nipigon River, which still supports a spawning run, and the Cypress, Gravel and Little Gravel Rivers (Hansen 1994), which have small annual runs. The number of individual fish using these streams is unknown. Throughout the remainder of Ontario's Lake Superior shoreline, coasters are caught in small numbers or occur occasionally in catch reports from many locations.

In Michigan, the Salmon Trout River is the last river on the U.S. mainland known to have a spawning run of coaster brook trout. Detailed harvest records maintained by the Huron Mountain Club show that fishing in the Salmon Trout declined after 1950. Electroshocking this river, in October of 1974, produced only 14 fish, most of which were under 31 cm (12 inches) (B. Miller, MI DNR, Baraga, pers. commun.).

Coasters are still occasionally reported from many other locations on the Michigan shoreline but the Michigan Department of Natural Resources (DNR) considers coaster abundance along the south shore of Lake Superior to be very low (B. Miller, MI DNR, Baraga, pers. commun.). Michigan's Isle Royale also maintains a few, perhaps several, remnant coaster brook trout populations that support a fishery of unknown size. Washington Harbor, Tobins Harbor and Big Siskiwit Bay (Slade 1994) are known to contain coasters. Washington and Grace Creeks on Isle Royale are reported to have spawning runs (Hansen 1994).

In Minnesota, the Little Marais River, has had a few brook trout migrating up to spawn (B. Borkholder, 1854 Authority, Fond du Lac, MN, Ceded Territory, pers. commun.) in recent years. In the past two years coasters appeared in some numbers (see results) in Lake Superior in the vicinity of the Grand Portage Indian Reservation. Returning adults were observed in two different tributary streams on the reservation in 1995. These coasters however, are known to be the result of reintroduction efforts by the Grand Portage Band and the U.S. Fish and Wildlife Service (R. Novitsky, Grand Portage Band, MN, pers. commun.).

In Wisconsin, no reproducing coaster populations are known. The last reports of fish thought to be native coasters came from the Bois Brule River in the 1940's (O'Donnell 1944). Several streams had runs of coasters during the late 1960's and early 1970's, but they, like occasional fish caught in Wisconsin waters in recent years, are thought to be the result of hatchery stockings (B. Swanson, WI DNR, Bayfield, pers. commun.).

## CURRENT MANAGEMENT STRATEGIES

### Ontario District Plans

(Sue Greenwood, Ont. MNR, Sault Ste. Marie)

**Thunder Bay District: 1988-2000**

This plan identifies brook trout existing in watersheds that drain into Lake Superior downstream from the first barrier to upstream migration. It states that 1,250 kilometers of stream have self-sustaining populations but does not differentiate between resident and anadromous fish. Management strategies include stocking in some rivers and rehabilitation of deteriorated stream habitats. Harvest regulations (for all of Ontario and all states) are summarized in Table 1 (not attached).

**Nipigon District: 1988-2000**

The protection and rehabilitation of brook trout in the Nipigon River and other nearby Lake Superior tributaries is a priority of the district's fisheries program (Wilson 1990). Plan strategies focused on bag limit reduction, open season reductions, minimum size restrictions, and possible stocking into the river following investigation into the genetic makeup of hatchery broodstock and wild river fish. Habitat management on the Nipigon River focused on protection of the spawning beds and nursery areas through a water-level-fluctuation agreement with Ontario Hydro.

**Wawa District: 1988- 2000**

The Wawa plan identifies coasters as part of the sportfish community for Lake Superior and the Michipicoten River. Salmonid habitat concerns focus on the tributaries to the lake. Acid precipitation, fluctuating water levels due to hydro dams, and the effects of mining and logging are cited as possible causes of degradation. Harvest management recommends maintaining the current three-fish daily catch limit. Fish community management recommends stocking brook trout at the Gargantua and Brule Harbours.

**Lake Superior Strategic Fisheries Plan: 1986-2000**

This plan does not have specific strategies or objectives for brook trout, but includes them in the broad objectives for sportfish. The specific strategies of the plan require the cooperation of the Districts for implementation where anadromous species are concerned. Brook trout may benefit from those strategies that focus on rehabilitative stocking, encouragement of commercial fishermen to target fish that are not of angler interest, encouragement of public involvement in decision making processes, provision of opportunities for anglers to learn about the biology and use of fisheries, insure that there is no net loss of aquatic habitat or desirable species, and that degraded habitats are rehabilitated.

## Michigan

(Barry Miller, MI DNR, Baraga)

In 1991, a strategic management plan was formulated for all species of fish in Lake Superior including coaster brook trout. The objective of the plan is to:

Manage the development and rehabilitation of coaster brook trout populations capable of producing 2000 fish annually by the year 2000 through planting of yearling fish. Rehabilitation efforts will be concentrated in the areas of historical coaster populations.

Since 1989, brook trout yearlings have been planted annually in the Big Iron River. Michigan DNR has not formulated other plans for stocking or research.

## Minnesota

(Ted Halpern, MN DNR, Duluth)

In 1992, responding to increased public sentiment for native species, and to provide for a high level of public involvement in the formulation of a plan for brook trout management for Lake Superior, a document entitled "Lake Superior Anadromous Brook Trout Plan: Recommendations for Plan Development" was prepared (Halpern and Schreiner 1992). This document included background materials on brook trout biology, reviewed recent experiences of agencies with brook trout in Lake Superior, specified the obstacles to the successful restoration of anadromous brook trout, and laid out a blueprint for developing an anadromous brook trout program. In light of the poor results of most efforts experienced by many agencies in the past, it stressed the need for a clear statement of goals, determined with public input; an approach that was experimental in nature, so that the program could be properly evaluated; and a set of criteria to determine whether or not the program was successful.

During the past two years, the Lake Superior Area of the MNDNR has completed a "Fisheries Management Plan For Minnesota Waters Of Lake Superior." This plan addresses the management of all species of interest, including brook trout, in the context of the Lake Superior ecosystem. With respect to brook trout, the goal of this plan is to determine whether rehabilitation of self-sustaining [coaster] brook trout stocks in the Minnesota waters of Lake Superior is feasible. To this end, the MNDNR will cooperate with other agencies on Lake Superior and participate in multi-agency projects to gather the information necessary to evaluate whether such restoration is realistic. Further, if there is potential for successful coaster rehabilitation and support from user groups, MNDNR will use the planning document cited above (Halpern and Schreiner 1992), and information gained from the brook trout working group to develop a rehabilitation plan.

## Wisconsin

(Bruce Swanson, WI DNR, Bayfield)

For the decade from 1988 to 1998, Wisconsin management plans for Lake Superior called for an experimental stocking program that would provide for an annual brook trout catch of 2000. Returns to the creel from the stocking program have been disappointing to date, and the program has been discontinued as of 1996. While not specifically targeting coasters, Wisconsin is conducting research and management activities to protect and restore instream and riparian habitat on Lake Superior tributaries that will benefit brook trout and other salmonines.

# COASTER BROOK TROUT BIOLOGY

### General Description

Brook trout are widely distributed throughout northeastern North America in well-oxygenated rivers, streams, and lakes having maximum water temperatures less than about 20º C. They are relatively short-lived, at least in those populations that have been well studied, with few individuals surviving beyond 5 years of age (Naiman et al. 1987; Bullen 1988). The maximum size is about 5 kg, but average sizes are much smaller especially in heavily exploited parts of their range.

Although most salmonines have populations that are to some extent anadromous, species differ greatly in their degree of anadromy, or the extent to which they exhibit anadromous traits (Rounsefell 1958). Strongly anadromous salmonids (obligatory anadromy) tend to have an extended period of residence in the sea, engage in oceanic migrations for great distances from their natal rivers, attain an advanced state of maturity at sea, invest sufficient energy in reproduction that they survive to spawn only once (semelparous), and have limited occurrences of freshwater forms. By contrast, less strongly anadromous salmonids (optional anadromy) are characterized by a tendency to have short periods of residence in the sea, remain in coastal or estuarine areas often close to natal streams, mature in freshwater, survive to spawn more than once (iteroparous), and have frequent occurrences of freshwater forms. Among salmonine genera, *Oncorhynchus* exhibits anadromous traits most strongly, *Salmo* is intermediate, and *Salvelinus* is least strongly anadromous. Throughout their range, brook trout typically exhibit either exclusive freshwater stream residence or only weakly anadromous traits.

Coaster brook trout were greatly reduced or eliminated from most areas of Lake Superior before scientific data about their populations could be collected. Although some reduced or remnant populations still exist in the Nipigon River system and other north shore areas of the lake, in the vicinity of Isle Royale, and perhaps in other isolated locations, these populations may either not be representative of most of the historic Lake Superior stocks or may be so reduced as to no longer exhibit traits typical of healthy populations. Additionally, the healthier populations appear to persist in remote and inaccessible areas and are therefore difficult to study. To understand the life history of the Lake Superior coaster, we must therefore collect and summarize as much information as possible from extant but reduced populations while also reconstructing their probable population characteristics from themes common to anadromous brook trout throughout their range.

## Reproduction

Brook trout spawn in late summer or autumn in freshwater streams. They mature over a wide range of ages and sizes with a greater proportion of males than females maturing at small sizes; size is a more important determinant of maturation than either age or growth rate (Naiman et al. 1987). Anadromous populations mature at a later age than nonanadromous populations, often not reaching maturity until their third summer (White 194; Dutil and Power 1980; Castonguary et al. 1982). Maturation of the gonads, which is dictated by photoperiod, occurs throughout the summer months. Timing of final maturation varies regionally with some populations spawning as late as December. Anadromous brook trout generally exhibit final gonad development upon their return to natal streams (Power 1980).

Anadromous brook trout are flexible in choosing spawning sites with lower river and river mouth areas (White 1940; Vladykov 1942; Slade 1994) and nearshore lacustrine and estuarine settings (Scott and Crossman 1973; Weed 1934) often being used where suitable conditions exist. Specific conditions required for redd locations include loose, silt-free gravel or coarse sand over strong groundwater seepage. Thermal stability seems to be a key factor in the use of spring seeps as redd sites. Water temperatures falling from the 40's to the 30's (degrees Fahrenheit) typically trigger spawning activity. Anadromous brook trout usually spawn each year once maturity is reached (Naiman et al. 1987).

Fecundity of anadromous brook trout is size-dependent and varies only slightly among stocks. However, fecundity of anadromous stocks is greater than that of nonanadromous stocks to an extent beyond that predicted from simple increases in body size (Naiman et al. 1987). Egg counts ranged from 444 to 1,857 per female for Ungava stocks (Power 1966); the Koksoak River, Quebec, stock seemed to increase fecundity with increasing fish size more rapidly than other stocks (Naiman et al. 1987). For the anadromous population in Riviere a la Truite, Quebec, egg numbers ranged from 138 to 2,305 per female (Montgomery et al. 1990). Female, Lake Nipigon strain brook trout broodstock at the Dorion, Ontario hatchery produce about 1,500 eggs per kg. of bodyweight.

Hatching is temperature and oxygen dependent. Time required for hatching ranges from 100 days at 5 C to about 50 days at 10 C (Scott and Crossman 1973). The upper lethal temperature limit for egg survival is 11.7 C (Scott and Crossman 1973). Upon hatching, alevins remain in the redd until the yolk sac is nearly fully absorbed. Emergence from the redds usually occurs in March, but may be earlier or later depending on latitude. Despite extensive observations, Naiman et al. (1987) were not able to detect any significant differences in choice of spawning sites, reproductive behavior, fertility, early ontogeny, or early life history between anadromous and nonanadromous stocks.

## Feeding

Brook trout are carnivorous, opportunistic feeders on a wide variety of organisms depending on their size and the availability of prey. Feeding behaviors of anadromous brook trout vary greatly from young to mature fish and riverine to sea environments. In rivers, the newly emerged young feed on Copepoda and Cladocera and soon add Diptera (mainly chironomids and simuliids), terrestrial insects, and the larvae of Trichoptera, Ephemeroptera, and Plecoptera to the diet during their first summer of life (White 1940; Bridges 1958; Miller 1974; Williams 1981). As they grow, aquatic insect larvae and terrestrial insects continue to form the dominant foods, but small fish become increasingly important in the diet as the growing brook trout reach 8 to 12 inches in length (Bridges 1958; Verreault and Courtois 1989; Montgomery et al. 1990). Annelids, crustaceans and mollusks are also occasionally eaten (Brasch et al. 1982; Verreault and Courtois 1989). Larger fish will occasionally take larger prey such as frogs and mice (Scott and Crossman 1973). Food choices in freshwater lakes are similar to those in rivers, with chironomids, gastropods, amphipods, coleopterans, cladocerans, ephemeropterans, trichopterans, and fish forming the major components of the diet (Power 1966). Brook trout are voracious feeders, leading Scott and Crossman (1973) to comment that the list of organisms eaten is astonishing and suggestive that they will eat anything their mouths can accommodate.

There are no data to describe the diet of coaster brook trout in Lake Superior. Miller (1968, MI DNR, unpublished data) examined the stomachs of a small sample of hatchery brook trout that had been planted in Keweenaw Bay, Michigan. He found that isopods, amphipods, gastropods, a variety of aquatic insects (mostly Diptera), and fish primarily sticklebacks, (*Gasterosteidae)*and sculpins (*Cottus*) were the dominant food items. Coaster brook trout in Lake Superior likely fed opportunistically on whatever small fish species and arthropods that were available in nearshore areas.

Significant qualitative and quantitative changes in the forage base of nearshore waters have occurred since the late 1800's (MacCallum and Selgeby 1987; Hansen 1994) when coasters were last abundant in Lake Superior. There is also now a much more diverse predator complex exerting pressure on available forage. However, these predators appear to be less strongly tied to nearshore areas than are coasters, which may minimize the severity of direct competition for food in the lake.

## Movements

The movement pattern characteristic of anadromous salmonines includes hatching and rearing of young in natal streams, migration from these streams as smolts at ages that vary among species down to a large lake or the sea (functionally equivalent habitats), movements during the growth phase in the sea that are usually unknown or poorly described for most species, and return to the natal streams for spawning by mature adults. There is virtually nothing known about the movements of anadromous brook trout in Lake Superior beyond the assumption that they generally fit into the above model. For sea-run populations that have been studied, downstream migration was characterized by the sudden movement, usually during spring, of primarily 2 to 4-year-old smolts (we follow Randall et al. (1987) in using the term "smolt" for emigrating juvenile brook trout although we recognize that because of life history differences between the charrs and Atlantic and Pacific salmon, the proper terminology to use is questionable (Johnson 1980)). These fish then maintained a coastal sea residence for just 1-5 months before returning to the natal stream (White 1940; Wilder 1952; Dutil and Power 1980; Castonguay et al. 1982; Montgomery et al. 1990). A variety of environmental cues for movement have been suggested including temperature, spring flooding, lunar cycles, tides and migrations by other species (Naiman et al 1987; Montgomery et al. 1983), but rises in river discharge appear to trigger most movements (White 1940; Montgomery et al. 1990). Anadromous populations of brook trout often live sympatrically with resident forms (Randall et al. 1987). It is not clear how and to what extent these life history differences between forms are influenced by genetics, the environment, and chance.

Sea-run brook trout usually made relatively short upriver migrations during late summer or autumn. Maximum distances traveled to spawning areas were between 30 and 50 km in the Moisie and St. Jean Rivers (MacGregor 1973; Castonguay et al. 1982).

Movements within the ocean were quite limited for sea-run stocks; fish either remained in estuaries or in nearshore areas within 10 miles of their natal rivers (White 1942; Smith and Saunders 1958; Dutil and Power 1980; Naiman et al. 1987).

Straying to non-natal streams for short periods occurred (White 1942; Castonguay et al. 1982), but extensive straying was unusual (Gibson and Whoriskey 1980; Whoriskey et al. 1981; Naiman et al. 1987).

## Age and Growth

Personnel of the Michigan Department of Natural Resources (MIDNR) and U.S. Fish and Wildlife Service (Ashland, Wisconsin, Fishery Resources Office) have determined growth rates for coaster brook trout at Isle Royale by scale age and backcalculation of length-at-age. Mean lengths at each annulus were 112-113 mm at age I, 213-215 mm at age II, and 336-366 mm at age III. Growth rates appear to vary widely depending on the portion of life spent in the lake versus the stream.

Coaster brook trout of the Nipigon River, Ontario, have an unusually long life span. Spawners of ages III to V are common, and occasional trophy-size individuals may attain ages of VIII years. Nipigon River coasters reach sexual maturity at age III, when first-time spawning males average 401 mm and females average 457 mm (R. Swainson, OMNR, Nipigon, pers. commun.). Most of the spawning adults range from 1 to 2 kg, with an average of about 1.5 kg. The largest individuals may reach a weight of 4 kg.

In contrast to this age and maturation pattern in coasters, Becker (1983) describes inland populations:

*In Wisconsin, brook trout mature early in life. At Lawrence Creek, 5% of the males are mature at the end of the first summer of life; the smallest mature fish are about 89 mm (3.5in) long. Most females (about 80%) mature as yearlings, at minimum lengths of about 127 mm (5in).*

## Size Structure

Historical evidence suggests that coasters along the south shore of Lake Superior were smaller than those along the north shore of the lake. According to Shiras (1935), "the largest speckled trout taken on the south shore of Lake Superior prior to 1890 weighed 5.25 pounds; a much larger number varied from four to five pounds; and the minimum weight was about a pound." He went on to say that the immature trout do not enter the lake from the breeding streams (i.e. smolted) until they weigh about a pound. Shiras (1935) added that since 1900 speckled trout have been taken on the south shore that weighed more than 6.5 pounds. He attributed this increased weight to the decreased number of trout in relation to the food supply. Lanman (1847) described the weight of Lake Superior coasters as "varying from 10 to 40 ounces", but later mentions catching "boat-loads" of them at certain times that "averaged from three to four pounds in weight". Roosevelt (1865) stated that Lake Superior coasters averaged more than two pounds, but added significantly that those on the southern shore averaged a pound while those along the northern (Canadian) shore averaged fully two pounds in weight. Additionally, several articles from the *Bayfield County Press* from 1877 to 1880 indicate a size structure near Bayfield, Wisconsin, that ranged from one half pound to four pounds ten ounces and probably averaged well under 2 pounds. Any size differences that may have occurred between north shore and south shore areas of the lake could have been due to unique growth characteristics of genetically separate strains, to size selective commercial netting along the south shore, or to greater angling pressure along the more accessible south shore that led to a reduced size structure.

Shiras' (1935) statement that smolts weighed about a pound is at odds with all other available information on anadromous brook trout smolts. Smolts from populations that have been well studied out-migrated at an average size less than 8 inches in total length (less than one half pound), which is more typical of other anadromous salmonids (Wilder 1952; Dutil and Power 1980; Castonguay et al. 1982;

Montgomery et al. 1990).

## Community Ecology

There is some direct evidence to indicate that Lake Superior coasters can coexist with exotic salmonines. In the Nipigon River, Ontario, coasters spawn successfully near coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), rainbow trout, and brown trout, as well as adjacent to their native congener the lake trout (R. Swainson, OMNR, Nipigon, pers. commun.). Smaller streams in Ontario such as the Cypress, Gravel, and Little Gravel Rivers also have a suite of naturalized salmonines coexisting with coasters. Additionally, an unpublished set of stream salmonine population data of two-decades duration from Wisconsin tributaries to Lake Superior suggests that the recent (1970's) establishment of coho salmon in those streams has not measurably affected existing stream-resident brook trout populations (B. Swanson, WI DNR, Bayfield, pers. commun.).

However, some data pertaining to stream-resident brook trout exist that suggest that negative effects on coaster brook trout from competition with exotic salmonines are possible, at least during the riverine stage of their life history. Rose (1986) documented a growth reduction of sub-yearling brook trout in a Lake Superior tributary following emergence of rainbow trout in June. He suggested that such growth reductions could result from interspecific competition for food and space and that they may represent a mechanism by which brook trout could be excluded by rainbow trout from some areas. An historical anecdote by Shiras (1935) suggested that the introduction of rainbow trout may influence the survivorship of native brook trout in Lake Superior. This was the first recorded indication of interspecific competition involving coaster brook trout in Lake Superior.

Juvenile coho salmon may be the most serious competitive threat to brook trout in Lake Superior tributaries because of similar habitat preferences of the two species and the earlier emergence (2 - 3 weeks) and larger size at emergence of coho salmon (Fausch and White 1986). Moreover, in a laboratory study, Fausch and White (1986) found that coho salmon dominated brook trout of equal size and remarked that coho salmon should have an advantage over brook trout in Great Lakes tributaries when resources become limiting. Stauffer (1977) also reported data suggesting that when age 0 coho were abundant in three Lake Superior tributaries, numbers of brook trout were lower.

Cunjak and Green (1983) found that brook trout were displaced from preferred habitats when sympatric with rainbow trout in two Newfoundland streams. Additionally, encroachment by rainbow trout is thought to have contributed to reduced distributions of native brook trout since 1900 in streams in the southern Appalachian Mountains, but other factors were clearly involved as well (Moore et al. 1983; Larson and Moore 1985; Bivens et al. 1985).

Brown trout encroachment has also been associated with population reductions of brook trout. Waters (1983) reported an 88% reduction from 1965 to 1980 in the spring standing stock of brook trout in a Minnesota stream in which a burgeoning brown trout population had become established, but again, other habitat-related factors were involved. In the Ausable River, Michigan, brook trout (> 15 cm) were displaced from preferred habitats that were scarce when sympatric with brown trout (Fausch and White 1981). However, brook trout dominated brown trout of equal size in the laboratory (Fausch and White

1986).

Clearly, evidence from studies involving stream-resident brook trout leads to the conclusion that the potential for competitive interactions between coasters and several naturalized salmonid species warrants some concern. However, the reduction of coasters was well underway decades before competition with exotic salmonids might have come into play during the period from 1890 to 1930. It therefore appears doubtful that competition played a large role in reducing coaster brook trout and there is no direct evidence to suggest that this has happened along large areas of the Lake Superior shoreline.

An additional consideration is that well-documented reductions of brook trout have usually occurred in concert with habitat destruction, in marginal habitats, or near the periphery of their range, which according to Flebbe (1994) is an often overlooked kind of marginal habitat. Populations located within the heart of the species range where habitat conditions are generally not marginal, as is the case in general with Lake Superior tributaries, may be better able to coexist successfully with exotic salmonines. While it is certainly possible that a number of factors, including competition, combined to reduce coasters, we suggest that the role competition played was modest.

**Harvest**

Accurate harvest records for Lake Superior coasters are almost nonexistent. Bullen (1988) reported that records maintained by the Huron Mountain Club for the Salmon Trout River show a 3-year average harvest by club members of 267 fish during the late 1930's. Club records since 1969 show a small annual harvest of 14 to 30 fish. Numerous older accounts (e.g. Shiras (1935); Roosevelt (1985); Bayfield County Press articles during the late 1800's) mention dozens, even hundreds, of coasters being taken by various individuals or parties at certain times. A common theme running through these older accounts is that coasters were apparently not very difficult to catch and that anglers tended to keep whatever they could use.

## AREAS OF CONCERN

Although not entirely eliminated from Lake Superior, coaster brook trout have been eliminated from many areas and are greatly reduced in abundance relative to their probable historical condition. This loss was sharpest before the turn of the century but has apparently continued through relatively recent times. While the coaster form of brook trout has suffered the most conspicuous losses, stream resident brook trout populations are greatly reduced in the Lake Superior area as well.

Many factors have been implicated in the reduction of coaster brook trout including over-exploitation (angling, commercial and tribal netting), logging effects, other habitat losses including loss of spawning areas, pollution, loss of genetic diversity, man-made barriers to migration, and competition with exotic salmonines. Possibly several or all of these factors have worked in concert, or perhaps some influences, including some that may not have been widely discussed, were more important in some areas of the lake than others. Although we cannot be certain about the precise role these factors played in the decline of coasters, we must nonetheless examine their potential effects carefully, because the forces that contributed to the decline will likely also function to impede restoration.

## Overfishing

Overfishing has been frequently implicated as one of the primary factors in the reduction of coaster brook trout and a number of lines of evidence support this contention. First, brook trout are known to be highly vulnerable to angling and can be greatly reduced in localized areas with only modest angling effort (MacPhee 1966; Havey and Locke 1980). Anadromous brook trout throughout their range appear to be especially vulnerable to angling because of their habit of congregating in streams at certain times of the year for feeding, and before and during spawning. They would also have been easy targets for anglers while in the lake environment because of their close association with nearshore areas. With regard to the unexploited populations of both anadromous and non-anadromous brook trout of the Ungava region of Quebec, Power (1966) stated:

*"There is an abundance of large fish and the impression gained by casual observation, during the summer, is that the numbers are great. For example, anglers can go to many places and catch 20 to 30 trout of a pound or two in weight in an hour or less. The reason for this is that during the summer actively feeding trout move into fast water feeding on black fly larvae. In such places trout are particularly vulnerable to capture by angling. With little experience these feeding places can be recognized and angling effort concentrated in them. Casual estimates of abundance based on angling success in these favorable locations is very deceptive. During the same period very few trout can be caught in quiet stretches of the river or in lakes and it appears that most trout congregate where feeding is most favourable. Anglers fishing in these places could quickly and easily reduce substantially the numbers of large fish and if fishing pressure continued, deplete the population."*

Second, the limited historical record also implicates overfishing, especially in the spawning streams, in the decline of coaster brook trout from Lake Superior. Shiras (1935) stated that although anglers during the late 1800's apparently knew that their overharvest of coasters was destroying the fishery, they nonetheless continued with the onslaught believing that the extirpation of these fish was inevitable. The relevant portion of the Shiras account reads as follows:

"*It is a well-established fact that speckled trout never spawn in Lake Superior, but, like the salmon, leave a great body of water to breed in the headwaters of spring-fed streams. These trout begin gathering at the mouths of spawning streams early in August, lingering for several weeks there or in the deeper pools in the lower reaches of the streams. At such times the fishermen formerly visited the pools and were assured of easy success. Eventually this practice nearly exterminated this fine game fish along the south shore of the lake...Years ago the decrease was noticed, but nevertheless the pools were visited by anglers in greater numbers than before, some fishermen taking in a single day a hundred pounds of sluggish and inactive fish, and often salting down the surplus for winter use. In this onslaught others reluctantly joined, for, since the fishing in the open waters became poorer each season, they yielded on the theory that if the end was approaching they might as well have a share in the final distribution.*"

Similarly, Winchell (1880, cited in Smith and Moyle 1944), in lamenting the decline of coaster brook trout along the Minnesota north shore wrote:

"*The brook trout is an object of wanton destruction in northeastern Minnesota. This beautiful and universally admired species inhabits, in great numbers, the many small rivers flowing into Superior... One stream after another is visited. A camp is pitched beside each where it empties into the lake. Then for several days, perhaps a week, the river banks are lined with the creeping, stealthy forms of the fishermen throwing every temptation the ingenuity of man can devise before the eyes of the wary trout. By diligently and patiently continuing at their posts through every hour from daylight until evening, it is surprising if any fish are spared in the stream*."

Third, the present distribution of coaster brook trout in Lake Superior is consistent with the overfishing hypothesis. They have been virtually eliminated from areas easily accessible to large numbers of people and exist only in relatively unexploited areas such as some rivers along the north shore of Lake Superior, at Isle Royale, and in areas at least partially protected from angler harvest such as the privately controlled, Salmon Trout River in Michigan.

Fourth, there is growing evidence to support the theory that smolting and maturity (and hence growth) are physiologically opposed processes in anadromous salmonines (Thorpe 1987). Heavy exploitation favors early maturation of brook trout because larger, later-maturing fish have a higher risk of being harvested before they spawn than do early-maturing fish. Not only would over-exploitation favor the life history strategy of early maturation, which could reduce the tendency of the population to smolt, but additionally, if over-exploitation led to reduced densities in juvenile rearing areas, it would favor increased juvenile growth rates which could reduce the tendency to smolt. Supporting evidence for these phenomena in salmonines, although sketchy, is starting to accumulate. For example, Zalewski et al. (1985), using a resident, nonmigratory population of brown trout for experimental stocking, found that fish planted in the least productive of a range of habitats, where growth rates were lowest, did not mature there but smolted. Caswell et al. (1984) suggested that increased fishing pressure at sea caused an increase from 31% to 75% in male parr maturation in the Atlantic salmon of the Matamek River, Quebec. Thus, for brook trout, which lack a strong anadromous tendency under most circumstances, there is a theoretical basis, and some emerging evidence, for the idea that heavy exploitation could favor a shift toward exclusive freshwater residence at the expense of anadromy.

The evidence taken in aggregate therefore supports the conclusion that overfishing was probably the major factor in the decline of coaster brook trout in Lake Superior. Overfishing was capable of dealing a major blow to the population, the limited historical record affirms that it was responsible, the resulting distribution we see today is consistent with overfishing in the past, and a relevant theoretical argument is also consistent with the idea.

## Widespread Stocking of Domestic Strains

The genetic makeup of native brook trout populations throughout accessible parts of the Lake Superior basin has doubtlessly been altered substantially through breeding with domestic stocks which have been widely planted for many years. Domestic stocks have been strongly selected to favor fast growth and early maturation. Fast growth and early maturation appear to be directly opposed to smolting (Thorpe

1987). Thorpe et al. (1983) showed experimentally that the incidence of male Atlantic salmon that matured before smolting increased from 6.8 to 30.1% in three generations when rapidly developing fish were selected as brood stock. Thus the genetic contribution of domestic stocks may serve to reduce the tendency of an anadromous salmonine population to smolt. However, even if genetic contributions from domestic stocks did negatively affect the coaster population, such contributions would have come too late to have been the primary force in the decline.

However, it is possible that genetic influences from stocked strains may have functioned to inhibit the resurgence of the migratory trait in brook trout, at least in heavily stocked areas, and may continue to do so.

## Losses of Critical Habitat

Several types of habitat losses, mostly resulting from logging operations in the late 1800's, have been implicated in the decline of coasters. When forested watersheds within the Lake Superior basin were clear-cut near the turn of the century, the loss of forest cover in riparian areas must have caused widespread erosion and sedimentation of streams. Clear-cutting and the ensuing wildfires also resulted in reduced water storage and retention capacities in watersheds. Groundwater flows critical to brook trout survival and reproduction were reduced. Heding and Hacker (1960) reviewed the role of springs in brook trout reproduction and abundance:

*Detrimental land use practices, constructing dams on small streams, digging ponds, and creating small impoundments in spring fed areas of our trout streams all have a disastrous effect on the natural reproduction of trout....Springs are the "life blood" of our trout streams. Destroy that "life" in a trout stream and it's gone-forever.*

Additionally, many streams were used to transport large numbers of logs downstream (Harmon et al. 1986). This was accomplished by building logging dams (also known as splash dams) in strategic areas. After the resulting impoundments were filled with logs, the dams were breached sending a massive flow of logs and water downstream. This surge of material undoubtedly damaged stream banks and other existing habitat. Furthermore, the practice of snagging (removal of large logs and rootwads from stream channels) was in common use to create unobstructed channels for the quick transport of logs. Scientists now know that such large woody debris performs a crucial function in the creation of habitat for fish (Harmon et al. 1986). The extent of loss to brook trout populations from habitat damage from forest clearing (sedimentation, warming of water, loss of instream woody cover, damaged stream banks, reduction of critical ground water flows) must have been substantial, but cannot be quantified.

Logging dams built during the 1890's, although short-term, apparently represented the only significant sources of man-made blockage to south shore streams that could have functioned to reduce the migratory component of brook trout, particularly from larger streams. The Bois Brule River, which historically was one of the more important coaster streams in Wisconsin, is known to have been used for log driving for a number of years (DuBois and Pratt 1994). These dams may have blocked coaster migrations at critical times in some streams. However, logging dams alone do not seem to be a sufficient cause to explain the virtual loss of coaster brook trout from the south shore waters of Lake Superior and they have not been used for many decades. Coasters would have migrated when dams weren't in place or could have used nearby, undammed streams. By the time logging dams would have become a factor (late 1890's), coasters populations, especially near areas of substantial human habitation, were by most accounts already greatly reduced.

Other forms of habitat damage probably also occurred, including spawning area losses and altered flow regimes. While unquestionably negative to all brook trout it seems unlikely that this damage would have functioned to decimate the migratory component of brook trout. Also, the timing of habitat loss is not consistent with the timing of coaster reduction, with much of the latter occurring well before the era of intensive logging. The composite picture of coaster losses from south shore areas depicted by most accounts is of an abrupt decline from the 1860's through the 1880's, with a continual but apparently less abrupt further decline thereafter. Coasters were still occasionally taken in some south shore areas of the lake up until at least the 1930's or 40's, long after habitat losses had occurred. Therefore, most forms of habitat loss were probably not major factors in the decline of coasters, but migration route blockage by logging dams combined with other types of habitat damage may have contributed to the loss of already reduced coaster populations in some streams.

### Competition with Exotic Salmonines

It seems probable that some overlap of habitat use and competition would occur between coasters and salmonines in Lake Superior and its tributaries. However, existing information regarding the competitive relationship between coaster brook trout and exotic (introduced) salmonines is so limited and of such doubtful applicability that it may have little value. The extent or severity of competition with any one, or any combination of salmonines in a habitat is unknown.

## PROPAGATION AND STOCKING OF COASTER BROOK TROUT

### Stocks Available

At this time, no Lake Superior native strain of brook trout is held in any hatchery. Ontario MNR does maintain a broodstock derived from gametes collected from wild parents in Lake Nipigon in 1985. The genetic relationship of the Nipigon strain to Lake Superior coasters is unknown, but they are known to have significant genetic differences from some domestic broodstocks (Danzman et al. 1991). This Nipigon strain broodstock is held at the Dorion (Ontario) Fish Culture Center. The product of this broodstock has, and continues to be, widely stocked in Lake Superior and its tributaries.

Hatchery culture of the Nipigon strain brook trout is significantly different from domestic strains, largely due to the inherent "wildness" or wariness exhibited by Nipigons (J. Sagar, Ont. MNR, Dorion, pers. commun.). Care and feeding are also somewhat more difficult and mortality rates may be somewhat higher because of the "wild" characteristics. At Dorion, 85 % of hatchery reared Nipigon females are sexually mature at age $II^+$.

Nipigon strain brook trout reared in raceways at the Bayfield (WI) hatchery must be maintained at about 50% of densities at which domestics are produced (L. Nelson, WI DNR, Bayfield Hatchery, pers. commun.). Nipigons at the fingerling stage have also been noted to produce a heavier slime coating than domestic strains. Growth rates are slower for Nipigons, averaging 8 mm per month while domestics grow at 13 mm per month.

### Effectiveness of Current Stocking Programs

Smith and Moyle (1944), report that stocking of fingerling brook trout (probably domestic strains) in Lake Superior and the lower sections of some tributaries produced low rates of return to the creel. Reports of stocking success of Nipigon strain brook trout from Wisconsin, Minnesota, and Michigan in the past decade show production of some trophy size coasters, but overall return rates to the creel were low for both fingerlings and yearlings. No evidence has been seen that natural reproduction resulted from these stockings.

The cause of the poor returns in stocked Nipigons is not definitely known. Recent projects in Ontario (B. Hamilton, Ont. MNR Ret., Thunder Bay, pers. commun.) suggest that the life stage stocked may be important. In inland lakes in Ontario, changing from stocking Nipigon strain fingerlings to early stage fry proved the latter to be much more effective in producing fish to the catch, and also produced natural reproduction in many lakes where fingerling stocking for many years had not.

At the Grand Portage (MN) Indian Reservation, fertilized eggs stocked in natural substrate of streams, and early stage fry stocked in streams produced four successive year classes of Nipigons that emigrated to Lake Superior (R. Novitsky, Grand Portage Tribe, MN, pers. commun.). Sexually mature adults from these stockings returned to "natal" streams in October and November of 1995.

## RESEARCH NEEDS

The subcommittee on brook trout in Lake Superior (1994), prepared a prioritized list of research needs for the Lake Superior Technical Committee. The list was updated in February, 1996 and now includes:

1) Employ genetic analysis, morphology, meristic means, and behavioral studies to describe past and present coaster stocks in Lake Superior.

2) Identify the critical habitats and needs of coasters, such as groundwater upwellings, nursery areas, and forage bases. Develop a habitat suitability index to identify potential reintroduction sites.

3) Study the life history and habitat use of coaster brook trout populations on a complete life cycle basis (biological, life history, age, growth, feeding, spawning).

4) Evaluate current harvest and mortality rates.

5) Study and describe the competitive relationship between coaster brook trout and exotic salmonines in

Lake Superior and in spawning and nursery habitats.

## ACKNOWLEDGMENTS

All members of the subcommittee on brook trout in Lake Superior contributed to the production of this report. Regional sections were authored by Barry Miller, Sue Greenwood, Ted Halpern, and Bob DuBois. Rob Swainson, Bob Hamilton, Bruce Swanson, Lee Newman and Tom Doolittle contributed ideas and information to the Community Ecology and Biology sections. This research was supported in part with funds authorized by the Anadromous Fish Conservation Act (project WI-AFS-16), the Federal Aid in Sport Fish Restoration Act (project F-95-P), and the Wisconsin Department of Natural Resources. Valuable editorial help was provided by Jim Peck, Dick Schorfhaar, Mike Donofrio and Mike Gallinat. Chris Young and Corinne Heemsbergen assisted with summarizing information for several topic areas. Lu Anne Mieloszyk was invaluable in assembling and completing the report.

## LITERATURE CITED

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press. 1052 pp.

Behnke, R. 1994. Coaster brook trout and evolutionary "significance" (About Trout). Trout (Autumn 1994). Pp. 59-60.

Bivens, R. D., R. J. Strange, and D. C. Peterson. 1985. Current distribution of the native brook trout in the Appalachian region of Tennessee. J. Tenn. Acad. Sci. 60:101-105.

Brasch, J., J. McFadden, and S. Kmiotek. 1982. Brook trout - Life History, Ecology, and Management. Wis. Dep. Nat. Resour., Pub. 26-3600(82), Madison.

Bridges, C. H. 1958. A compendium of the life history and ecology of the eastern brook trout (*Salvelinus fontinalis*) (Mitchill). Mass. Div. Fish. Game. Fish. Bull. No. 23.

Bullen, W. H. 1988. Fisheries management plan for the Salmon Trout River, Marquette County, Michigan. Mich. Dep. Nat. Resour. Fish. Div. Tech. Rep. No. 88-7.

Busiahn, T. R. (Ed) 1990. Fish community objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 90-1. 23 pages.

Castonguay, M., G. J. Fitzgerald, and Y. Cote. 1982. Life history and movements of anadromous brook charr, *(Salvelinus fontinalis*), in the St. Jean River, Gaspe, Quebec. Can. J. Zool. 60:3084-3091.

Caswell, H., R. J. Naiman, and R. Morin. 1984. Evaluating the consequences of reproduction in complex salmonid life-cycles. Aquaculture 43:123-134.

Cunjak, R. A. and J. M. Green. 1983. Habitat utilization by brook char (*Salvelinus fontinalis*) and rainbow trout (*Salmo gairdneri*) in Newfoundland streams. Can. J. Zool. 61:1214-1219.

Curtis, G. L. 1990. Recovery of an offshore lake trout (*Salvelinus namaycush*) population in Eastern Lake Superior. J. Great Lakes Res. 16(2):279-287 Internat. Assoc. Great Lakes Res.

DuBois, R. B. and D. M. Pratt. 1994. History of the fishes of the Bois Brule River system, Wisconsin, with emphasis on the salmonids and their management. Trans. Wis. Acad. Sci., Arts and Lett. 82:33-71.

Danzman, R.G.; P.E. Ihssen and P.D.N. Hebert Genetic Discrimination of Wild and Hatchery Reared Brook Char, *Salvelinus fontinalis* (Mitchell) in Ontario Using Mitochondrial DNA Analysis. J. Fish. Biol.; 39(suppl. A):69-77. 1991. FR 37(4)

Dutil, J. D. and G. Power. 1980. Coastal populations of brook trout, (*Salvelinus fontinalis),* in Lac Guillaume-Delisle (Richmond Gulf) Quebec. Can. J. Zool. 58:1828-1835.

Fausch, K. D. and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a

Michigan stream. Can. J. Fish. Aquat. Sci. 38:1220-1227.

Fausch, K. D. and R. J. White. 1986. Competition among juveniles of coho salmon, brook trout, and brown trout in a laboratory stream, and implications for Great Lakes tributaries. Trans. Am. Fish. Soc. 15:363-381.

Flebbe, P. A. 1994. A regional view of the margin: Salmonid abundance and distribution in the southern Appalachian Mountains of North Carolina and Virginia. Trans. Am. Fish. Soc. 123:657-667.

Gibson, R. J. and F. G. Whoriskey. 1980. An experiment to induce anadromy in wild brook trout in a Quebec river on the north shore of the Gulf of St. Lawrence. Naturaliste Can. 107:101-110.

Goodier, J.L. 1981. Native lake trout stocks in the Canadian waters of Lake Superior prior to 1955. Masters Thesis, Dept. Of Zoology and Inst. For Env. Studies, University of Toronto.

Goodier, J. L. 1982. The Fish and Fishes of Canadian Lake Superior. Institute for Environmental Studies, University of Toronto and Ontario Ministry of Natural Resources.

Goodyear, C.D., T.A.Edsall, Ormsby Dempsey, G.D. Moss and P.E.Polanski. 1982. Atlas of spawning and nursery areas of Great Lakes Fishes. Vol.II, Lake Superior. U.S. Fish. Wild. Serv., FWS/OBS-82/52: 122 pp.

Halpern, T. And D. Schreiner. 1992. Lake Superior anadromous brook trout plan: recommendations for plan development. Minn. Dept. Nat. Res. 15 pp.

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

Harmon, M. E. and 12 others. 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133-302.

Heding, R. And V. Hacker. 1960. A trout's thermostat; springs. Wis. Cons. Bull. 25(5):19-22

Havey, K. A. and D. O. Locke. 1980. Rapid exploitation of hatchery-reared brook trout by ice fishermen in a Maine lake. Trans. Am. Fish. Soc. 109:282-286.

Johnson, L. 1980. The Arctic charr, (*Salvelinus alpinus*). Pages 15-98 *in* E. K. Balon, ed. Charrs: salmonid fishes of the genus *(Salvelinus)*. Dr. W. Junk, The Hague, The Netherlands.

Lanman, C. 1847. A summer in the wilderness; embracing a canoe voyage up the Mississippi and around Lake Superior. D. Appleton & Co., New York. 208 p.

Larson, G. L. and S. E. Moore. 1985. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian Mountains. Trans. Am. Fish. Soc. 114:195-203.

MacCallum, W. R. and J. H. Selgeby. 1987. Lake Superior revisited 1984. Can. J. Fish. Aquat. Sci. 44 (Supplement 2):23-36.

MacGregor, R. B. 1973. Age, growth, and fecundity relationships of anadromous brook trout, *(Salvelinus fontinalis)* (Mitchill), in the Moisie River, Quebec. Undergrad. Hon. Thesis, Univ. Waterloo, Ontario.

MacPhee, C. 1966. Influence of differential angling mortality and stream gradient on fish abundance in a trout-sculpin biotope. Trans. Am. Fish. Soc. 95:381-387.

Miller, B. R. 1968. Stomach analysis of brook trout released in Keweenaw Bay, Baraga County, Michigan. Unpublished Report filed at Mich. Dept. Conserv., Fish Div., Baraga.

Miller, J.M. 1974. The food of brook trout (*Salvelinus fontinalis)* (Mitchill) fry from different subsections of Lawrence Creek, Wisconsin. Trans. Am. Fish. Soc. 103:130-34.

Montgomery, W. L., S. D. McCormick, R. J. Naiman, F. G. Whoriskey, and G. A. Black. 1983. Spring migratory synchrony of salmonid, catostomid and cyprinid fishes in Riviere a la Truite, Quebec. Can. J. Zool. 61:2495-2502.

Montgomery, W. L., S. D. McCormick, R. J. Naiman, F. G. Whoriskey, and G. A. Black. 1990. Anadromous behaviour of brook charr (*Salvelinus fontinalis*) in the Moisie River, Quebec. Pol. Arch. Hydrobiol. 37:43-61.

Moore, S. E., B. Ridley, and G. L. Larson. 1983. Standing crops of brook trout concurrent with removal of rainbow trout from selected streams in Great Smoky Mountain National Park. N. Am. J. Fish. Manage. 3:72-80.

Naiman, R. J., S. D. McCormick, W. L. Montgomery, and R. Morin. 1987. Anadromous brook charr, *(Salvelinus fontinalis)*: opportunities and constraints for population enhancement. Marine Fisheries Review 49:1-13.

O'Donnell, D. J. 1944. A history of fishing in the Brule River. Trans. Wis. Acad. Sci., Arts and Lett. 36:19-31.

Opel, F. 1986. Fishing in North America 1876-1910. Castle, a Division of Book Sales Inc., Seaucus, N.J.

Power, G. 1966. Observations on the speckled trout in Ungava. Naturaliste Can. 93:187-198.

Power, G. 1980. The brook charr, Salvelinus fontinalis. Pages 141-203 *in* E. K. Balon, ed. Charrs: salmonid fishes of the genus (*Salvelinus)*. Dr. W. Junk, The Hague, The Netherlands.

Randall, R. G., M. C. Healey, and J. B. Dempson. 1987. Variability in length of freshwater residence of salmon, trout, and char. Am. Fish. Soc. Symp. 1:27-41.

Roosevelt, R. B. 1865. Superior fishing - The striped bass, trout, and black bass of the northern states. Originally published by G.W. Carleton. Minnesota Historical Society Press. St. Paul. 1985. 310 pp.

Rose. G.A. 1986. Growth decline in subyearling brook trout (*Salvelinus fontinalis*) after emergence of rainbow trout (*Salmo gairdneri*). Can. J. Fish. Aquat. Sci. 43:187-93.

Rounsefell, G. A. 1958. Anadromy in North American salmonidae. U. S. Fish and Wildl. Serv., Fishery Bull. 58(131):171-185.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa.

Shiras, G. 1935. Hunting wild life with camera and flashlight; a record of sixty-five years' visits to the woods and waters of North America. Chap. 20, The Huron Mountain District; Fishes of Lake Superior. National Geographic Society. Vol. 1, Lake Superior Region. Washington, D. C.

Slade, J.W. 1994. A pilot study on the status of coaster brook trout in the waters of Isle Royale National Park, Lake Superior. Unpublished report, U.S. Fish and Wildlife Service. Ashland, WI.

Smith, L. L. and J. B. Moyle. 1944. A biological survey and fishery management plan for the streams of the Lake Superior north shore watershed. Min. Dep. Cons. Tech. Bull. No.1.

Smith, M. W. and J. W. Saunders. 1958. Movements of brook trout, (*Salvelinus fontinalis)*(Mitchill), between and within fresh and salt water. J. Fish. Res. Bd. Can. 15:1403-1449.

Staufer, Thomas M. 1977. Numbers of juvenile salmonids produced in five Lake Superior Tributaries and the effect of juvenile coho salmon on their numbers and growth, 1967-1974. MI DNR Fisheries Research Report No. 1846

Thorpe, J. E. 1987. Smolting versus residency: developmental conflict in salmonids. Am. Fish. Soc. Symp. 1:244-252.

Thorpe, J. E., R. I. G. Morgan, C. Talbot, and M. S. Miles. 1983. Inheritance of developmental rates in Atlantic salmon. Aquaculture 33:123-132.

Verreault, G. and R. Courtois. 1989. Changements saisonniers de l'alimentation de l'omble de fontaine anadrome (*Salvelinus fontinalis*) dans les rivieres Matapedia et Ristigouche (Quebec). Naturaliste Can. (Rev. Ecol. Syst.) 116:251-260.

Vladykov, V. D. 1942. Precision with which speckled trout (*Salvelinus fontinalis*) return to the same spawning grounds. Can. Field-Naturalist 56:134-136.

Waters, T. F. 1983. Replacement of brook trout by brown trout over 15 years in a Minnesota stream: production and abundance. Trans. Am. Fish. Soc. 112:137-147.

Waters, T. F. 1987. The Superior north shore. Univ. Of Minn. Press. Minneapolis. viv + 361 pp.

Weed, A. C. 1934. Notes on the sea trouts of Labrador. Copeia 3:127-133.

White, H. C. 1940. Life history of sea-running brook trout (*Salvelinus fontinalis*) of Moser River, N. S. J. Fish. Res. Bd. Can. 5:176-186.

White, H. C. 1942. Sea life of the brook trout (*Salvelinus fontinalis*). J. Fish. Res. Bd. Can. 5:471-473.

Whoriskey, F. G., R. J. Naiman, and W. L. Montgomery. 1981. Experimental sea ranching of brook trout, (*Salvelinus fontinalis*) Mitchill. J. Fish. Biol. 19:637-651.

Wilson, L. 1990. Historical literature review of the Nipigon area with emphasis on fisheries from 1654 to 1990. Ont. Min. Nat. Res. 178 pp.

Wilder, D. G. 1952. A comparative study of anadromous and freshwater populations of brook trout (*Salvelinus fontinalis)* (Mitchill). J. Fish. Res. Bd. Can. 9:169-203.

Williams, D.D. 1981. The first diets of post-emergent brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) alevins in a Quebec river. Can J. Fish. Aquat. Sci. 38:765-71.

Winchell, N.A. 1880. The geological and natural history survey of Minnesota. 8th Annual Report for the year 1879. St. Peter, 183 plus iv pp.

Zalewski, M., P. Frankiewicz, and B. Brewinska. 1985. The factors limiting growth and survival of brown trout, (*Salmo trutta* m. *fario*) L., introduced to different types of streams. J. Fish. Biol. 27 (supplement A):59-73.

## APPENDIX 1.

## TERMS OF REFERENCE SUBCOMMITTEES OF

## THE LAKE SUPERIOR TECHNICAL COMMITTEE

TITLE: The Brook Trout Subcommittee

MEMBERSHIP: *Chairperson*-From any agency

*Members*-One representative from each fishery research and management agency, including at least, but not limited to, the Michigan, Minnesota, and Wisconsin Departments of Natural Resources, the Ontario Ministry of Natural Resources, the Great Lakes Indian Fish and Wildlife Commission, the Chippewa-Ottawa Treaty Fishery Management Authority, the United States Fish and Wildlife Service, and the National Biological Survey.

*Resource Persons*-As required from any agency or university.

RESPONSIBILITIES:

1-Membership of the subcommittee will be determined in accordance with the above criteria by invitation of the chairperson within ½ year of the appointment of the chairman.

2-Exchange of data and information about the species should be completed within one year of the formation of the subcommittee.

3-The status of the species and its component stocks, for use in developing a restoration goal and plan, should be completed within two years of the formation of the subcommittee.

4-An objective for restoration of the species, to be included in the Lake Superior Fish Community Objectives, should be completed within three years of the formation of the subcommittee.

5-A restoration or rehabilitation plan for the species should be completed within four years of the formation of the subcommittee.

6-A report on the status of the species in Lake Superior, for inclusion in the next revision of the State of the Lake Report, should be completed within five years of the formation of the subcommittee.

REPORTING:

The subcommittee chairperson or other designated individual will report annually on the progress of its activities at the Lake Superior Technical Committee's winter meeting.

FREQUENCY OF MEETINGS:

Meetings or teleconferences should be held as often as deemed necessary by the chairperson.

AGENCY COMMITMENTS:

Agencies are encouraged to commit employees and resources as a regular component of their work plans, in order to ensure accomplishment of subcommittee responsibilities.

## APPENDIX 2.

## MEMBERS

**Brian Borkholder**
**Fond Du Lac Ceded Territory**
**105 University Rd.**
**Clouquet, MN 55720**

**Mike Donofrio**
**Keweenaw Bay Indian Community**
**P.O. Box 10**
**L'Anse, MI 49946**

**Tom Doolittle**
**Bad River Band of**
**Lake Superior Chippewa**
**P.O. Box 39**
**Odanah, WI 54861**

**Dob Dubois, or Larry Nelson**
**(Alternate),Wisconsin**
**Department of**
**Natural Resources**
**Ranger Station Road**
**P.O. Box 125**
**Brule, WI 54820**

**Mike Gallinat, or Greg Fischer**
**(Alternate)**
**Red Cliff Band of Lake Superior**
**Chippewas**
**Red Cliff Fisheries Management**
**P.O. Box 529**
**Bayfield, WI 54814**

**Ken Gebhardt**
**Bay Mills Indian Community**
**Route 1 Box 313**
**Brimley MI, 49715**

**Sue Greenwood**
**Huron-Superior Management Unit**
**Ontario Ministry of Natural**
**Resources**
**875 Queen St. East**
**Sault Ste. Marie, ONT P6A-5L5**

**Ted Halpern**
**Minnesota Department of**
**Natural Resources**
**Lake Superior Fisheries**
**5351 N. Shore Drive**
**Duluth, MN 55804**

**Barry Miller**
**MI Department of Natural**
**Resources**
**427 US 41 North**
**Baraga, MI 49908**

**Larry Nelson**
**Wisconsin Department of Natural Resources**
**P.O. Box 589**
**Bayfield, WI 54814**

**Jack Oelfke**
**Isle Royale National Park**
**800 E. Lakeshore Dr.**
**Houghton, MI 49931**

**Lee Newman (Chairman)**
**US Fish and Wildlife Service**
**Ashland Fishery Resources Office**
**2800 Lake Shore E**
**Ashland, WI 54806**

**Rob Swainson**
**Ontario Ministry of Natural Resources**
**Box 970**
**Nipigon, Ontario POT 2JO**

**Rick Novitsky, or**
**Ray Johnson (Alternate)**
**Grand Portage Tribal Government**
**P.O. Box 428**
**Grand Portage, MN 55605**

---

**U.S. Fish and Wildlife Service Home Page**

**Ashland FRO Home Page**

**Region 3 Home Page**

---

**Return to Top**