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Lake Trout Rehabilitation in the Minnesota Waters of Lake Superior, 1962-2014

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Abstract

This paper synthesizes efforts from the last 52 years to rehabilitate Lake Trout *Salvelinus namaycush* in the Minnesota waters of Lake Superior. Lake Trout were once the keystone predator in four of the five Laurentian Great Lakes. Major declines in Lake Trout abundance were caused by overfishing, Sea Lamprey predation, interactions with non-indigenous species, and in some areas of the lakes, habitat degradation. By the early 1940s, Lake Trout were extirpated in all the Great Lakes except for Lake Superior, where some remnant offshore stocks remained. The Great Lakes Fishery Commission was formed in 1955 in an effort to rehabilitate Lake Trout stocks by controlling Sea Lamprey, facilitating fisheries research, and coordinating management activities among fishery agencies on the Great Lakes. Sea Lamprey control has been the cornerstone for successful Lake Trout rehabilitation in Lake Superior. Restrictive harvest regulations, stocking, and habitat protection have also contributed to successful Lake Trout rehabilitation. In Minnesota, Lake Trout rehabilitation efforts accelerated in the early 1960s when Sea Lamprey control implemented the use of lampricides in Lake Superior tributaries. In 1962, restrictive harvest regulations were imposed on both the commercial and sport fisheries, and intensive Lake Trout stocking programs began. Lake Trout abundance increased in response to these strategies and by the early 1980s the sport fish harvest, largely supported by stocked fish, was at very high levels. Natural reproduction of Lake Trout began to increase in the late 1980s as stocked fish reached maturity, and the abundance of wild spawners increased in response to successful Sea Lamprey control. Survival of stocked Lake Trout begin to decline in the early 1990s, and by the late 1990s the abundance of wild Lake Trout had surpassed that of stocked Lake Trout in much of Minnesota waters. Based on the increased abundance of wild Lake Trout, and the low contribution of hatchery-reared fish, stocking was discontinued along the upper Minnesota shore (MN-3) in 2003, and along the central shore (MN-2) in 2007. Stocking continued along the lower Minnesota shore (MN-1), but was greatly reduced in 2007. Total catch and catch rate of Lake Trout in the sport fishery are at very high levels and wild fish now comprise over 95% of the total Lake Trout catch from the upper and central shore, and over 75% from the lower shore. In response to increased wild Lake Trout abundance, an Expanded Assessment fishery open to commercial fishers was implemented along the upper shore in 2007 and along the central shore in 2010. No expansion along the lower shore was warranted given the high sport harvest and continued stocking. Lake Trout stocks in Minnesota waters are now at or near carrying capacity based on stock-recruitment and bioenergetics models. To sustain the successful rehabilitation of Lake Trout in Minnesota's portion of Lake Superior, fishery managers and the public must remain vigilant against threats from Sea Lamprey, overfishing, habitat degradation, and contamination. Sea Lamprey abundance must be controlled at present or lower levels to decrease Sea Lamprey induced mortality on Lake Trout. Sport and commercial harvest must be monitored and further restricted if Lake Trout mortality targets are exceeded. Habitat must be protected and contaminant levels must continue to decline. Lake Trout rehabilitation in Minnesota's portion of Lake Superior has required over half a century to achieve, and continuing the efforts listed above will be critical to maintain a self-sustaining Lake Trout fishery well into the future.

Introduction

Rehabilitation of Lake Trout *Salvelinus namaycush* in the Laurentian Great Lakes has been a major goal of fishery management agencies since Lake Trout stocks collapsed in each lake in the nineteenth and twentieth centuries. The causes and timing of Lake Trout collapse varied for each lake. However, it is widely accepted that overharvest in the early commercial fisheries, and predation by the non-indigenous Sea Lamprey *Petromyzon marinus* were major contributors to Lake Trout declines in all the lakes (Hansen 1999; Krueger and Ebener 2004; Muir et al. 2012).

To address the failing Great Lakes fishery, the governments of Canada and the United States formed the Convention on Great Lakes Fisheries (U.S. Department of State 1956), which is a treaty between both nations to establish the Great Lakes Fishery Commission (GLFC) with the major objectives to (1) control Sea Lamprey, (2) coordinate fisheries management among the various agencies, and (3) foster communication and research on fishery problems in the Great Lakes. Minnesota, seven other Great Lakes states, tribal governments, and the province of Ontario agreed to manage their portion of the Great Lakes in a cooperative manner facilitated by the GLFC. Because native Lake Trout were historically the keystone predator in the Great Lakes, and Sea Lamprey predation was a primary cause of catastrophic collapse of the stocks basin-wide, much of the attention was focused on controlling Sea Lamprey and rehabilitation of self-sustaining Lake Trout stocks. State, provincial, tribal and federal agencies worked together to form lake specific committees in the mid-1960s that coordinated management of the shared fisheries in each lake.

To formalize and better coordinate the cooperative management efforts throughout the Great Lakes basin, the participating fisheries management agencies in the GLFC developed *A Joint Strategic Plan for Management of Great Lakes Fisheries* (Great Lakes Fishery Commission 1981). Fish stock assessment, reporting, and management strategies were coordinated through interagency committees on each lake that addressed both policy (Lake Committees) and biological issues (Lake Technical Committees) (Figure 1). The Joint Strategic Plan has evolved, with the most recent version (Great Lakes Fishery Commission 1997) identifying four broad strategic areas: consensus, accountability, information sharing and ecosystem management (Gaden et al. 2009).

To address rehabilitation of Lake Trout in Lake Superior, biologists from each fish management agency participated on a committee originally called the Lake Superior Lake Trout Technical Committee (LSLTTC), which became the more general Lake Superior Technical Committee (LSTC) in 1980. This committee developed standardized assessment techniques, allocated hatchery-reared Lake Trout, developed harvest regulations and monitored the effectiveness of the Sea Lamprey control program.

Since the early 1960s, significant progress has been made in the rehabilitation of Lake Trout in Lake Superior through the cooperative efforts of all Lake Superior fishery management agencies (Hansen et al. 1995b; Krueger and Ebener 2004; Muir et al. 2012). Lake Trout stocks are now self-sustaining throughout most of the lake and supplemental stocking has been discontinued in all but a few isolated areas (Schreiner and Schram 1997; Sitar et al. 2010). A case history describing the lake-wide rehabilitation of Lake Superior Lake Trout (Hansen et al. 1995b) and additional papers describing rehabilitation of Lake Trout in specific areas of Lake Superior are included in the RESTORE volume (Selgeby et al. 1995b). Although general information on rehabilitation of Lake Trout in Minnesota’ s portion of Lake Superior is included in the lake-wide papers, no comprehensive description of Lake Trout rehabilitation specific only to Minnesota has been compiled.

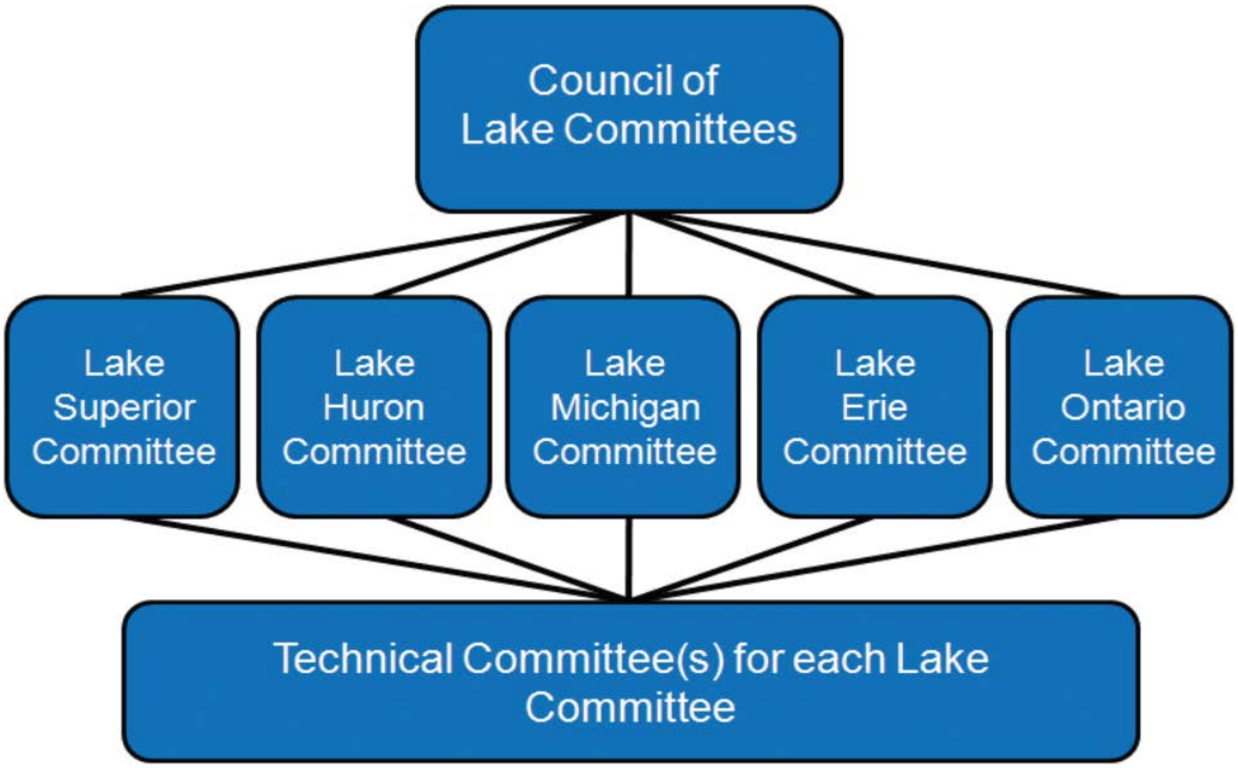


FIGURE 1. Generalized structure of GLFC Lake Committees (Gaden et al. 2009).

Most early papers describing the status and rehabilitation of Lake Trout in Lake Superior refer to Michigan and Wisconsin waters, but little information on Minnesota stocks in the peer reviewed literature prior to 1990 was recorded. This omission may be due in part to the location of the Bureau of Commercial Fisheries Office in Ashland WI (presently the US Geological Survey (USGS) Lake Superior Biological Station) where much of the early assessment and research occurred in Michigan and Wisconsin waters, the previous experience that Michigan Department of Natural Resources (MIDNR) had in the lower lakes with declining Lake Trout stocks, the relative importance of the Great Lakes fishery to Michigan and Wisconsin as compared to Minnesota, and the much slower rate of Lake Trout rehabilitation in Minnesota. While specific observations and timing of Lake Trout rehabilitation may vary between Lake Superior jurisdictions, inferences on Lake Trout rehabilitation can be made for the Minnesota fishery based on the observations and research reported from the early Michigan and Wisconsin studies.

This paper synthesizes efforts from the last 52 years to rehabilitate Lake Trout in the Minnesota waters of Lake Superior. We include a brief description of Lake Trout forms found in Minnesota, a history of Lake Trout exploitation, potential causes of Lake Trout stock collapse, management actions and strategies used to rehabilitate Lake Trout, progress achieved toward Lake Trout rehabilitation, and conclude with present status and future management considerations for Lake Trout in Minnesota's portion of Lake Superior. Much of the historical information on exploitation and causes of the Lake Trout decline came from GLFC publications, meeting notes from GLFC Lake Committee meetings, and internal MNDNR file documents. Management actions to rehabilitate Lake Trout are summarized from strategies outlined in a series of MNDNR Lake Superior Fishery Management plans, LSTC Lake Trout Restoration Plans, GLFC State of the Lake Reports and internal MNDNR file documents. Progress toward Lake Trout restoration has been documented by analysis of MNDNR Lake Superior assessment data including both creel surveys and fishery independent surveys (spring and fall large mesh gill net, and summer small mesh gill net surveys). Future management considerations are based on the current status of the Lake Trout stocks and the opportunities and threats that have potential to affect the long-term sustainability of the Lake Trout fishery in Minnesota's portion of Lake Superior.

We have documented the success of Lake Trout rehabilitation in the Minnesota waters of Lake Superior to help others learn strategies that worked, and avoid strategies that were not successful. This fishery is unique to the state and is one of very few fisheries world-wide for which production was restored from extremely low levels to near levels approaching historical production. The Lake Superior fishery is now one of the best Lake Trout fisheries in North America. It is important for future fisheries biologists and interested citizens to understand how difficult, expensive, and time-consuming the efforts were to achieve successful Lake Trout rehabilitation in Lake Superior. In addition, both commercial and sport fishers made major sacrifices to achieve this success. Much has been learned during rehabilitation of Lake Trout in Lake Superior and it is our belief that this document will serve as a useful tool for managers that are implementing similar Lake Trout rehabilitation programs in the lower Great Lakes.

Diversity of Lake Trout Forms

Up to 12 localized Lake Trout forms were described by aboriginals, early European settlers and a number of commercial fishing operators prior to the severe declines in Lake Superior Lake Trout stocks in the 1950s. These diverse forms had adapted to specific niches that they had inhabited since glaciation, and evolved recognizable phenotypic characteristics that were noted by early observers (Waters 1987; Krueger and Ihssen 1995; Muir et al. 2014).

Presently, three general forms of Lake Trout (Figure 2) are routinely described that inhabit Lake Superior: lean Lake Trout, Siscowet or "fat" Lake Trout, and Humper Lake Trout (Burnham-Curtis 1993; Krueger and Ihssen 1995; Moore and Bronte 2001; Bronte and Moore 2007). The "lean" form of Lake Trout is the form most commonly recognized by commercial fishing operators, anglers and biologists and is normally referred to as Lake Trout. In this paper, unless specifically stated, the term "Lake Trout" will refer to the lean Lake Trout form. Lean Lake Trout have a straight pointed snout, slender body and low fat content. Throughout Lake Superior lean Lake Trout are less abundant than the Siscowet form, but the lean form is more common in near-shore waters and makes up the majority of both the sport and commercial harvest. Lean Lake Trout typically inhabit near-shore waters at depths less than 80 m (262.5 ft.) or about 40 fathoms.

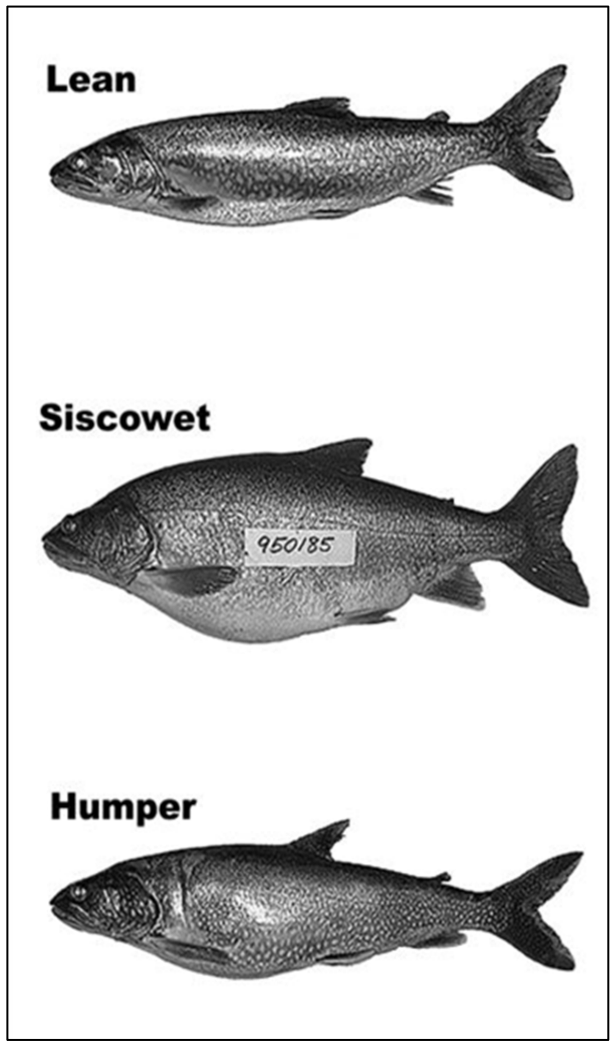


FIGURE 2. Three common Lake Trout forms found in Minnesota's portion of Lake Superior (from Moore and Bronte 2001).

The deep-water or “fat” form of Lake Trout is commonly referred to as Siscowet *Salvelinus namaycush siscowet* (Agassiz 1850). Siscowets have a convex snout, robust body and high fat content. Siscowets are normally found offshore at depths greater than 80 m (262.5 ft.) or 40 fathoms, but routinely exhibit diel vertical migration in search of prey (Hrabik et al. 2006; Stockwell et al. 2010; Pratt et al. 2015). Siscowets are approximately ten times as abundant as lean Lake Trout in Lake Superior and by far comprise the greatest biomass of top predators in the lake (Ebener 1995; Bronte et al. 2003; Sitar et al. 2010). Targeted assessments designed to monitor Siscowet abundance first began in the mid-1990s by all management agencies on the LSTC (Ebener 2001) and much has been discovered about this sub-species over the last 20 years. Information on Lake Superior is presently being compiled in a synthesis paper by members of the LSTC for publication by the GLFC, and a peer-reviewed journal (Pratt et al. 2015, in preparation). Although Siscowets are relatively common in the deep waters of Minnesota, there has been little fishing effort targeting them since the 1940s due to low market demand, and since the 1960s, high levels of PCBs and mercury found in their tissue.

Humpers are the least common Lake Trout form in Minnesota, with only a few specimens sampled in the Grand Portage area. Humpers are routinely found over isolated offshore shoals at depths of approximately 50 m surrounded by water greater than 100 m. In general, Humpers are more similar to Siscowets than leans, but have reduced levels of body fat, very thin body walls, a snout similar to a lean with a relatively large eye, and they mature at relatively small sizes. Some commercial fishers commonly refer to Humpers as “paper-bellies”. Those found in Minnesota waters likely strayed from areas close to Isle Royale where they are more commonly found (Muir et al. 2014).

Lake Trout Management Areas

Lake Superior is divided into Lake Trout management areas for planning and reporting purposes (Figure 3), (Smith et al. 1961; Hansen 1996). The size and distribution of management areas within each jurisdiction differs because Lake Trout stocks and the factors that affect them differ across the basin. Lake Trout management areas in the United States are also called statistical districts (or zones), which define the total area occupied by the various Lake Trout stocks found in Lake Superior. These statistical districts are composed of smaller statistical grids that are used to report commercial catch (Figure 4) (Smith et al. 1961). Management areas in Ontario, often referred to as Lake Trout management units, are generally smaller and reflect the province’s quota-based management plan.

The Minnesota waters of Lake Superior represent approximately 7% of the total surface area of Lake Superior. In Minnesota there are three statistical districts and when combined with the two Wisconsin statistical districts, this area is often referred to as the “western arm” of Lake Superior (Figure 4). The Minnesota Lake Trout statistical districts differ greatly in size and physical characteristics (Negus et al. 2008) (Table 1). MN-1 is located in the far south-west corner of Lake Superior and shares a common boundary with WI-1 in Wisconsin. MN-1contains approximately 11.4% of the surface area in Minnesota waters and is closest to the metropolitan area of Duluth-Superior. MN-2 is located mid-shore and shares a common boundary with WI-2 in Wisconsin. MN-2 contains approximately 31.4% of Minnesota’s surface area. MN-3 is the largest statistical district in Minnesota at 57.1% of surface area and shares a common border with WI-2, MI-2, and MI-1 (Figure 3). It also contains the Grand Portage Commercial fishing zone. With the exception of MN-1, the Minnesota shoreline is generally characterized by a steep decline just offshore into predominately deep water. This bathymetry and the prevailing winds routinely cause upwelling along the shore which can drastically change water temperatures over short periods of time greatly influencing fish distributions.

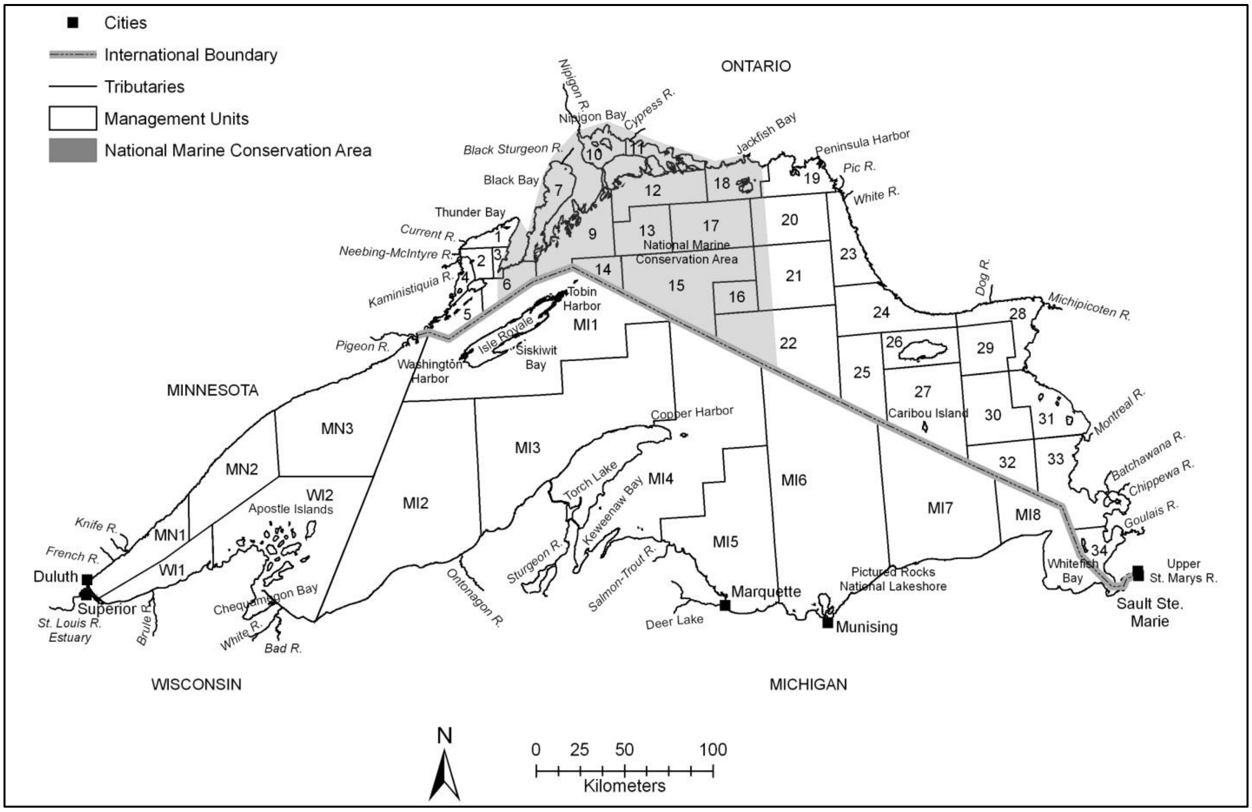


FIGURE 3. Lake Trout management areas in Lake Superior (Gorman et al 2010).

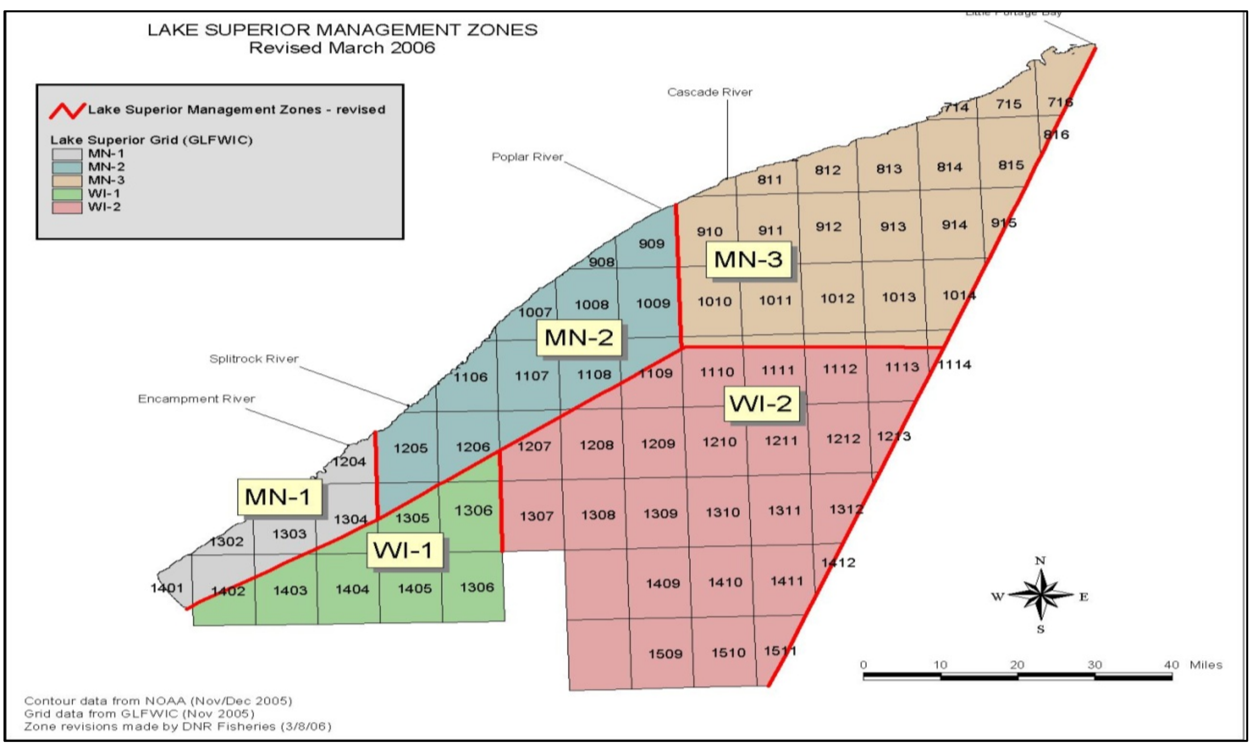


FIGURE 4. Lake Trout management areas in Minnesota and Wisconsin, with corresponding statistical grids (Negus et al. 2008).

TABLE 1. Physical attributes of Lake Trout management areas in Minnesota's portion of Lake Superior.

	Near-shore (<80 m)			Offshore (>80 M)			Total area	
Mgmt. zone	Hectares	% of zone	% of near-shore area	Hectares	% of zone	% of offshore area	Hectares	% of state waters
MN-1	38,758	51.3	55.5	36,761	48.7	6.2	75,519	11.7
MN-2	12,678	6.1	18.2	194,975	93.9	33.0	207,651	31.4
MN-3	18,408	4.9	26.3	359,212	95.1	60.8	377,620	57.1
Total	69,843	10.6	100.0	590,947	89.4	100.0	660,790	100.0

History of the Lake Trout Fishery

Commercial Fishery

Native Americans were the first group of people to harvest Lake Trout in Lake Superior for subsistence as evidenced by early explorer reports from the mid-1600s (Nute 1944; Kaups 1984; Waters 1987; Lawrie and Rahrer 1973). The native Ojibwe depended heavily on the Lake Trout fishery for food, to maintain their life style, and for trading with other bands. From the 1650s through the 1730s many Ojibwe moved from the Sault St. Marie area in Michigan, along the south shore of Lake Superior and settled in the Chequamegon Bay area of Wisconsin. From 1730–1750, a small band moved from the Chequamegon Bay area to settle the Fond Du Lac area on the St. Louis River in Minnesota with approximately 380 band members as reported in the 1824 Ojibwa census (Kaups 1984). The abundance of Lake Trout taken by the Ojibwe was impressive to the early explorers and became legendary, which often caused exaggerated reports of fish harvest to be relayed to their sponsors. Following the first explorers were the French-Canadian voyageurs of the fur trade. Fur companies established the first commercial fisheries as a way to feed their employees and trade for various goods (Kaups 1978). The first commercial fisheries depended heavily on the knowledge of the Ojibwe for the best locations and timing to exploit the most productive fish stocks. Originally the prime fishing locations for Lake Trout occurred at the extreme ends of the Minnesota shoreline and were centered around the Grand Portage Post of the American Fur Company located near the mouth of the Pigeon River, and at the opposite end of the Minnesota shoreline near the Fond Du Lac/Duluth area on the St. Louis River (Nute 1944). Both areas had large established trading posts operated by the Northwest Fur Company, the parent company of the American Fur Company. The boom years for the fur trade dependent fishery lasted from approximately 1800–1850. While supplying the voyagers with fresh fish, predominately Lake Trout, the American Fur Company in 1838 also started the first out-of-basin commercial fishery and began to ship barrels of salted Lake Trout by boat to markets around the Great Lakes, especially the metropolitan areas of Chicago and Detroit (Kaups 1978).

When the fur trade ended in the early 1850s, commercial fishing also abated for a short time (Nute 1944). Commercial fishing gradually expanded again in the late 1850s to meet the demand from the logging industry that harvested much of the timber throughout Minnesota's portion of the Lake Superior watershed. The growing logging industry, along with the signing of the 1854 treaty with the Ojibwe, and the discovery of rich iron ore deposits on the Iron Range in Minnesota supported an expansion of the Lake Trout fishery from both ends of the shore to many small settlements along the entire shoreline. These small near-shore fisheries supplied Lake Trout and other fish species for the many loggers, miners and European immigrants that began to settle the area. This era lasted from approximately 1850–1870 (Waters 1987).

Efficient transportation to major markets continued to be the major bottleneck for an expanded fishery. However, in 1870, the Lake Superior and Mississippi railroad was completed from Duluth to St. Paul and commercial markets for Lake Trout and other species were greatly expanded (Waters 1987). The expanded transportation route increased interest in the commercial bottom set gillnet fishery for Lake Trout and other Lake Superior species, and harvest increased dramatically from 1870 through the mid-1900s. In 1890, only 50 commercial fishing operators were active, by 1917 there were 273 license applications along the Minnesota shore, and by 1930 there were approximately 400 active commercial operators fishing in Minnesota waters for a variety of species (Waters 1987). During this period, technologies had greatly changed the fishery from small row boats fishing in limited areas with cotton twine nets, to small boats fishing all along the Minnesota shore and large tugs fishing out of the Duluth Harbor that were powered by gasoline engines, equipped with mechanical gill net lifters, using much more effective gillnets made of multifilament nylon. Many other technical advances, more efficient transportation systems, and the ever-expanding fishery markets created a more effective and profitable commercial fishery.

In the Duluth area, by the 1880s, overfishing had already reduced fish stocks significantly, especially Lake Whitefish *Coregonus clupeaformis* and Brook Trout *Salvelinus fontinalis* stocks. In 1886-1887, the Minnesota Commission on Fisheries, and the Duluth Commercial Fisheries Association successfully lobbied the federal government to build a hatchery near the Lester River. This hatchery produced various species of salmonids for stocking both inland and in Lake Superior until 1947, when it was closed and transferred to the University of Minnesota. In 1913, the State Legislature directed the Minnesota Fish Commission to build a state run hatchery on Lake Superior, and in 1918 construction began on a state hatchery located at French River.

By the 1940s the commercial Lake Trout catch began to decline significantly in Minnesota from overfishing, similar to the earlier declines in Wisconsin and Michigan. By the mid-1950s, the Sea Lamprey had also made its way to Minnesota (Lawrie and Rahrer 1973; Smith et al. 1974) decreasing the abundance of Lake Trout even further. Both the Lake Trout harvest and number of commercial operators declined dramatically by the early 1960s until the Lake Trout commercial fishery was formally closed in 1962.

Sport Fishery

The sport fishing industry in Lake Superior was much smaller than the commercial fishing industry that had first been established by the early fur traders. The earliest sport anglers who arrived sometime between the 1820s and 1850s were wealthy businessmen and European nobleman who had heard stories of the large and plentiful fish in Lake Superior (Roosevelt 1865). Many of the early sport anglers targeted the large Brook Trout found in Lake Superior called “coasters”. This fishery was only accessible by boat, and many sport anglers hired guides out of Duluth who used small sail and oar boats to access the stream mouths along Minnesota’s shore. Many of the fishing expeditions lasted well over a week with the anglers camping along the shore and moving from one stream mouth to another (Roosevelt 1865). A newspaper report from the *Duluth Minnesotan* in 1869 reported that “five sport anglers caught 367 Brook Trout from the French River in a single day” (Kaups 1978). Lake Trout were a secondary species and were not as well regarded by early sport anglers due to their inferior “game” qualities, meaning much less fight per pound (Roosevelt 1865). Lake Trout also inhabited the deeper offshore waters during much of the year making them more difficult to access by boat before gasoline engines were widely used.

By the late 1890s, Brook Trout populations along the Minnesota shore had already declined noticeably causing the interest in sport fishing to decline as well. Life changed dramatically along the Minnesota shoreline in the mid-1920s when the first effective road-way accessing the “North Shore” was constructed (now State Highway 61).

This road allowed much greater access for settlers and tourists alike (Nute 1944). An interesting development was that most of the earliest tourist and fishing resorts located along the Minnesota's shoreline were operated by commercial fishing families, and many of the first "charter boat or deep-sea fishing operations" were also operated by commercial fishers. Following the invention of the gasoline engine and the severe reduction in Brook Trout stocks, most anglers targeted the more abundant and larger Lake Trout (Waters 1987). Although less lucrative than the commercial fishing operations, income from sport anglers helped sustain the early commercial fishing families when markets were poor, and more importantly helped fill the resorts with customers.

By the early 1940s, the sport fishery for Lake Trout along the Minnesota shore was growing rapidly and many sport fishing guides ran productive seasonal businesses. The small fishing businesses were normally located in the few protected harbors and major river mouths along the shore, and stretched from Hovland, where one sport fishing operator ran 15 trolling boats that routinely landed 20-25 Lake Trout in a few hours, to Duluth (Nute 1944). Major sport fishing locations included the areas near Grand Marais, Beaver Bay, Temperance River, Split Rock River, Gooseberry River and Knife River. However, like the commercial fishery, once the abundance of Lake Trout declined from commercial over-harvest and Sea Lamprey predation, interest in the unproductive sport fishery all but disappeared starting in the late 1950s.

Causes of the Lake Trout Collapse

The collapse of Lake Trout stocks in Lake Superior from both intensive fishery exploitation and Sea Lamprey predation is well documented (Hile et al. 1951; Lawrie and Rahrer 1973; Pycha and King 1975; Hansen et al. 1995b; and Bronte et al. 2003). Although intensive fishing may have initiated the inevitable decline, there is strong evidence that Sea Lamprey accelerated the decline dramatically and retarded the ultimate recovery of Lake Trout (Lawrie 1978). This progression was evident in Minnesota waters when Sea Lamprey invaded the far western portion of Lake Superior in the mid-1950s. Habitat destruction was also a factor for Lake Trout declines in portions of the lower Great Lakes. Habitat destruction in Lake Superior may have resulted from timber mill and mining operations in specific near-shore embayments and harbors, but the cumulative effect on Lake Trout abundance in Lake Superior was likely minimal (Lawrie and Rahrer 1973).

Exploitation by Commercial Fishery

Early evidence and analysis suggests that intensive harvest of Lake Trout stocks by the commercial fishery decreased abundance to levels of concern before Sea Lamprey invaded Lake Superior (Coble et al. 1990; Hansen et al. 1995b). Hile et al. (1951) referencing the Michigan Lake Trout fishery in Lake Superior, concluded that:

> *" …rising fishing pressure has brought about a decrease of abundance and that the fisherman in the face of this reduced availability have intensified their efforts in order to keep production at a good level. If so, a continuation of present trends until fishing becomes unprofitable is to be anticipated."*

They go on to conclude that:

> *" ….Lake Trout stocks of the state of Michigan waters of Lake Superior are fast nearing a dangerously low level and are in poor condition to withstand the impending ravages of a growing population of Sea Lampreys."*

Pycha and King (1975) summarized the status of both the Michigan and Wisconsin Lake Superior Lake Trout fisheries through 1970 and concluded that *"intensive fishing, aided by the introduction of nylon gillnets, was the principal factor involved in the early years of the post-World War II decline of Lake Trout in Lake Superior.*" Lawrie and Rahrer (1973) presented data from Michigan waters that indicate an approximate 2% annual decline in Lake Trout abundance between 1926 and 1953, before invasion by Sea Lamprey. Hansen et al. (1995a), referring to the above historical information and upon further analysis, argued that "Lake Trout abundance declined well before Sea Lampreys colonized the lake."

The first formal records of commercial Lake Trout harvest from Lake Superior were reported from Canada starting in 1867 and in the U.S. starting in 1879. Specific reporting by each state and the Provence of Ontario began in 1885

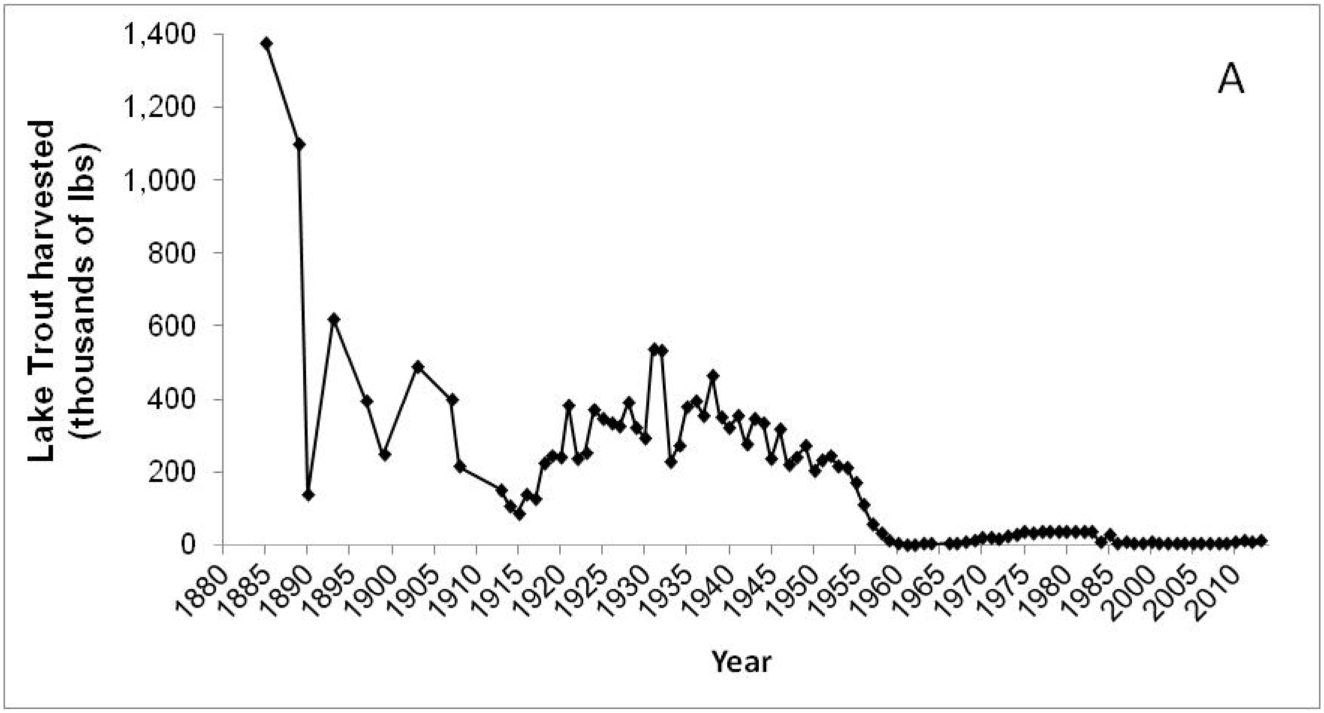
(Baldwin and Saalfeld 1962). Production estimates in kg (lb) of Lake Trout from the early fishery were sketchy due to inaccuracies in reporting the location of the catch, species caught (Siscowet vs lean), weights of catch, and non-reporting (Hile 1962; Wilberg et al. 2003).

Minnesota intermittently reported commercial Lake Trout harvest results beginning in 1885, and in 1913 began annual reporting (Baldwin and Saalfeld 1962). Before 1929, much of the commercial reporting was incomplete and included some inaccuracies, however, after 1929 the reports were deemed to be adequate for statistical analysis (Hile 1962). Some of the early Isle Royale harvest was likely reported as being caught in Minnesota because many of the commercial fishing operations were based in Minnesota. The large commercial fleet located in Duluth fished on or near the Minnesota–Wisconsin state line, and in the early years reported their catch based on which state their port was located rather than the actual fishing grounds (Wilberg et al. 2003). Although many of the early commercial operators could identify the various forms of Lake Trout harvested, they did not distinguish them on their catch reports and all forms were reported as Lake Trout (Wilberg et al. 2003). In addition, since limited monitoring occurred during the early fishery, harvest and weights may have been incorrectly reported for various reasons. By far the largest variability in the early Lake Superior Lake Trout harvest data occurred between 1885 and 1890 in Minnesota, when the reported catch declined from 624 thousand kg (1.376 million lb) to 62.6 thousand kg (138 thousand lb), a ten-fold decrease. Hile et al. (1951) questioned the accuracy of these early reports, warning that they should be treated with skepticism. Starting in 1893, the harvest numbers from Minnesota were more consistent and considered more reliable (Baldwin and Saalfeld 1962).

A summary of the commercial Lake Trout harvest from the Minnesota waters of Lake Superior from 1885–1960 was published by the GLFC in 1962 (Baldwin and Saalfeld 1962). Since 1960 commercial Lake Trout harvest data was updated based on records supplied by the MNDNR. All Lake Trout harvest data is reported in pounds dressed weight, with a conversion factor to round weight of 1.25. Commercial harvest records for all species are available on the GLFC website (Baldwin et al. 2009) and are updated annually. In Minnesota, the commercial Lake Trout fishery was closed from 1962–2006, but several commercial operators were recruited as permit netters to conduct a Lake Trout assessment fishery beginning in 1962, a practice which continues today. From 1962-1985 Lake Trout harvest from the assessment fishery, and any by-catch in the commercial fishery for other species was included as "commercial harvest". Commercial harvest of Lake Trout from 1986-1995 was less than 1,000 kg/yr and only included incidental harvest, so was not reported in this publication. Details are available at the Lake Superior Area fisheries office. From 1996-2006 commercial harvest only included incidental harvest of Lake Trout in the commercial fishery and Lake Trout harvest from the Grand Portage Band when reported. From 2007-2014, commercial harvest included incidental Lake Trout harvest in the commercial fishery for other species, harvest from the Grand Portage Band when reported, and harvest from the Expanded Assessment fishery for Lake Trout that begin in 2007 in MN-3 and 2010 in MN-2 (Figure 5, Appendix 1). Lake Trout harvest statistics from the assessment fishery are summarized in the Assessment Section of this report, and details on the "Expanded Assessment" fishery are discussed in the Regulations Section.

In Minnesota, almost all the commercial fishing effort for Lake Trout after the 1920s used large mesh of 11.4-14 cm (4.5-5.5 in) stretch mesh bottom set gill nets. Prior to the 1920s, some commercial Lake Trout fishing also occurred using trot lines, but the recorded harvest using this gear was minimal in most years. Fishing effort (measured in length of gill net set) from the historical commercial catch was poorly reported and is largely considered unreliable for calculating an index of abundance (CPUE) prior to 1960 (Hile et al. 1951; Pycha and King 1975). Examination of commercial Lake Trout catch records in Minnesota from 1891-1960 reveals that harvest was variable in the early years from 1893-1920, fairly stable from 1921-1940, declined slightly beginning in the 1940s, with a severe decline in the 1950s Figure 5, Appendix 1).

As in Michigan and Wisconsin (Pycha and King 1975), the fishing effectiveness for Lake Trout in Minnesota increased greatly from 1880-1940 due to improved technology, larger gasoline powered vessels, and the use of nylon nets, which were 2.5 times more effective than cotton nets (Pycha 1962). The true abundance of Lake Trout in Minnesota was likely in serious decline starting in about the 1920s, as harvest levels remained relatively constant despite the increase in commercial fishing effort and efficiency. Unfortunately, once Sea Lamprey predation was added to this intensive exploitation, the fishery crashed hard and fast in the mid-1950s.



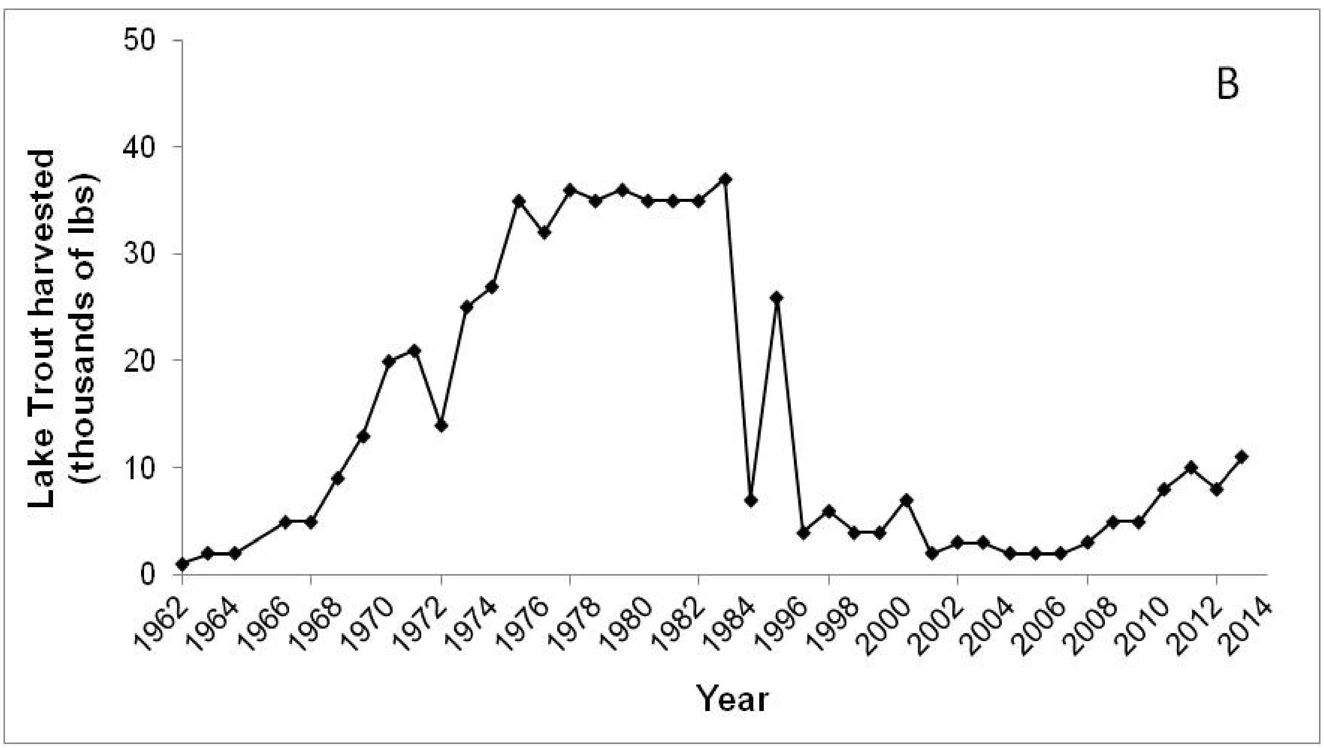


FIGURE 5. Commercial Lake Trout harvest in the Minnesota waters of Lake Superior from: A) 1880-2014; and B) 1962-2014.

Sea Lamprey

The history and disastrous effects of Sea Lamprey invasion on the Great Lakes fishery is well documented (Applegate and Smith 1950; Lawrie 1970; Smith and Tibbles 1980; Hansen 1999; Siefkes et al. 2012). Lake Superior was the last of the Great Lakes to be invaded by Sea Lamprey, with the first specimen reported in 1946 (Lawrie and Rahrer 1973; Smith et al. 1974). By the time Sea Lamprey had entered Lake Superior, the Lake Trout fishery in each of the lower four lakes had undergone dramatic declines. The invasion of Sea Lamprey in Lake Superior generally progressed from east to west. Sea Lamprey targeted both Lake Trout and Lake Whitefish stocks, with larger Lake Trout being the preferred prey (Lawrie and Rahrer 1973, Pycha and King 1975). Following the invasion of Sea Lamprey, commercial Lake Trout harvest declined sharply from east to west, until most Lake Trout stocks were ultimately decimated. The last remaining Lake Trout spawning stocks were located in offshore areas of the lake near Isle Royale, Stannard Rock, Superior Shoal, the Caribou Islands and Gull Island Shoal.

Minnesota tributaries to Lake Superior supported very little reproductive habitat for Sea Lamprey, as natural barriers to upstream migration are located very close to most stream mouths. The limited stream reaches accessible to Sea Lamprey had rock and rubble substrate, which is extremely poor habitat for ammocete (larval Sea Lamprey) survival. A comprehensive survey of Minnesota streams in the early 1950s revealed only a few streams with potential to support Sea Lamprey reproduction (Loeb 1953). Only the Nemadji-Blackhoof River system, the Minnesota Brule (Arrowhead), and the lower portion of the Pigeon River were notable Sea Lamprey producers. Although the St. Louis River had access and appropriate substrate, severe pollution and contaminated sediment prior to the 1970s likely inhibited Sea Lamprey reproduction.

Although Sea Lamprey production was extremely low in Minnesota, Sea Lamprey wounding rates on Lake Trout were some of the highest reported in Lake Superior. Many of the Sea Lamprey that preyed upon Minnesota Lake Trout in the Duluth area (MN-1) likely originated from the soft-bottom streams along the south-west shore of Wisconsin. Most Sea Lamprey that preyed upon Lake Trout in the more northern Minnesota waters (MN-3) likely originated from some of the large north-western Ontario streams and lentic areas. Sea Lamprey from both areas likely preyed upon Lake Trout in the mid-shore area (MN-2) of Minnesota.

The shoreline bathymetry of Minnesota may have influenced the success Sea Lamprey had on locating and attacking large Lake Trout. Lake Trout habitat was confined to a limited amount of relatively shallow water along most of the Minnesota shoreline, which may have created areas of much higher Lake Trout density than in the relatively expansive shallow waters along the Wisconsin shoreline. The high concentration of Minnesota Lake Trout in proximity to large Sea Lamprey producing streams like the Wisconsin Bad, Brule, Middle, Amnicon and Nemadji may have influenced the high Lake Trout wounding rates found along the lower portion of the Minnesota shoreline. In any case, during the 1950s commercial Lake Trout harvest in Minnesota dropped almost 100-fold (Figure 5, Appendix 1).

Habitat Degradation

Prior to the 1950s, habitat degradation contributed minimally to the catastrophic Lake Trout declines in each of the lower Great Lakes (Eshenroder et al. 1999) and even less so in Lake Superior (Lawrie and Rahrer 1973; Hansen et al. 1995b). Much of the degradation that did occur in Minnesota was a result of the timber industry practices that occurred during the late 1800s and the early 1900s, dredging in the St. Louis River to provide access for shipping, and the release of taconite tailings into Lake Superior by the Reserve Mining Company. The major effects of habitat degradation from the timber industry included the destruction of some stream and inshore spawning habitat that occurred during major log drives, rafting logs near river mouths, and oxygen depletion from lumber mills dumping sawdust and slag into a number of embayments and estuaries, including the St. Louis River. Direct effects of habitat degradation from the timber industry, and dredging of the St.

Louis River on Lake Trout stocks in Minnesota are difficult to determine, but were likely minimal since there is no evidence that Lake Trout were ever plentiful in the St. Louis River, or used Minnesota tributaries to spawn. The greatest influence in Minnesota may have been on species used as prey by Lake Trout, but this was likely not a significant factor in the collapse of Lake Trout. Because organic contaminants were not present at high levels prior to the 1950s, there is little evidence that they contributed to the major Lake Trout declines prior to 1960.

In 1955, the Reserve Mining Company's taconite processing facility in Silver Bay, MN came online. For each ton of iron ore produced, 2 tons of waste rock, or tailings, had to be disposed of. As much as 47 tons of tailings were dumped into Lake Superior every minute. Initially, the tailings were thought to be no more harmful than sand, but by the late 1960s environmental groups and commercial and sport fishing groups argued the tailings were killing fish, causing the once clear waters to become turbid, and risked the safety of the water source for surrounding communities. In 1972, a lawsuit was filed against Reserve Mining Company and the presence of asbestos-like fibers in the tailings turned the argument of an environmental issue into a public health issue since communities relied on Lake Superior water for their drinking supply. In 1974, Judge Miles Lord ordered the plant closed temporarily, but federal appeals court allowed it to reopen until an alternative method could be found. In 1980, Reserve Mining Company began dumping its tailings into an inland holding pond, which continues today. It is still unknown how the large amount of sediment in this area has impacted Lake Trout spawning habitat and other species Lake Trout depend on for prey.

Lake Trout Rehabilitation Efforts

Reestablishment of self-sustaining Lake Trout stocks over their historical range in the Great Lakes basin is a major goal of the GLFC (Great Lakes Fishery Commission 1964; Great Lakes Fishery Commission 1997; Great Lakes Fishery Commission 2008). Two Lake Trout restoration plans for Lake Superior were published to help direct and facilitate rehabilitation efforts in Lake Superior (Lake Superior Lake Trout Technical Committee (LSLTTC) 1986; Hansen 1996). The goal of Lake Trout rehabilitation in Lake Superior as stated in these plans is to "restore self-sustaining stocks that can provide an annual catch of 2 million kg (4.4 million lb), the average annual yield in 1929-1943" (Busiahn 1990, Hansen 1996). If this rationale were applied only to Minnesota waters the annual catch figure would be approximately 164,000 kg (361,000 lb). The obvious strategies to rehabilitate Lake Trout stocks in Lake Superior were to decrease the abundance of Sea Lamprey and reduce the effects of overexploitation by the commercial fishery. The GLFC facilitated the control of Sea Lamprey, and fishery management agencies either reduced or eliminated commercial fisheries until progress in Lake Trout rehabilitation could be realized. Once the severe decline in Lake Trout was halted, stocking of hatchery-reared Lake Trout was undertaken to help rebuild the stocks at a faster rate.

Sea Lamprey Control

Initial control of Sea Lamprey in Lake Superior was attempted starting in 1953 by constructing barriers to Sea Lamprey migration in Lake Superior tributaries (Smith et al. 1974; Smith and Tibbles 1980). Knowledge and experience had been gained in the lower lakes in an attempt to control Sea Lamprey with the use of mechanical and electric barriers (Applegate and Smith 1950; Lawrie 1970). These techniques were immediately applied to Lake Superior tributaries where the highest number of Sea Lamprey had been captured (Lawrie and Rahrer 1973; Smith et al. 1974). By the early 1960s, facilitated through the formation and actions of the GLFC, a Sea Lamprey-specific pesticide was developed called 3-trifluormethyl-4-nitrophenol (TFM) (Applegate et al. 1961). TFM was first used in Lake Superior because it was the only lake where remnant Lake Trout stocks remained and protection of these remaining stocks was deemed critical.

From 1950-1954, 1,915 Lake Superior streams were surveyed to determine their potential to produce Sea Lamprey. Approximately 424 were determined to have potential; and 136 were considered for TFM treatment. These streams were divided into three categories: Category 1 included 52 streams that were treated at least once every 5 years; Category 2 included 19 streams that were treated approximately once every 10 years; and Category 3 included 65 streams that were treated only when Sea Lamprey numbers were high enough to consider them worth treating (Heinrich et al. 2003). In Minnesota, only the Pigeon and Nemadji Rivers were listed for routine TFM treatments.

Lampricide treatments in Lake Superior began in 1958, with 12 tributaries located in Michigan and Ontario. Additional lampricide treatments were spread to many other Lake Superior streams by the early 1960s (Smith and Tibbles 1980, Smith et al. 1974). In addition to TFM, granular Baylicide 73, another chemical that is toxic to Sea Lamprey (Howell et al. 1964), was used in lentic areas and the deep-slow moving water of streams beginning in 1967 (Heinrich et al. 2003). By 1962 adult spawning Sea Lamprey abundance as measured by traps operated in major tributaries had already decreased by 86% (Smith et al. 1974). Five years later, reduced Sea Lamprey abundance became apparent with decreased Lake Trout wounding and slowly increasing abundance in the Lake Trout assessment fishery (Lawrie and Rahrer 1973; Pycha and King 1975). Success was first reported from Michigan, followed by Wisconsin, Ontario and lastly in Minnesota.

TFM treatments in western Wisconsin tributaries likely had the greatest impact on early Lake Trout recovery in Minnesota. The construction of the Wisconsin Brule River Sea Lamprey barrier in 1984 removed 72 km (45 mi) of Sea Lamprey spawning and nursery habitat, greatly reducing annual Sea Lamprey production in western Lake Superior (Heinrich et al. 2003). Treatments of large Sea Lamprey producing streams in western Ontario waters like the Kaministiqua and the Nipigon rivers, along with granular Baylicide treatments of lentic areas near their stream mouths, also benefited Lake Trout recovery in northern Minnesota waters.

The first *Fish Community Objectives for Lake Superior* (FCOs) which were written by the Lake Superior Committee (Busiahn 1990) stated the objective for Sea Lamprey control was to reduce Sea Lamprey spawner abundance to 50% by 2000 and 90% by 2010, compared to the average spawning population of about 26,000 that existed from 1986–1989. Unfortunately, the average Sea Lamprey spawning population from 1996-1999 was 84,000 due to reduced funding for Sea Lamprey control, reduced chemical treatments, issues with regulatory permitting, and a variety of other reasons (Heinrich et al. 2003). The Lake Superior Committee reviewed and modified the Sea Lamprey objective in the next version of the FCOs (Horns et al. 2003). The 2003 objective states that abundance of spawning Sea Lamprey should be reduced to levels that would cause “insignificant mortality of adult Lake Trout” which is considered less than 5 fresh wounds per 100 adult Lake Trout. Although this goal has at times been met in Minnesota, wounding continues to remain above the criteria in many years. In 2012, Individual Lake Management Plans for Sea Lamprey Control were developed in a renewed effort to reach control targets and better link fishery managers and Sea Lamprey control staff (Steeves 2012). These plans described Sea Lamprey control strategies that attempt to meet the targets for both spawning Sea Lamprey abundance and Lake Trout wounding. Despite the continued struggle to meet targets, and the variable results of Sea Lamprey control, self-sustaining Lake Trout stocks have been established throughout Lake Superior and Sea Lamprey control is the primary reason for this success.

Regulations – Commercial, Tribal and Sport Fisheries

Lake Superior fishery management agencies continued to allow both commercial and sport fishing for Lake Trout through 1961 despite the dramatic declines in Lake Trout stocks. The rationale was that the fishery might as well be allowed to harvest Lake Trout since experience in the lower lakes had shown that Sea Lamprey could easily eliminate any of the remaining Lake Trout. However, once TFM was discovered and a Sea Lamprey control strategy for Lake Superior was implemented, both the commercial and sport Lake Trout fishery was closed in 1962 (Pycha and King 1975; Pycha 1980), except for minimal harvest under special state-issued permits for assessment purposes. For some commercial operators the Lake Trout assessment fishery helped fill the void created when the commercial fishery was closed.

The idea for the Expanded Assessment fishery originated during the 2006 revision of the *Fisheries Management Plan for the Minnesota Waters of Lake Superior.* During the planning process stakeholders and Lake Superior Area fisheries staff agreed the Lake Trout population could sustain a limited commercial fishery in Minnesota waters. However, senior level agency personnel were uncomfortable with the idea of setting precedent for commercial harvest of a sport species in Minnesota waters and rejected the proposal. Instead of a limited commercial fishery, an Expanded Assessment was proposed which worked the same way as the current permitted commercial assessments, but expanded the season to include the months of June thru September. In 2007, the Expanded Assessment was initiated in MN-3 with an annual quota of 3,000 Lake Trout, and in MN-2 the Expanded Assessment began in 2010 with an annual quota of 2,000 Lake Trout. No Expanded Assessment was approved for MN-1 due to the high sport fishing effort near the Duluth/Superior metropolitan area (Schreiner et al. 2006). All commercial operators are required to keep detailed records of their catch and collect specific biological information as outlined in their assessment permits.

In Minnesota, restrictions were also placed on state commercial fisheries targeting other species in an attempt to limit by-catch of Lake Trout. Lake herring or Cisco *Coregonus artedi* were the most targeted commercial species in Minnesota. In 1971, all gill nets were prohibited within 0.4 km (0.25 mi) of shore, and in 1974, bottom gillnet sets were prohibited in depths less than 73 m (240 ft). Beginning in 1978, incidental catch of dead Lake Trout longer than 430 mm (17 in) had to be tagged, and all live adults, and any undersized (<430 mm (17 in)) Lake Trout dead or alive, had to be returned to the water (Hansen et al. 1995b). Each commercial netter was initially issued 20 incidental Lake Trout tags and information on each fish harvested had to be recorded. Additional incidental tags were issued if warranted, and all unused tags had to be returned at the end of each commercial season.

Tribal fishing rights were affirmed in 1988 with the signing of a Memorandum of Agreement (MOA) between the Grand Portage Band of Chippewa and the State of Minnesota (Minnesota Department of Natural Resources 1988). The agreement defined the Grand Portage Commercial Fishing Zone as the area in Lake Superior from the mouth of the Reservation River to the Michigan state line to the Canadian border. The Lake Trout quota set in this area for commercial and non-commercial use by the Grand Portage Band was 12,273 kg (27,000 lb) annually. The agreement required the Grand Portage Band to maintain records and report Lake Trout harvest in the Grand Portage Zone annually and required that all commercially harvested Lake Trout be tagged. Under the MOA, the Grand Portage Band retained exclusive rights to fish in Grand Portage Bay and could take Lake Trout in Grand Portage Bay with any gear, at any depth, for commercial purposes and sell them on or off the reservation (Minnesota Department of Natural Resources 1988).

Sport fishing harvest for Lake Trout in Minnesota waters has been regulated since 1893, when the minimum length limit was set at 152 mm (6 in). In 1925 the daily bag limit for Lake Trout was set at 10 with 15 in possession and angling was only permitted from November 15 – September 1. In 1939 the bag limit was reduced to 5 Lake Trout per day with 10 in possession and the season was lengthened from December 1 to September 30. In 1962, in an attempt to further protect recovering Lake Trout stocks and provide information on the sport harvest, all anglers in Minnesota were required to obtain a state-issued permit to fish for Lake Trout. In 1964 the sport fishing permit requirement was removed as the fishery was so poor that little effort existed and the program was deemed more costly than it was worth. In 1970, after the sport fishery was re-opened, the daily bag limit was reduced to 3 with 10 in possession (Hansen et al. 1995b). In 2010, the bag and possession limit was lowered to 3 and the season was lengthened slightly to Dec. 1 through the first full weekend in October (Schreiner et al. 2006). Most of the commercial, tribal and sport fishing regulations were implemented to protect Lake Trout stocks that were recovering from overfishing and Sea Lamprey predation. Since the early 1960s Lake Trout rehabilitation has made significant progress and regulations were changed to reflect such progress, although they remain conservative to enhance the continued recovery of self-sustaining Lake Trout stocks.

A seasonal fish refuge (Fitger's Reef Refuge) in the far south-west corner of Lake Superior (Duluth) was created in 2004 to protect Lake Trout during their spawning season. The area inland from a line drawn from the mouth of Chester Creek to the end of the left break-wall on the Duluth Entry was closed to all fishing during the closed Lake Trout season (Appendix 2). Since the mid-1970s, this area has attracted high numbers of spawning Lake Trout. In the mid-1980s an artificial spawning reef (Fitger's Reef) was created in this area to increase the amount of suitable spawning substrate for Lake Trout. This further concentrated Lake Trout spawner abundance in this area during the spawning season. Beginning in the late-1990s, some anglers that claimed to be fishing for other species caught and released many large spawning Lake Trout which at times were running with eggs. The seasonal refuge was established to protect Lake Trout spawning in this area. The closure was strongly supported by the public and remains in effect. This is the only area in the Minnesota waters of Lake Superior where there is a complete seasonal closure to all fishing.

Stocking

Hatchery-reared Lake Trout were first stocked in the Minnesota waters of Lake Superior in the late 1880s when commercial overharvest was primarily impacting Lake Whitefish stocks in the western tip of Lake Superior. The Lester River Federal Fish Hatchery was constructed in 1888 in Duluth to primarily rear Lake Whitefish for supplemental stocking into Lake Superior. In addition, a small number of Lake Trout and a variety of other species were also reared and stocked into Lake Superior until the hatchery closed in 1947. Subsequent stocking of Lake Trout from state hatcheries occurred in the early 1950s to supplement wild stocks that were initially in decline from overharvest. All stocked yearling Lake Trout were marked with a fin clip so they could be readily identified as a hatchery-reared product when recaptured in the various fisheries and assessments. The early stocking events were evaluated to determine optimal size, age and location to provide the best survival (Hile et al. 1951; Lawrie and Rahrer 1973; Pycha and King 1975; Hansen et al. 1995b). The Lake Superior Lake Trout stocking program began with relatively small numbers of both fingerlings and yearlings stocked annually from 1950–1955 and then nearly continuous stocking since 1951 in Wisconsin, 1952 in Michigan, 1957 in Ontario and 1962 in Minnesota (Hansen et al. 1995b). Yearlings comprised 88% of the Lake Trout stocked lake-wide through 1992 (Hansen et al. 1995b), because they were found to survive 4-10 times better than fingerlings (Buettner 1961; Pycha and King 1975). Success of the early Lake Trout stocking events varied among jurisdictions based on different stocking strategies and the status of Sea Lamprey control at the time of stocking (Dryer and King 1968; Lawrie and Rahrer 1973; Pycha and King 1975). Hansen et al. (1995b) summarized contemporary Lake Trout stocking programs through 1993. After Sea Lamprey control was initiated, and commercial exploitation was curtailed in the early 1960s, survival of stocked Lake Trout was relatively high, and the contribution of hatchery-reared fish to the rehabilitation of the Lake Trout fishery was determined to be significant in Michigan from 1970-1990 (Richards et al. 2004) and likely contributed to the reestablishment of spawning stocks in Minnesota from 1970-1980 (Corradin et al. 2008).

In Minnesota, commercial netters were utilized as early as 1947 to provide Lake Trout eggs to the hatchery system for rehabilitation efforts. This initial effort was relatively small, but demonstrated that the commercial fishers that volunteered were already concerned with the noticeable decline in Lake Trout abundance. The reason that stocking hatchery-reared Lake Trout produced in the federal hatcheries for rehabilitation purposes did not begin until 1962 in Minnesota is unknown, but once stocking began, the numbers stocked increased significantly through the early 1970s (Figure 6, Appendix 3). Minnesota, like many other agencies, received Lake Trout from the federal hatchery system to compensate for the introduction of Sea Lamprey through the Welland Canal. In addition, state hatchery production of Lake Trout was initiated and increased over time to supplement the federal allocation.

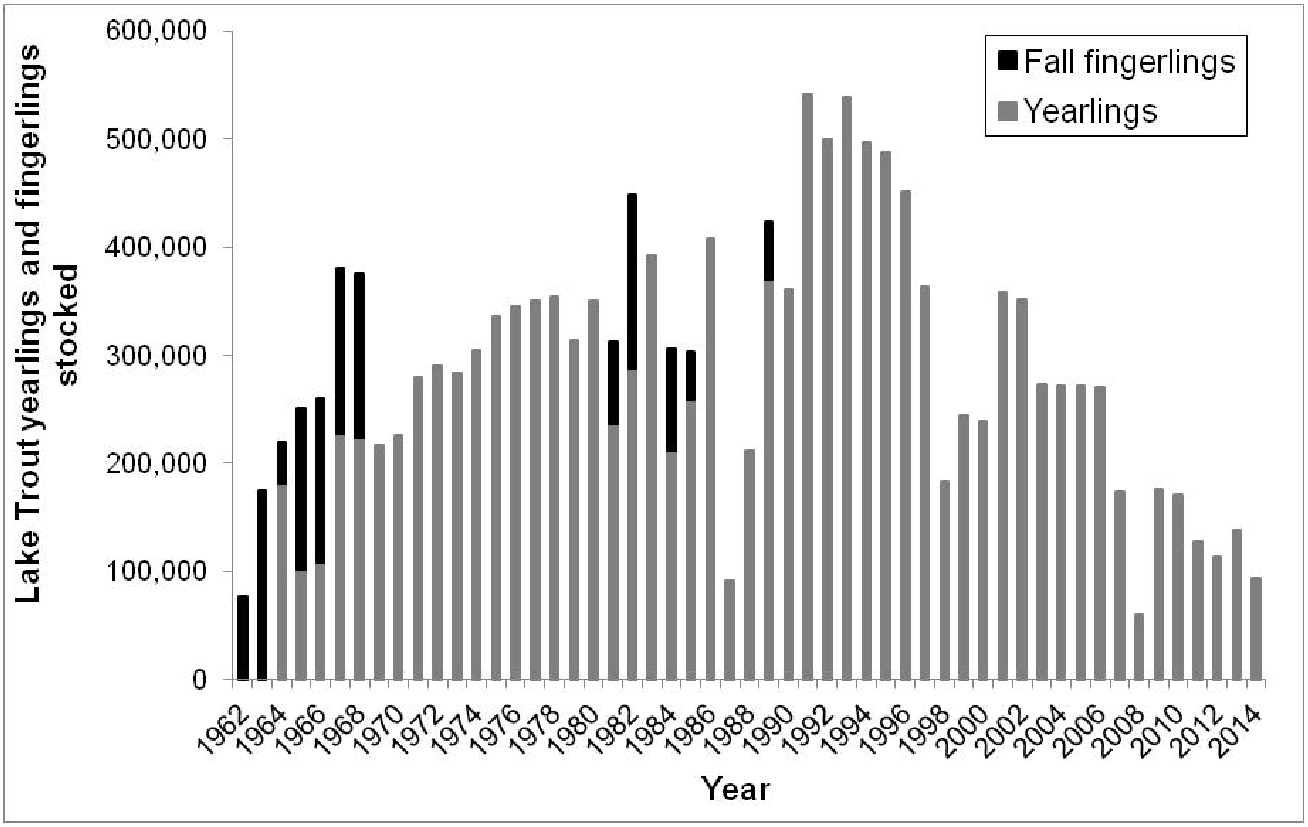


FIGURE 6. Numbers of Lake Trout yearlings and fall fingerlings stocked in Minnesota waters of Lake Superior.

In the U.S. waters of Lake Superior, the Marquette hatchery strain of Lake Trout (originating from wild stocks near Marquette Michigan) was the dominate strain stocked by Michigan and Minnesota. Beginning in 1958 Wisconsin predominately stocked the Gull Island Shoal strain taken from Wisconsin waters and reared in state hatcheries. Minnesota changed from the Marquette strain of Lake Trout to the Isle Royale strain in 1981. Gametes were collected for brood stock creation from wild stocks near Isle Royale, MI in 1978-1980. Mr. Stanly Sivertson and a number of other commercial netters that fished at Isle Royale were instrumental in locating and assisting in the collection of the wild Lake Trout gametes. The Isle Royale strain was produced at both state and federal hatcheries for stocking in Minnesota from 1981 to the present.

During the 1950s and 1960s Lake Trout yearlings weighing about 25 g (0.9 oz) stocked in Lake Superior had the highest survival rate (Pycha and King 1967). In 1986 the first Lake Superior Lake Trout rehabilitation plan called for yearlings that ranged from 18-25 g (0.6-0.9 oz) to be produced in federal hatcheries. However, Lake Trout produced in Wisconsin and Minnesota state hatcheries averaged about 10 g (0.4 oz) larger than the federal fish, increasing the size to approximately 30 g/fish (1.1 oz/fish) in Minnesota by the early 1990s, when Lake Trout abundance was much higher and survival of stocked fish had begun to decline (Hansen et al. 1994; Schreiner 1995).

The restoration plan for Lake Trout in Lake Superior recommended stocking levels for each jurisdiction based on historical Lake Trout yield and availability of shoreline habitat less than 73 m (240 ft) deep (LSLTTC 1986). Average annual lake-wide releases of hatchery-reared Lake Trout were only 24-67% of the average annual estimated recruitment of Lake Trout yearlings that sustained the historical commercial harvest before the collapse of the stocks (Hansen et al. 1995b). Recommended stocking rates for yearlings in Lake Superior were 347/km^2 (1.4/acre) for 5 consecutive years then reduced to 232/km^2 (0.94/acre). These rates were based on the high density of spawners captured in central Michigan waters in the 1970s that produced adequate numbers of recruits to increase the Lake Trout population (LSLTTC 1986).

Minnesota had the lowest amount of near-shore habitat at 614 km^2 (151,720 acres), followed by Wisconsin at 3,134 km^2 (774,412 acres), Ontario at 6,198 km^2 (1,531,526 acres) and Michigan at 6,431 km^2 (1,589,100 acres) (Hansen 1996). Only in Minnesota was the average suggested yearling stocking density exceeded at 543/km^2 (2.2/acre). Based on the continued high Sea Lamprey wounding rates, the time lag in initial stocking, and the relatively low abundance of remnant wild stocks (except for Isle Royale), Minnesota chose to exceed the stocking density guidelines by producing Lake Trout from state hatcheries to supplement the relatively low amount of federal hatchery production. The expanded stocking rates likely increased the abundance of stocked Lake Trout to unsustainable levels in the early 1980s, but provided high levels of spawning stock to reproduce and eventually reestablish self-sustaining populations in the 1990s. Stocking levels remained relatively high until wild Lake Trout increased and stocking was reduced beginning in 1997 (Schreiner 1995), and further reduced in 2003 and 2007 (Schreiner et al. 2006).

In 1996, the LSTC revised *A Lake Trout Restoration Plan for Lake Superior* (Hansen 1996) to include guidelines for discontinuation of Lake Trout stocking given the continued success of Lake Trout rehabilitation. The criteria to discontinue stocking were:

1) Agency Commitment

There must be a political commitment to Lake Trout restoration. Stocking should be discontinued in any area where the management agency or agencies fail to support Lake Trout restoration.

2) Harvest Control

Agencies committed to Lake Trout restoration should institute programs of fishery regulation and enforcement. Discontinuance of stocking should be considered for any area where the allowable harvest is exceeded by more than 10% for three successive years.

3) Wild-Fish Abundance

Evaluation of Lake Trout restoration is based on the relative numbers of wild and stocked fish in the spawning stock and the stability of the wild component of the stock. Stocking should be discontinued in any area where:

- wild-fish compose at least 50% of the catch of spawning-size (>63.5 cm or 25 in) Lake Trout in the spring assessment fishery,

- wild-fish abundance is stable or increases for three consecutive years.

4) Stocked-Fish Survival

Even exceptional commitment and regulatory enforcement by managers may be inadequate to ensure the survival of stocked fish in Lake Superior. Stocking should be discontinued in any area where the survival index for stocked fish falls below 1.0 for three successive years. Relative survival is calculated as the number of age-7 stocked Lake Trout caught per 304 m (1,000 ft) of gillnet divided by the number (in 100,000s) of yearling Lake Trout stocked seven years earlier.

By 1996, most Lake Trout management units had met or exceeded the criteria and only a relatively small portion of Lake Superior continued to be stocked with hatchery-reared Lake Trout (Schreiner and Schram 1997). In Minnesota, the stocking criteria based on increases in wild Lake Trout abundance and decreases in survival of stocked fish were met in 2001 in MN-3, and stocking was discontinued in 2003. In 2005, the same criteria to discontinue stocking were met in MN-2 and stocking was ceased in 2007, while in MN-1 Lake Trout stocking continued, but was reduced from 232,000 to 170,000 yearlings in 2007 (Schreiner et al. 2006). Criteria to discontinue Lake Trout stocking was met in MN-1 from 2010–2013 and elimination of stocking will be recommended to the public during the Lake Superior Management Plan process from 2015-2016.

Many stocked Lake Trout tend to home to the area in which they were stocked (Marsden et al. 1995). The effectiveness of stocking for rehabilitation was largely dependent on the amount of spawning habitat available near the stocking site. The best substrate for Lake Trout spawning is rock, rubble and boulders with many interstitial spaces that protect eggs and sac-fry from predation and allow for the eggs to develop (Marsden et al. 1995). In Wisconsin, where shoreline spawning habitat for Lake Trout is limited but offshore spawning habitat is plentiful, stocking contributed little to Lake Trout rehabilitation (Krueger et al. 1986). However, in Michigan and some portions of Minnesota, where shoreline spawning habitat is more plentiful and widespread, stocking was shown to contribute significantly to Lake Trout rehabilitation (Hansen et al. 1995b). In Minnesota, most hatchery-reared Lake Trout were stocked from shore and rehabilitation progressed most rapidly in areas with significant amounts of quality shoreline spawning and nursery habitat, such as MN-2 and MN-3, when compared to MN-1 which has less quality shoreline spawning and nursery habitat (Richards et al. 1999; Netto 2006). The initial stocking of hatchery-reared Lake Trout in Minnesota likely contributed to the reestablishment of spawning stocks in the late 1960s and 1970s, however contribution of recruits from stocked spawners decreased significantly beginning in the 1980s based on stock-recruitment relationships of Lake Trout in the western arm of Lake Superior (Corradin et al. 2008). The stock-recruitment models also indicated that after 1980 there was a negative relationship between the number of spawners derived from stocking and the recruitment of naturally produced Lake Trout. Despite this finding, stocking continued at a reduced rate in MN-1, likely inhibiting the rate of Lake Trout rehabilitation in this area. The negative relationship was likely due to predation on recruits by stocked fish (Hansen et al. 1995a), and increased competition for food and spawning habitat (Bronte et al. 1995b).

In many cases stocked yearlings did not appear to return to historical spawning areas since it was felt that they were stocked beyond the time when major imprinting occurs (Swanson and Swedberg 1980; Krueger et al. 1986; Negus 2010). In an attempt to increase homing, experimentation by stocking early life history stages of Lake Trout such as eyed eggs in Wisconsin (Bronte et al. 2002) and marked fry in Minnesota (Negus 2010) were initiated in the 1980s and 1990s. These methods attempted to increase homing to areas of high quality spawning habitat. The method of using eyed eggs embedded in Astroturf sandwiches proved successful on Devil's Island shoal in Wisconsin based on mathematical analysis comparing number of eggs stocked to timing of recruitment (Bronte et al. 2002).

In Minnesota, otoliths of Lake Trout fry were thermally marked and the fry were stocked on a near-shore reef in MN-2 from 1994-1996. All unclipped Lake Trout collected in assessment netting from the appropriate year classes, near the stocking site, were examined for thermal marks. Approximately 5.6% of Lake Trout from the target year classes had thermal marks demonstrating that stocked fry contributed to the adult Lake Trout population, and returned to the reef where they were stocked (Negus 2010). Although the Minnesota experiment came relatively late in the Lake Trout rehabilitation progress for Lake Superior, these methods should be considered and may prove valuable for Lake Trout rehabilitation in the lower lakes, especially when trying to rehabilitate offshore Lake Trout spawning reefs as found in the lower Great Lakes.

Since the publication of the STOCs symposium in the early 1980s (Berst and Simon 1981), many Great Lakes fish managers and researchers recognized the need to manage Lake Trout by implementing the stock concept (Burnham-Curtis et al. 1995). The Lake Superior Lake Trout Restoration Plans (LSLTTC 1986; Hansen 1996) recommended stocking Lake Trout strains derived from remnant local populations when possible. Genetic analysis using micro-satellite techniques showed that most stocked Lake Trout in the Great Lakes maintained the genetic diversity found in the local populations from which the brood stock was derived (Page et al. 2003; Page et al. 2004). In Minnesota, the Marquette strain was first stocked since it was readily available, but in the early 1980s, based on the stock concept, the state switched to the Isle Royale strain. Each strain appeared to contribute to the present population of self-sustaining Lake Trout stocks (Hansen et al. 1995b). In hind sight, this change seemed appropriate in MN-3, but it may have been better to stock Gull Island Shoal strain Lake Trout in MN-2 and MN-1 given the close proximity of Gull Island Shoal spawning grounds to the two more southern Minnesota zones. In addition, Wisconsin has historically stocked and continues to stock Gull Island Shoal strain Lake Trout in WI-1, immediately adjacent to MN-1.

Habitat

Efforts to protect Lake Trout habitat in Lake Superior are more critical than the relatively small number of expensive projects aimed at improving a few impaired sites. Protecting habitat is important on a lake-wide scale rather than jurisdictional. The Clean Water Act and the Great Lakes Water Quality Agreement both enacted in 1972, are examples of basin-wide efforts that have helped maintain high water quality standards in Lake Superior. Efforts to reduce contaminants such as mercury and PCBs are also more global in nature, but have improved both Lake Trout health and human health through reductions in contaminant loading (Bronte et al. 2003, Lake Superior Binational Program 2012).

In 1937, the State Legislature passed laws requiring MNDNR permits for any proposed work below the ordinary high water mark for all protected waters in the state, including rivers and lakes. Through consultation and/or denial of such permits in the Lake Superior watershed, streams and the lake have been protected and habitat degradation has been reduced. Seasonal work windows are in place to minimize the adverse effects of any proposed work on Lake Trout spawning stocks and juvenile nursery areas.

Although invasive species are not normally considered habitat, many have the ability to affect habitat directly, such as Dreissenid muscles and various invasive algal species. These invasive organisms can alter food-webs (Dreissenids), and create areas on spawning substrate that become devoid of oxygen, suffocating Lake Trout eggs and sac-fry. Policies, programs, and laws passed to address introduction of invasive species through ballast water control, and movement by sport, commercial and recreational boaters have all been important in limiting the spread of these organisms and their effect on Lake Trout rehabilitation.

In Minnesota's portion of Lake Superior, habitat work on the St. Louis River Area of Concern (AOC) that began in the 1980s has been successful in moving the AOC closer to the delisting status. Although Lake Trout do not use the St. Louis River directly, both Lake Trout prey (Rainbow Smelt *Osmerus mordax*, various cyprinids, etc.) and predators (Sea Lamprey) spawn in this area. There is growing concern that improvements in water quality, and decreases in contaminated sediments, will lead to increases in habitat available for Sea Lamprey reproduction, causing increased Sea Lamprey induced mortality on Lake Trout. Much of the habitat in the St Louis River that Sea Lamprey could use for spawning has been identified. Reconnaissance surveys in these areas have found only a small number of ammocoetes (juvenile Sea Lamprey) in limited portions of the habitat identified. So far, the number of ammocoetes captured has not justified the costly treatments that would be required to control Sea Lamprey in the St. Louis River. It will be important to continue the larval Sea Lamprey assessments in the St. Louis River on a routine basis so any significant increase in Sea Lamprey abundance can be addressed.

Near-shore Lake Trout spawning habitat was mapped as part of a remediation project, triggered by an ash slide at LTV Steel in 1993. The mapping project, used sonar technology (RoxAnn), identified depth, location, and quantity of specific substrate types along the Minnesota shoreline and provides a baseline from which to measure future changes in an atlas format (Richards et al. 1999). Substrate types used by spawning and juvenile Lake Trout can be identified and were highlighted in the atlas. The information has been used repeatedly to justify protection of critical Lake Trout habitat when development in important areas has been proposed. This atlas can also be used to quickly determine the amount and type of habitat impacted if a spill or some other type of catastrophic event occurs, such as the LTV ash slide in 1993.

The availability of detailed substrate data published in the Lake Trout spawning atlas (Richards et al. 1999) allowed for the comparisons of the physical attributes of specific habitat areas within the lake, and the simulation of Lake Trout population processes that are dependent upon habitat characteristics and spatial location. Using the Lake Trout spawning atlas, Netto (2006) developed a spatially explicit model that incorporates the interaction between habitat and environmental conditions to describe Lake Trout population dynamics in the Minnesota waters of Lake Superior. The model addressed a number of hypotheses concerning Lake Trout rehabilitation in Lake Superior using data from Minnesota. Model predictions suggested that habitat conditions for Lake Trout vary along the Minnesota shore, and may have caused differences in the rate of Lake Trout rehabilitation and reproduction potential of the population. The model also predicted that eggs deposited by shallower spawning hatchery reared Lake Trout realized lower survival than eggs deposited by wild fish.

In 1988 an artificial Lake Trout spawning reef was constructed in the far south-west corner of Lake Superior, about 0.5 mi northeast of the Duluth Harbor Ship Canal (Loran Location TD1-32605.5; TD2-45809.7). The reef was placed in front of the old Fitger's Brewery complex, thus the reef is referred to as Fitger's Reef. The reef is approximately 13.7 m (45ft) wide at the base and tapers to 4.6 m (15 ft) wide at the top. It is approximately 1.5 (5 ft) high and about 366 m (1,200 ft) long. The reef was constructed of approximately 76,460 m^3 (10,000 yd^3) of blast rock from the Interstate 35 tunnels and the rock ranges from 15-61 cm (6-24 in) in diameter. The reef was placed on hard bottom that starts in about 9 m (30 ft) of water and extends to about 15m (50 ft) in depth.

The reef was constructed as mitigation for shoreline filling during construction of the "Lake-walk" by the City of Duluth. It was anticipated that Lake Trout, which had historically spawned in this area would use the newly constructed reef. Assessment netting during the 1988 spawning season captured gravid females on the reef. From 1990-1992 egg traps were deployed on the reef and approximately 100 Lake Trout eggs were captured (Schreiner 1995). Lake Trout continue to use the reef for spawning, but no studies have been conducted to determine if natural reproduction on Fitger's Reef has contributed to the wild abundance of Lake Trout in MN-1. Given the extensive amount of substrate available for Lake Trout spawning along Minnesota's shoreline, there is little need for construction of additional artificial spawning habitat.

Lake Trout Rehabilitation Progress

In Minnesota, progress toward Lake Trout rehabilitation was measured using large mesh gill nets that targeted adults, small mesh gill nets that targeted juveniles, creel surveys that monitored the general sport fishery, and mandatory reports submitted by charter captains and commercial netters that monitored annual Lake Trout catch. All mesh sizes in the various gill net assessments are reported as stretch mesh. Various models were also developed to describe the status, and predict the future condition of Lake Trout stocks in Minnesota. This section summarizes the methods and results of each assessment or monitoring program, and describes the changes in Lake Trout stocks that have occurred in Minnesota's portion of Lake Superior.

Large Mesh Assessments - Spring (May) and Fall (September)

In Minnesota, large mesh gill net assessments formally began in 1962 in MN-2 and MN-3, and 1982 in MN-1. The assessments were designed to monitor the results of Sea Lamprey control, evaluate stocking, and track the status of Lake Trout rehabilitation. In MN-2 and MN-3 commercial fishing operators willing to participate in the assessment program were issued an assessment permit by the MNDNR to set gill nets targeting Lake Trout in areas where they had traditionally fished. In exchange for specific information on the gill net sets, and biological information on Lake Trout captured, the commercial operators were allowed to keep and sell their catch, provided they tagged each fish as described in their assessment permit. The number of permit netters ranged from two in 1962 to 14 in 1968, with an average of about 10 permits granted annually until the mid-1990s when a number of permit netters retired from the program (Figure 7).

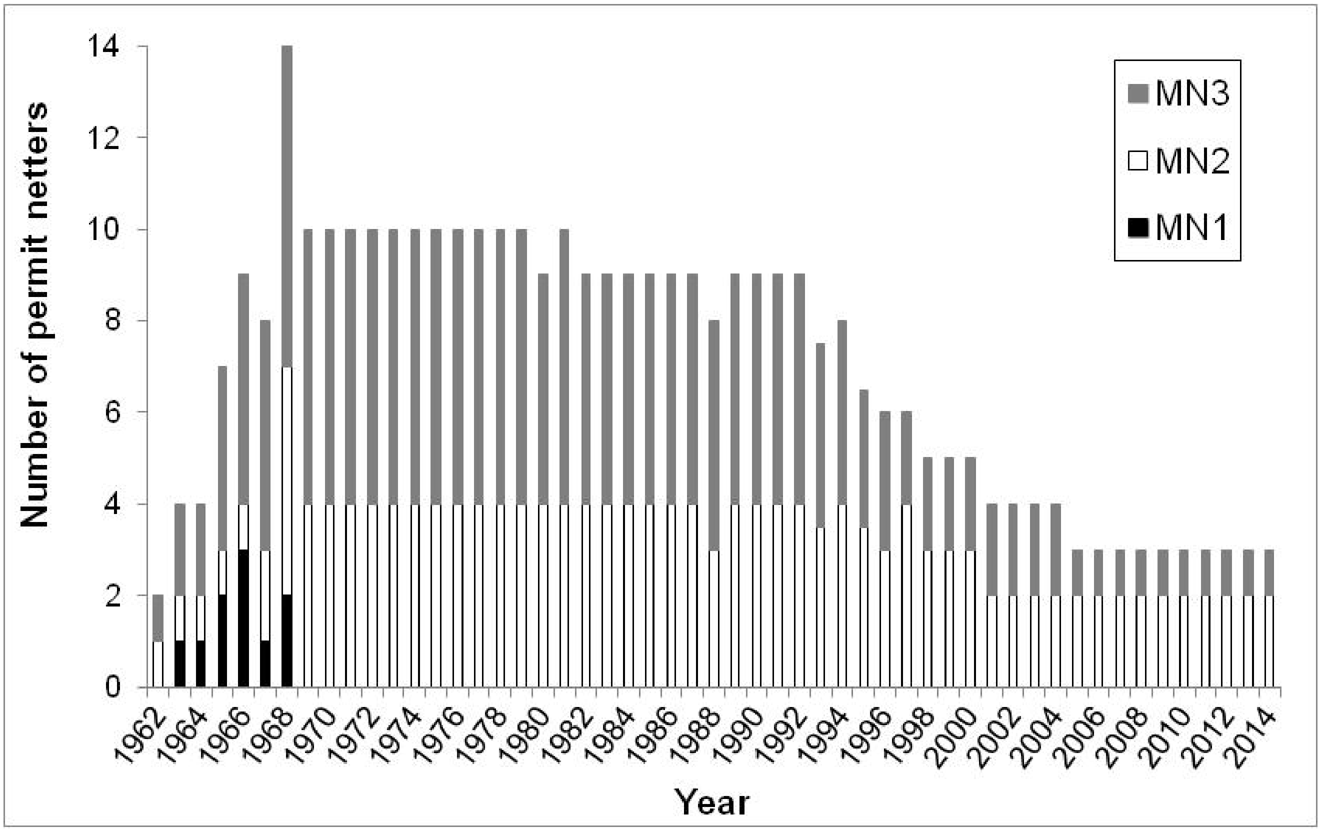


FIGURE 7. Number of permit netters in each Lake Trout management zone in Minnesota waters of Lake Superior.

Some permit netters were not replaced because the Lake Trout catch had increased dramatically and the need for additional samples was no longer required. In 2005, one of the original permit netters retired from the assessment fishery in the Grand Portage area of MN-3. In most years since 2005, biologists from the Grand Portage Band have conducted the spring assessment in the same general area and shared the data with the MNDNR, where it has been included in the spring assessment results for MN-3. In MN-1, four commercial netters initially participated in the assessment fishery for a few years each in the 1960's, but none were willing to continue participation during the late 1960s – 1970s since they caught so few Lake Trout (Geving 2010). Beginning in 1982, with the increase in Lake Trout, formal gill net assessments began in MN-1 and were conducted by MNDNR fisheries staff to reduce potential conflict between commercial and sport fishers.

Methods

The large mesh assessment for Lake Trout in Minnesota's portion of Lake Superior has been conducted annually for over 50 years and is one of the longest annual fishery databases in the state. Locations, netting effort and time periods for the large mesh assessment for Lake Trout has varied over time. Initially the large mesh gill net assessment for Lake Trout was only conducted in MN-2 and MN-3 using the same types of gill nets, 11.4-14.0 cm stretch mesh (4.5-5.5 in) multifilament nylon, and techniques (bottom set gill nets) that had been used by operators in the commercial Lake Trout fishery. In reality, the Lake Trout assessment fishery began as a continuation of the commercial fishery, although much more limited, with the goal of monitoring the results of the rehabilitation strategies (Sea Lamprey control, stocking, etc.). As payment for their time, commitment, and operational costs, the permit netters were allowed to keep and sell their catch of Lake Trout.

Permit netters were required to submit monthly reports that documented specific information on net sets and biological information on their catch. Information required for net sets or gangs included: net length, net location (grid), depth, nights out, number and total weight of Lake Trout caught, number and weight of other species caught, and in later years, gill net material and mesh size. Biological information collected from individual Lake Trout and other species caught included: total length, weight, fin clips, tags, Sea Lamprey wounds, scale samples, and beginning in 1998, stomachs and otoliths from a sub-sample of the total catch.

From 1962-1967 permit netters had no limit on the amount of net they could fish or Lake Trout they could harvest and although no old permits can be found, it is believed the assessment season was from March – early October, with separate permits granted for Lake Trout spawn taking purposes in late October - November. Beginning in 1968, permit netters were limited to a maximum of 1,830 m (6,000 ft) of gill net daily from March 25 to October 10 with no Lake Trout quota. In 1969 and 1970, the season was reduced further with start dates on April 10 and April 15, respectively. In 1971, gill net length was reduced to a maximum of 915 m/day (3,000 ft/day), and the assessment netting season was shortened in the spring to May 1 – June 30 and in the fall from September 1 to September 30. In 1974, the spring season was shortened again, ending on June 15. Since 1975, the spring assessment has only allowed assessment netting in the month of May and the fall assessment only included the month of September, with slight modifications over the years to avoid netting on Memorial Day and Labor Day. May also became the standardized month for spring Lake Trout assessment netting among all Lake Superior management agencies.

Historical records did not clearly indicate when a Lake Trout quota was first imposed on the permit netters. Records beginning in 1968 indicate only that the amount of gear fished was restricted, not the number or weight of Lake Trout caught. Although no specific documentation (old permits) can be found, it can be implied from catch records that a quota of approximately 1,328 kg (3,000 lb) of Lake Trout per assessment netter per year was imposed in about 1975, with a catch quota of about 600 Lake Trout per season, roughly split equally between May and September. All harvested Lake Trout from the assessment fishery had to be identified with an assessment tag supplied by the MNDNR. In 1992, historical permits indicate a total-allowable-catch restriction of 680 kg (1,500 lb) of Lake Trout per permit netter was enacted for both the spring and fall assessment fishery (1,360 kg (3,000 lb) total/assessment netter) and the number of Lake Trout requested from each permit netter could not exceed 600 per season, split equally between May and September. Each Lake Trout had to be marked with an assessment tag as stated in the permit. Beginning in 2004, the weight restriction was lifted and permit netters were allowed to harvest 300 Lake Trout in both the spring and fall seasons. The details and requirements of the assessment program for participants from 1962–2014 are summarized in Appendix 4.

In MN-1, assessment netting formally began in 1982 and was conducted by MNDNR staff to reduce potential conflict between sport and commercial fishers. All gill nets set were 11.4 cm (4.5 in) stretch mesh multifilament nylon. Prior to 2008, the amount of gill net set in the MN-1 spring assessment fluctuated from 762-2,973 m (2,500-9,750 ft). In 2008, effort was standardized to 3,200 m (10,500 ft) per year for the spring assessment. In the MN-1 fall assessment, netting effort was not standardized because catch was extremely variable and netting effort was determined by number of Lake Trout targeted in the year sampled. Similar to the spring assessment, only 11.4 cm (4.5 in) stretch mesh bottom set gill nets were deployed in the fall assessment. Unlike the spring assessment, gill nets were set at variable depths, and on slightly different dates to avoid high water temperatures and, in some years, significant by-catch of Walleye *Sander vitreus*. In 2010 the fall assessment was discontinued in MN-1 due to budget constraints and reprioritization of the sampling program.

Unfortunately, from 1962-1981 specific gill net mesh size was not consistently reported by permit netters, who were allowed to fish a range of mesh sizes from 11.4-14.0 cm (4.5–5.5 in). As the program evolved, permit netters were asked to include more 11.4 cm (4.5 in) mesh in their net gangs to better conform to the lake-wide standard established by the LSTC (Ebener 2001). Permit netters were reluctant to switch completely to 11.4 cm (4.5 in) mesh so from 1982-2004, as a permit condition, 11.4 cm (4.5-in) mesh gill net had to comprise at least 50% of the net fished. From 2005 to present, all gill net used in the spring assessment netting activities must be 11.4 cm (4.5-in) stretch mesh multi-filament nylon (Appendix 4). Since 1982, when determining catch statistics from the Minnesota assessment fishery, only 11.4 cm mesh (4.5 in) multifilament nylon net sets are included in the summary calculations.

In the spring assessment, gill nets were set across contour, on the bottom, beginning at a depth of approximately 40 m (130 ft) and extending out to no more than a depth of 80 m (262 ft). The fall Lake Trout assessment nets were also set across contour, but sets were more variable in starting depth and depended heavily on water temperatures, which were much less consistent than in the spring assessment on an annual basis.

Permit netters in MN-2 and MN-3 normally set their nets at fixed locations due to limited lake access, small boat size, and lean Lake Trout generally inhabiting areas near shore during both assessment periods. As permit netters changed, some net locations changed as well, but individual netters routinely sample in the same general area. A summary list of netting locations by permit netter complete with statistical district, grid, years sampled, and various codes through 1995 is summarized in Appendix 5. From 1996 forward, information on net location by permit netter can be found in the Lake Superior assessment database housed in the Lake Superior Area Office, located at French River. Sampling locations for the spring assessment have remained fairly constant from 2001-2014 and are depicted in Figure 8.

In 2001, formal sampling protocol was developed by the Lake Superior Technical Committee to standardize all fishery independent assessments for Lake Superior (Ebener 2001). Catch per effort has been determined using a variety of methods over the years, but the current standard is now calculated as catch per net night, and is expressed as the geometric mean abundance per km of gill net adjusted to one night of soak time based on the Hansen et al. (1998) conversion. In addition to the spring assessment survey Minnesota also conducted a fall Lake Trout assessment through 2009 that has been used for annual comparisons within Minnesota, with more limited use on a lake-wide basis. Both Sea Lamprey wounding and Lake Trout catch varied significantly between spring and fall assessments as described in the next section.

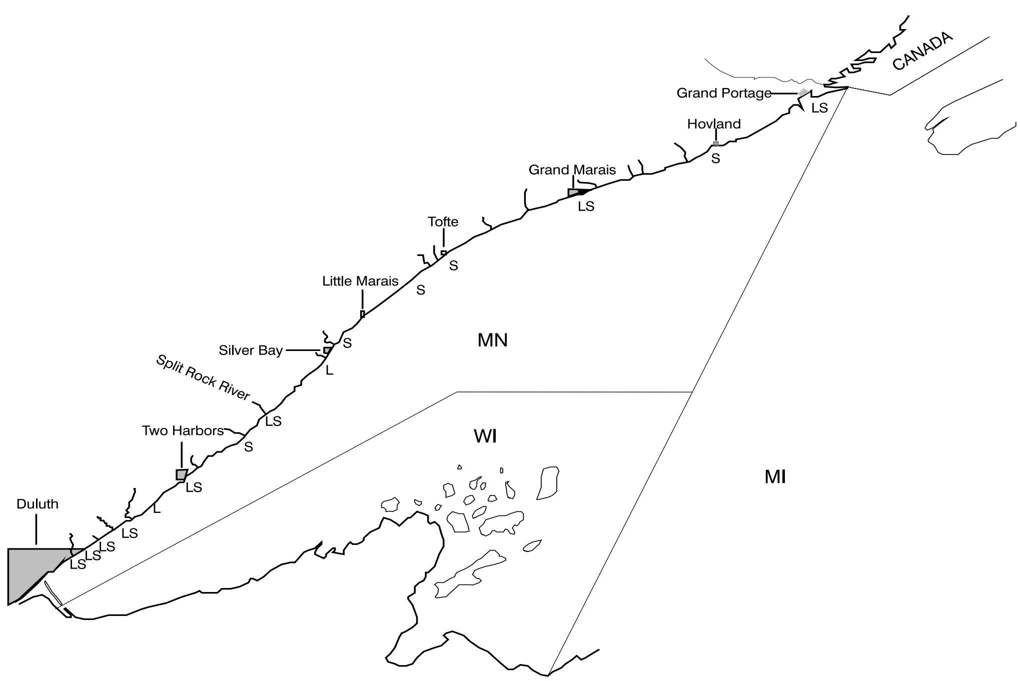


FIGURE. 8. Approximate sampling locations for spring assessment (large mesh - (L)) from 2001-2014 and small mesh assessments (S) from 1980 – 2014 in Minnesota waters of Lake Superior.

Spring Assessment Results

Most of the lake-wide criteria used to determine the status of Lake Trout rehabilitation in Lake Superior is based on the spring assessment data. Therefore, the progress toward Lake Trout rehabilitation in Minnesota is based on the criteria developed by the LSTC (Hansen et al. 1996, Schreiner et al. 2006) and will be reported on in this section.

Abundance indices - Abundance indices for Lake Trout are reported as catch per unit effort (CPUE) in either numbers or weight of Lake Trout captured per length of gill net. Because many changes have occurred over the years in the assessment procedures, the CPUE in any given year may not accurately reflect true Lake Trout abundance. However, the long term data set shows that the general trends reflect major changes in abundance. Direct CPUE (shown in all Figures found in text) and CPUE calculated using the geometric mean (shown in all Figures found in Appendix 6) show long-term Lake Trout rehabilitation trends in Minnesota.

In the shorewide spring assessment surveys CPUE of Lake Trout peaked in the mid-1980s, with over 90% of the catch composed of hatchery-reared Lake Trout (Figure 9; Appendix 6-1). Beginning in the mid-1990s, the shorewide CPUE of wild Lake Trout surpassed that of stocked fish, and by 2008 wild Lake Trout exceeded 80% of the total CPUE. Total CPUE is now lower in all three management zones than during the early 1980s when survival of stocked fish was high (Figure 9; Appendix 6-1). In the 1980s, a period when stocking levels of Lake Trout were high and Rainbow Smelt populations were abundant, the carrying capacity for Lake Trout was likely greater than it is today, producing the high CPUEs reported during that period.

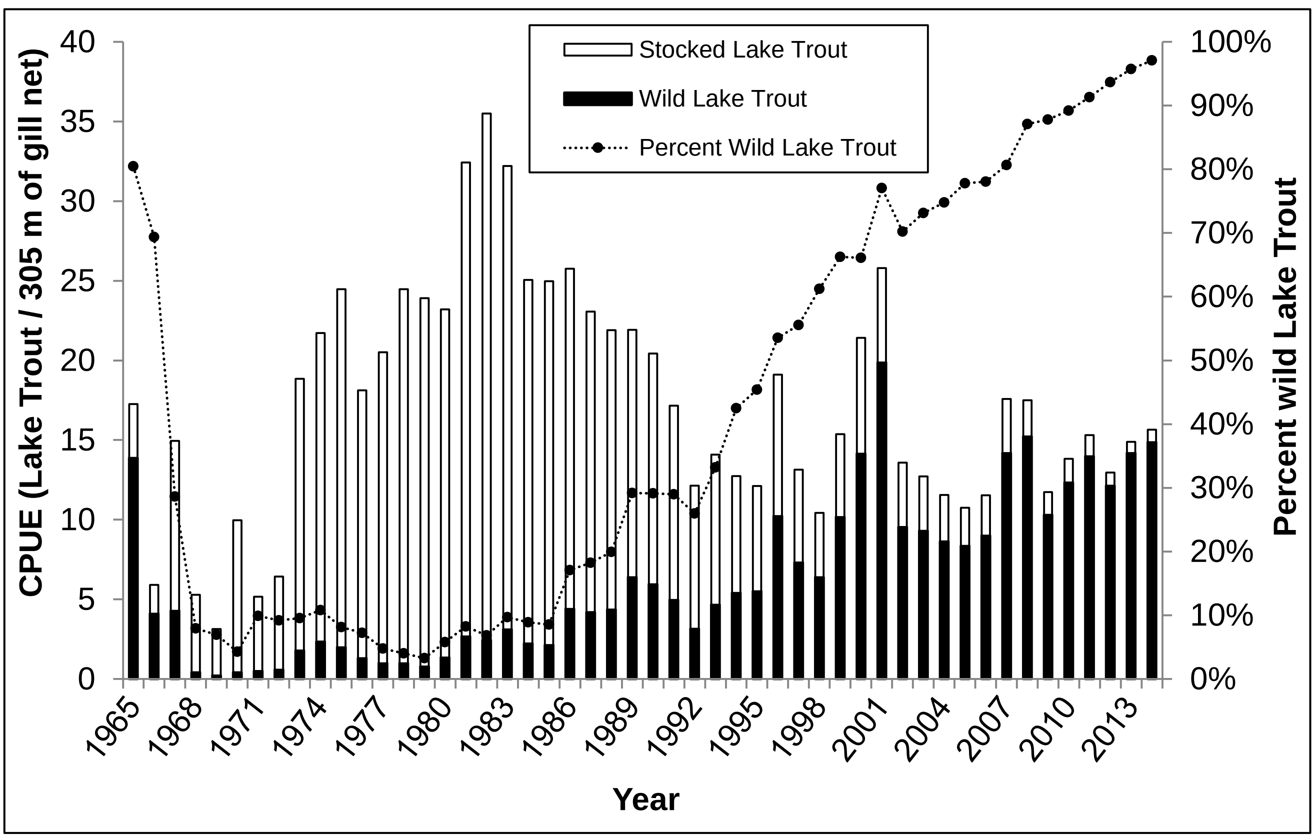


FIGURE 9. Percent wild and mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout shorewide in spring assessment surveys from 1965-2013. No spring assessment surveys were conducted in MN-1 from 1970-1981.

CPUE in MN-2 and MN-3 increased dramatically after Sea Lamprey control and stocking were initiated in the early 1960s. CPUE in both zones reached a peak in the late 1980s and was comprised of predominately hatchery-reared fish (Figure 10; Appendix 6-2). Once wild fish begin to enter the fishery in the early 1990s, both relative abundance and percentage of stocked fish started to decline. CPUE and rate of rehabilitation was much higher in MN-3 than in MN-2. The contribution of wild fish to the catch began to accelerate in MN-3 in the early 1990s, and in MN-2 in the early 2000s (Figure 10; Appendix 6-2).

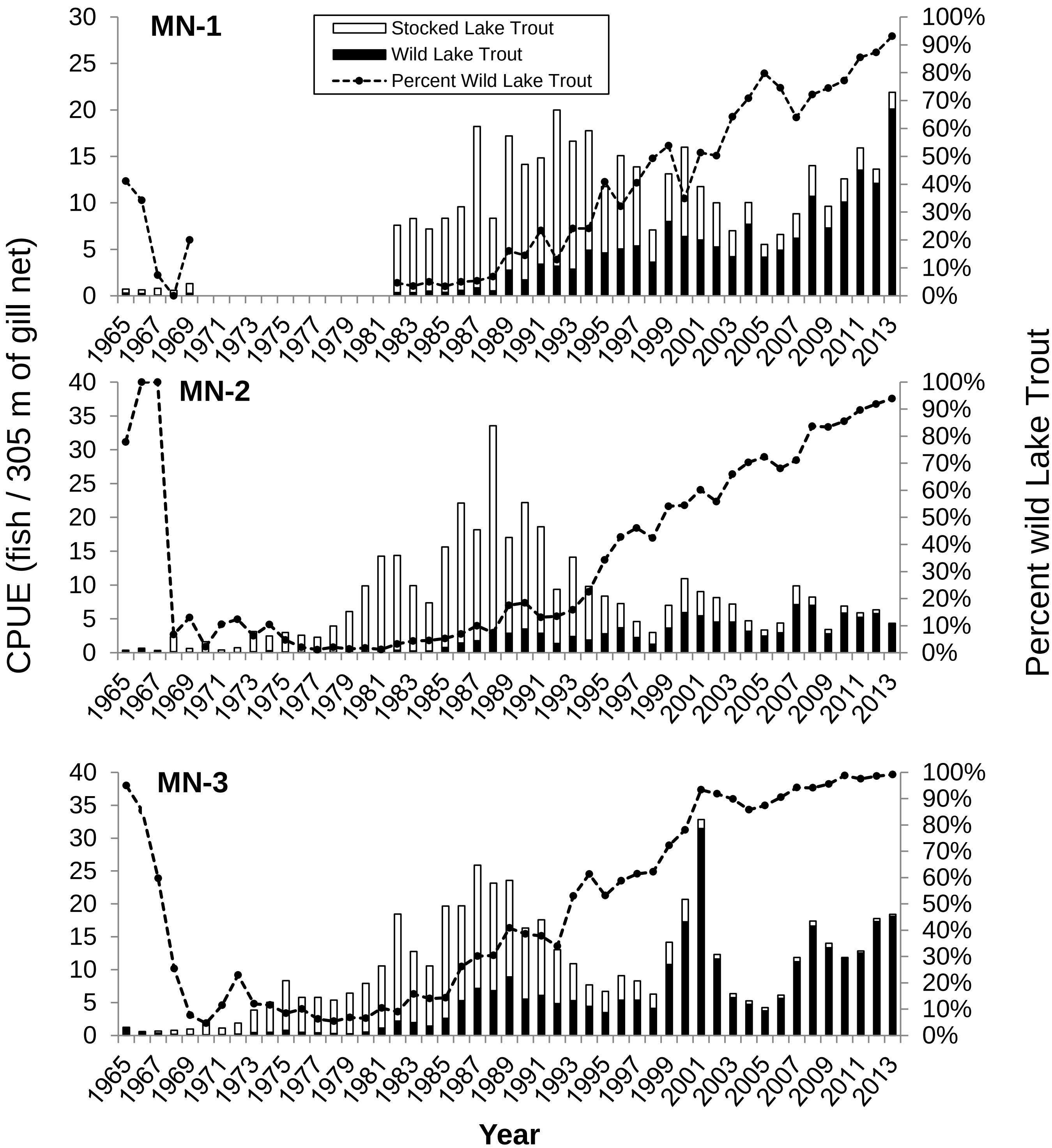


FIGURE 10. Percent wild and CPUE (number of fish/305 m [1,000 ft] of gill net) of stocked and wild Lake Trout by management zone in the spring assessment surveys from 1965-2013. No spring assessment surveys were conducted in MN-1 from 1970-1981.

The spring Lake Trout assessment did not formally begin in MN-1 until 1982, and contribution of wild Lake Trout in MN-1 showed a similar trend to MN-2, with rehabilitation in both zones somewhat delayed relative to MN-3. Relative abundance in MN-1 and MN-3 varied by year, but overall was similar ranging from approximately 10-20 fish per 305 m (1,000 ft) of gill net. Relative abundance in MN-2 was generally lower by about 50% than in the other two zones, except for a few years, 1985-1991, when MN-1 and MN-2 were similar (Figure 10; Appendix 6-2).

Sea Lamprey marking rates - A standardized system for reporting Sea Lamprey wounds on Lake Trout in Lake Superior was initiated in 1986. A detailed description of the protocol can be found in Ebener 2001. In Minnesota, shorewide Sea Lamprey wounding rates on Lake Trout captured in the spring assessment have decreased dramatically from the peak levels reported in the 1960s and early 1970s. Since the initial decline, overall shorewide wounding rates in the spring assessment have fluctuated within a relatively narrow range of 5-10 wounds per 100 Lake Trout (Figure 11). Wounding rates have historically been highest in MN-1, followed by MN-3 and MN-2, until the mid-2000s when wounding in MN-3 increased to relatively high levels, surpassing MN-1 in many years (Figure 12). The increased wounding in MN-3 may have resulted from newly discovered lentic Sea Lamprey production in the port of Thunder Bay, Ontario (ship turning basin). Once the turning basin was treated with Baylicide in the early 2000s, wounding rates in MN-3 returned to more normal levels. Wounding rates in MN-1 have always been relatively high; sometimes the highest among all Lake Superior Lake Trout management units. Sea Lamprey found in MN-1 are likely produced in Wisconsin streams and migrate to Minnesota waters where Lake Trout density is much higher. Lamprey wounding rates in MN-1 have fluctuated more than in the other two Minnesota management units and may reflect the cyclical treatments for Sea Lamprey in the Bad River, Wisconsin, a very large producer of Sea Lamprey (Steeves 2012).

Sea Lamprey normally target the largest individuals (spawners) in a Lake Trout population, which can greatly affect the reproductive potential of the stock (Lawrie and Rahrer 1973). As Sea Lamprey treatments became more effective, Lake Trout wounding rates declined among the larger individuals, increasing natural reproduction and facilitating self-sustainability of the Lake Trout population.

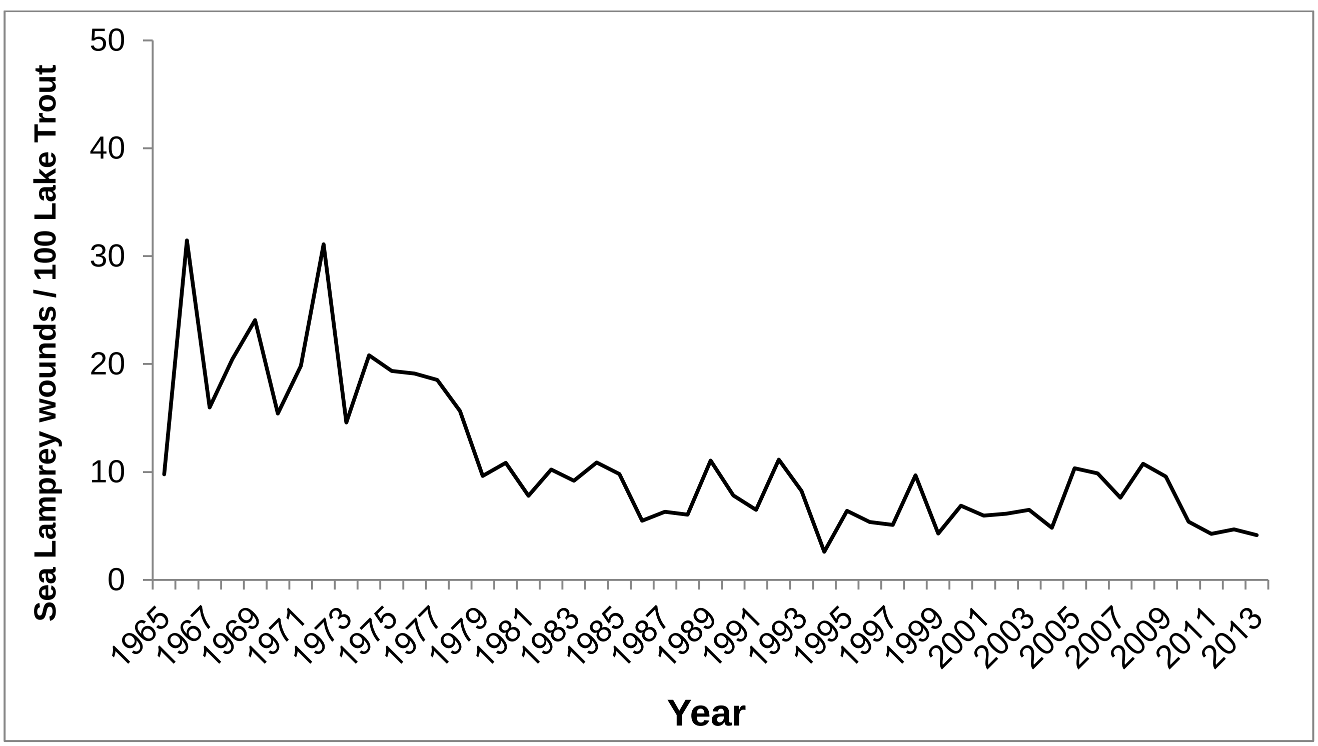


FIGURE 11. Number of Sea Lamprey Wounds/100 Lake Trout shorewide in spring assessments, 1965-2013.

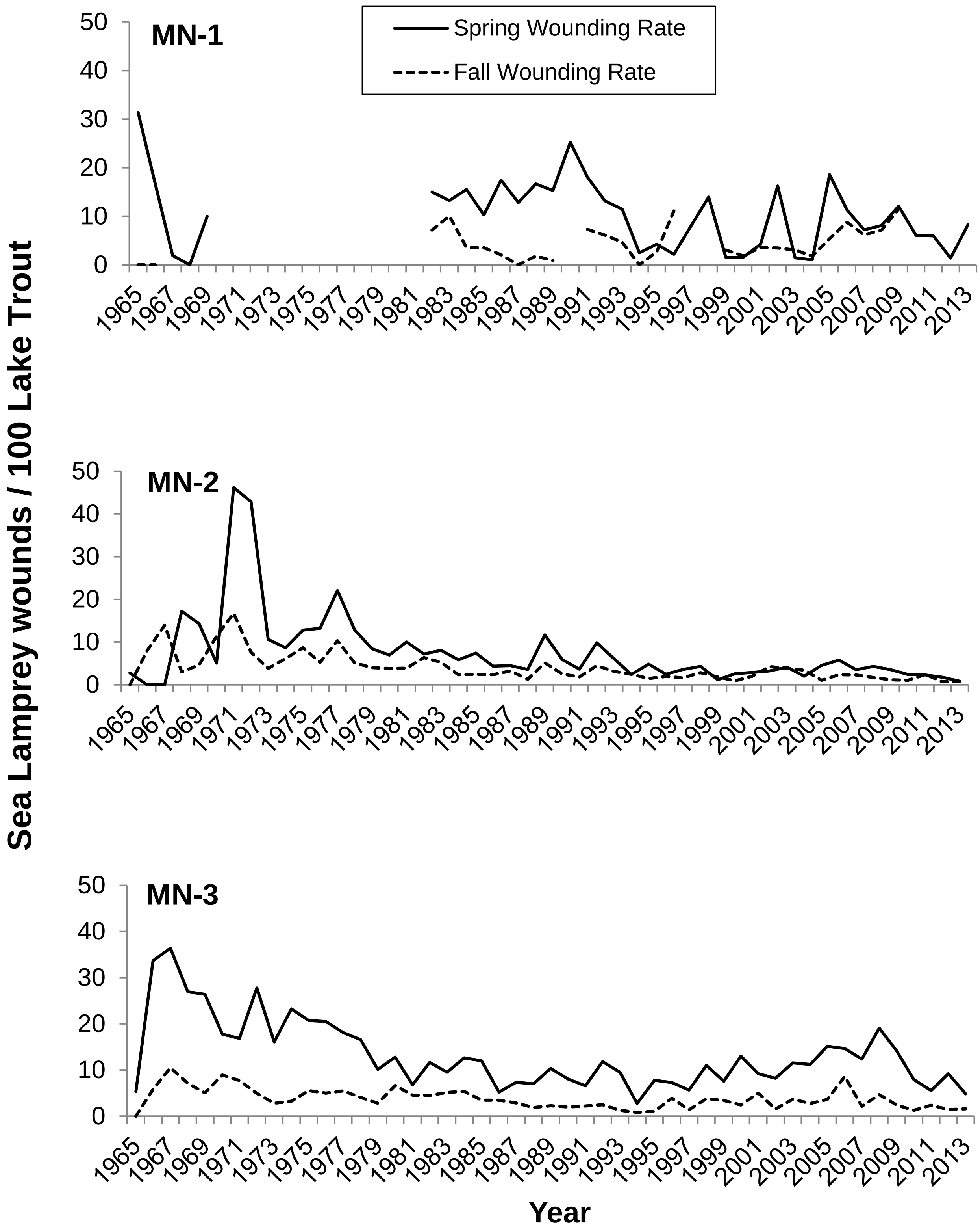


FIGURE 12. Sea Lamprey wounding rate (number of Sea Lamprey wounds/100 Lake Trout) of Lake Trout captured in the spring and fall assessment surveys, by management zone, 1965-2013. No assessments were conducted in MN-1 from 1970-1981.

Survival of Stocked Lake Trout - Two major criteria proposed by the LSTC when considering to discontinue Lake Trout stocking are survival of hatchery-reared Lake Trout to age-7 and percentage of wild Lake Trout greater than 63.5 cm (25 in) (Hansen 1996, Schreiner et al. 2006). The relative survival index for stocked Lake Trout in Lake Superior is based on data from the spring assessment, and is calculated as CPUE of age-7 Lake Trout in 304.8 km (1,000 ft) of net/100,000 Lake Trout stocked seven years earlier. A survival index of less than 1.0 is considered extremely poor, indicating that hatchery-reared Lake Trout no longer contribute significantly to the fishery, and discontinuation of further Lake Trout stocking should be considered. In Minnesota, MN-3 was the first management zone where the survival index for stocked Lake Trout fell below 1.0 for three consecutive years beginning in 1997. In MN-2, the survival index fell below 1.0 beginning in 2004, and in MN-1 the survival index has been below 1.0 since 2003 (Figure 13). In addition, the percentage of wild Lake Trout greater than 63.5 cm (25 in) in all three management areas exceeded 50% in 2001, which is an additional criterion used to eliminate stocking (Figure 14). Based on the Lake Trout stocking survival index, the percent wild Lake Trout greater than 63.5 cm (25 in), and the other criteria listed in the 1996 Lake Trout Rehabilitation Plan (Hansen 1996), Lake Trout stocking was discontinued in MN-3 in 2003 and in MN-2 in 2007 (Schreiner et al. 2006). In 2007, yearling Lake Trout stocking levels were decreased in MN-1 from 232,000 to 170,000, and discontinuation of stocking will be recommended when the next Lake Superior Fisheries Management Plan for Minnesota is revised in 2016 (Schreiner et al. 2006).

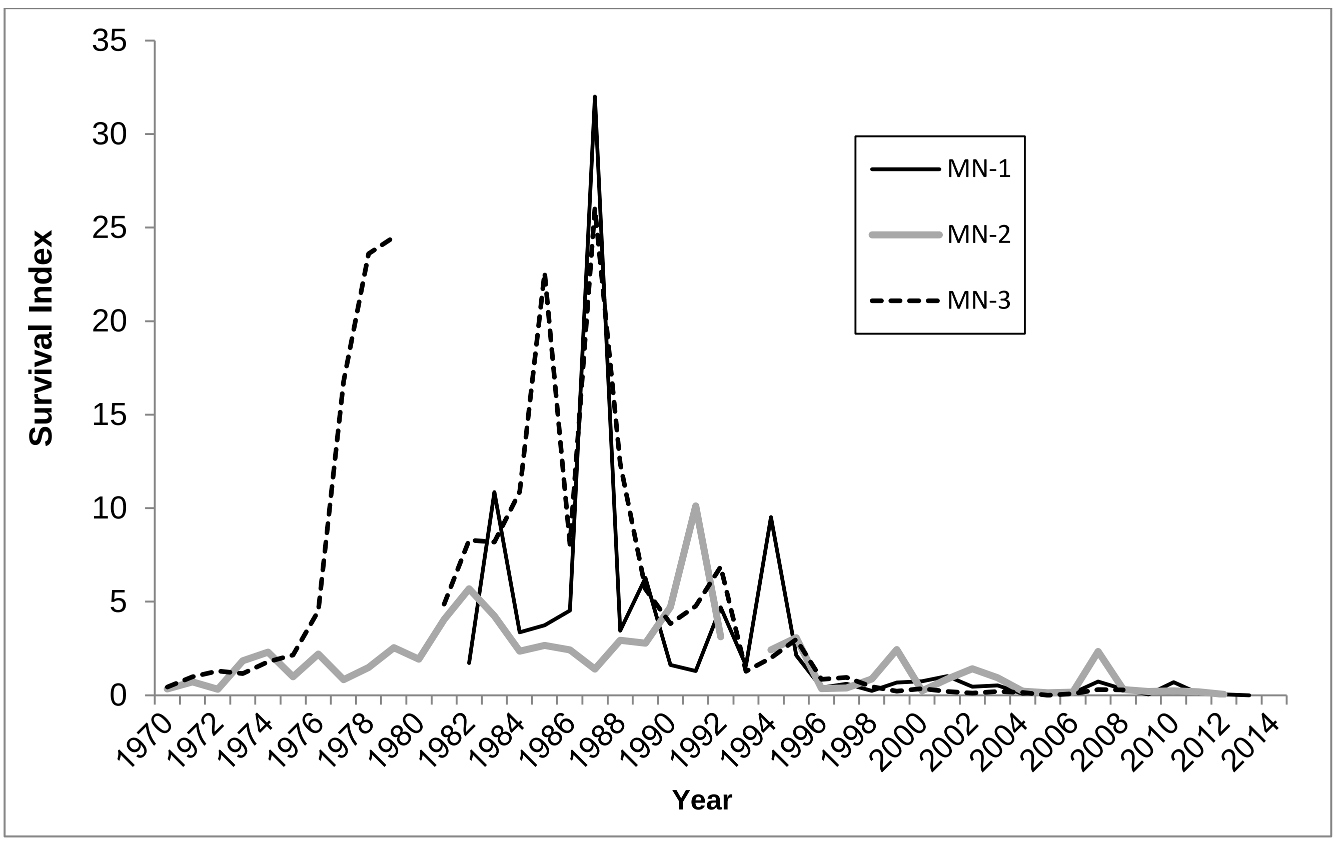


FIGURE 13. Survival index of stocked Lake Trout (number of age 7 stocked Lake Trout/305m gill net/100,000 Lake Trout stocked seven years earlier) in spring assessment surveys by management zone, 1970-2013. A survival index of < 1.0 for three consecutive years is one criteria used to evaluate the continued need for stocking.

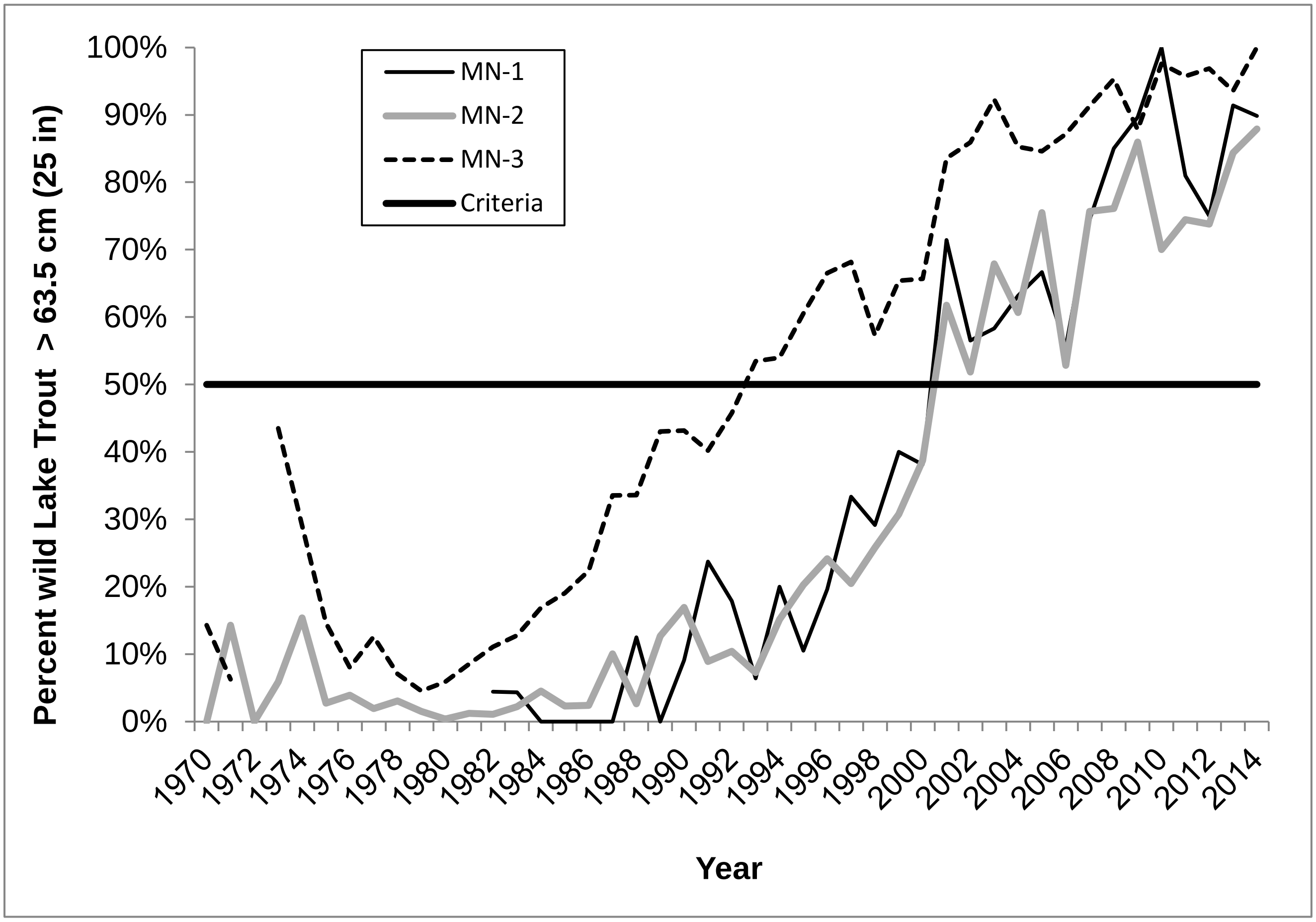


FIGURE 14. Percent wild Lake Trout > 63.5 cm (25 in) by management zone captured in spring assessment surveys, 1970-2013. Years with fewer than 5 fish > 63.5 cm (25 in) are not included. No spring assessment surveys were conducted in MN-1 from 1970-1981.

Size at age (growth rates) - A general estimate of trends in Lake Trout growth for Lake Superior has been calculated using average length of age-7 Lake Trout captured in the spring assessment using only 11.4 cm (4.5 in) mesh gill net over time (Hansen et al. 1996; Sitar et al. 2010). The growth trends calculated for age-7 Lake Trout shorewide indicate that growth declined in the late 1980s, was extremely variable in the 1990s, continued to decline in the 2000s, and appears to have stabilized at a lower level since 2008 (Figure 15). Growth is density dependent, and a decrease in size at age from 1988-2007 of approximately 7.5 cm (3.0 in) indicates that Lake Trout stocks in Minnesota may have reached carrying capacity, and further increases in abundance are unlikely, unless prey availability increases (Corradin et al. 2008; Negus et al. 2008).

Population age/size structure - The size structure of the Lake Trout population has changed dramatically over the last 50 years, shifting to the right with the proportion of older fish increasing significantly (Lake Superior Area files). This shift in size structure can be seen in all three Minnesota management zones and first began in MN-3 followed by MN-2 and MN-1. The survival of larger Lake Trout is likely the combined result of effective Sea Lamprey control and more restrictive harvest regulations.

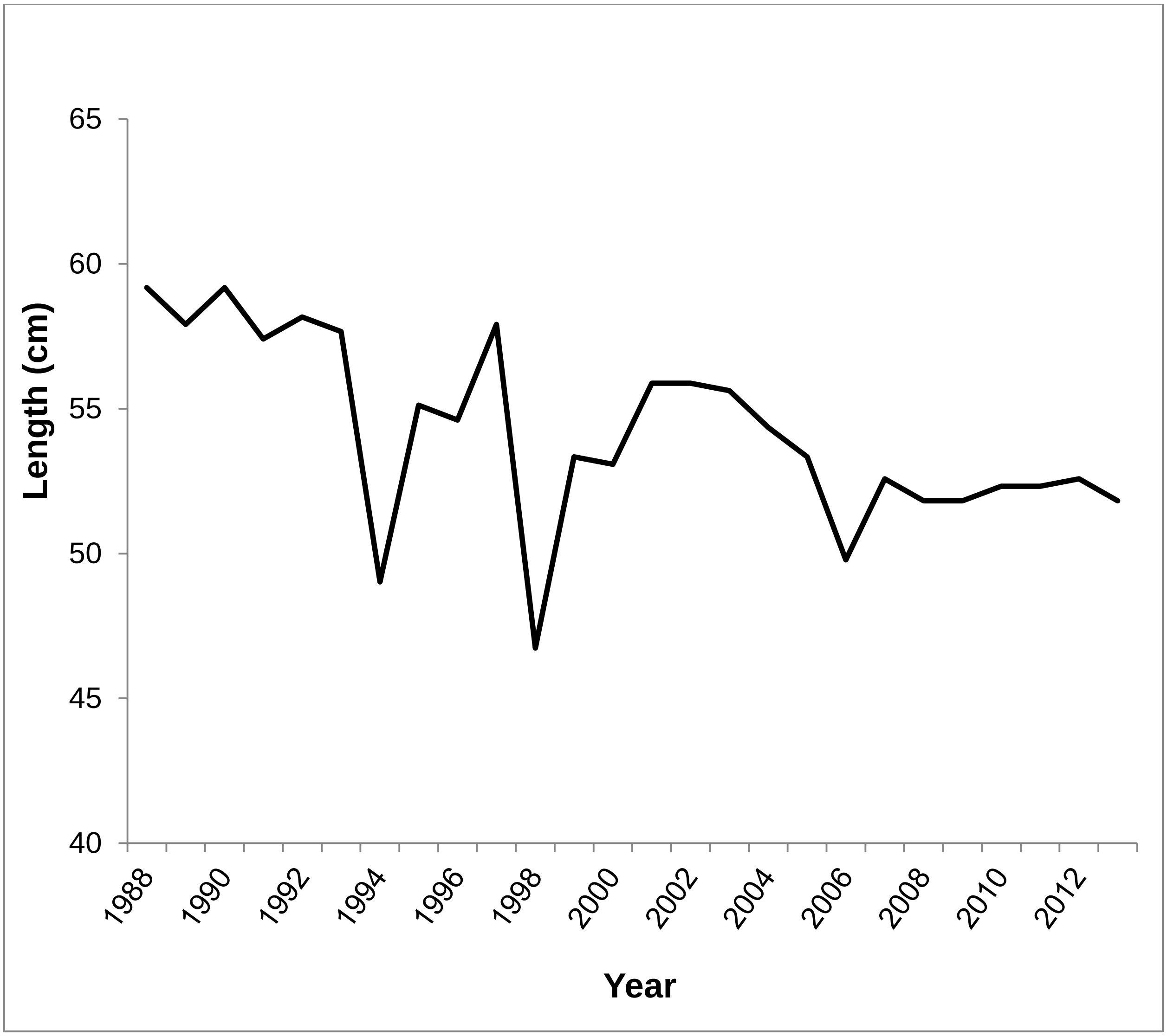


FIGURE 15. Mean length of age-7 Lake Trout captured in the spring assessment surveys, by year, 1988-2011.

Fall Assessment Results

In general, when compared to the spring assessment, Lake Trout captured in the fall assessment tend to be larger, have fewer Sea Lamprey wounds and are captured in shallower water, because many are starting to migrate to near-shore locations as pre-spawners.

Abundance Indices - Fall CPUE for Lake Trout was much higher overall than spring CPUE, while the rate of increase in wild Lake Trout lagged that found in the spring (Figure 16; Appendix 6-3). Stocked fish drove the highest CPUEs in the fall, most notably in the 1980s, with wild fish not becoming dominant until the early 2000s. In general, fall CPUE was highest in MN-1 beginning in the 1980s, followed by MN-3, while CPUE in MN-2 was extremely high in the early 1980s, but dropped to the lowest level of all three zones by the mid-1990s. (Figure 17; Appendix 6-4).

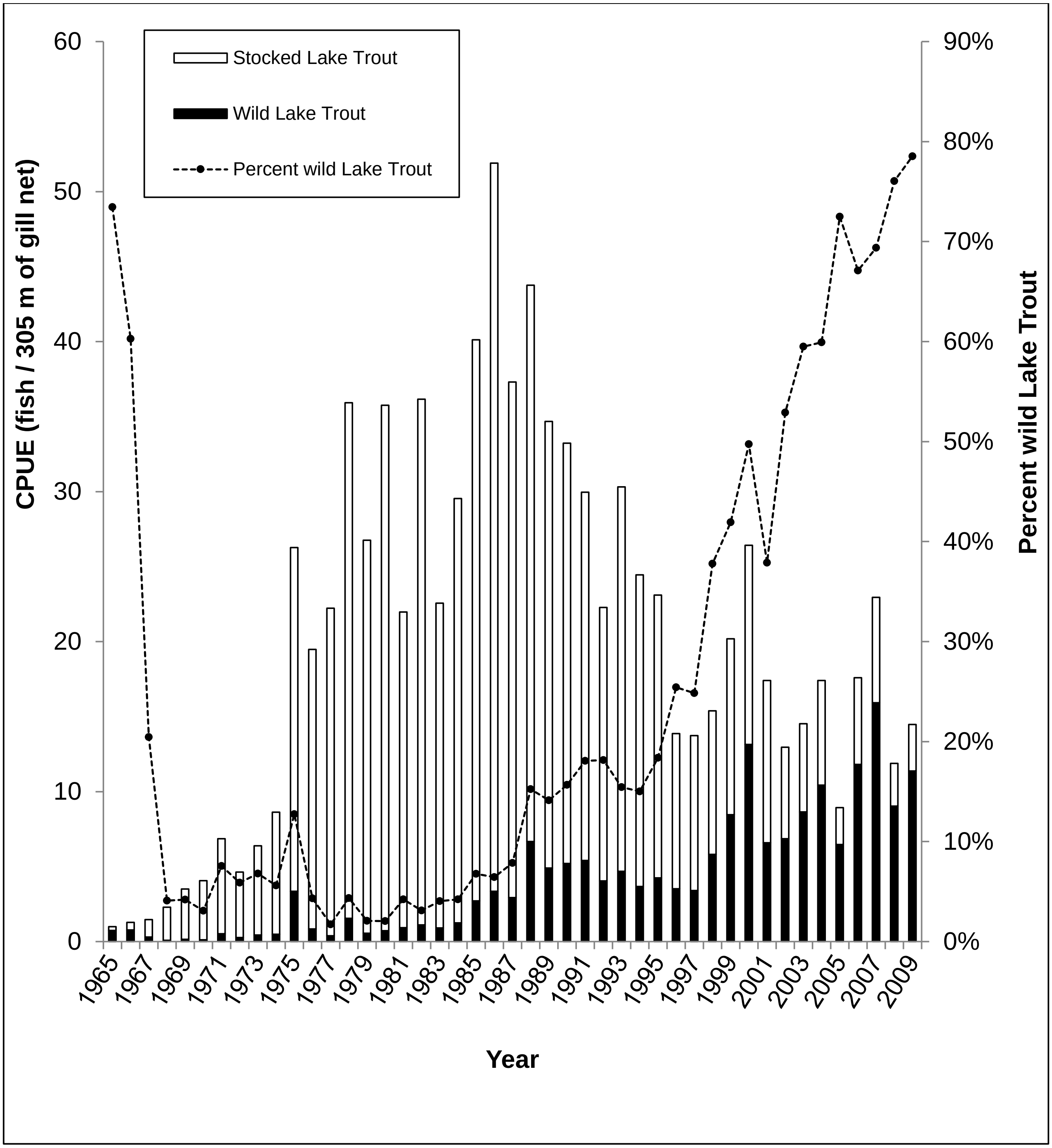


FIGURE 16. Percent wild and mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout shorewide in fall assessment surveys from 1965-2009. No fall assessment surveys were reported for MN-1 from 1965-1981 and in MN-3 the fall assessment was discontinued in 2009.

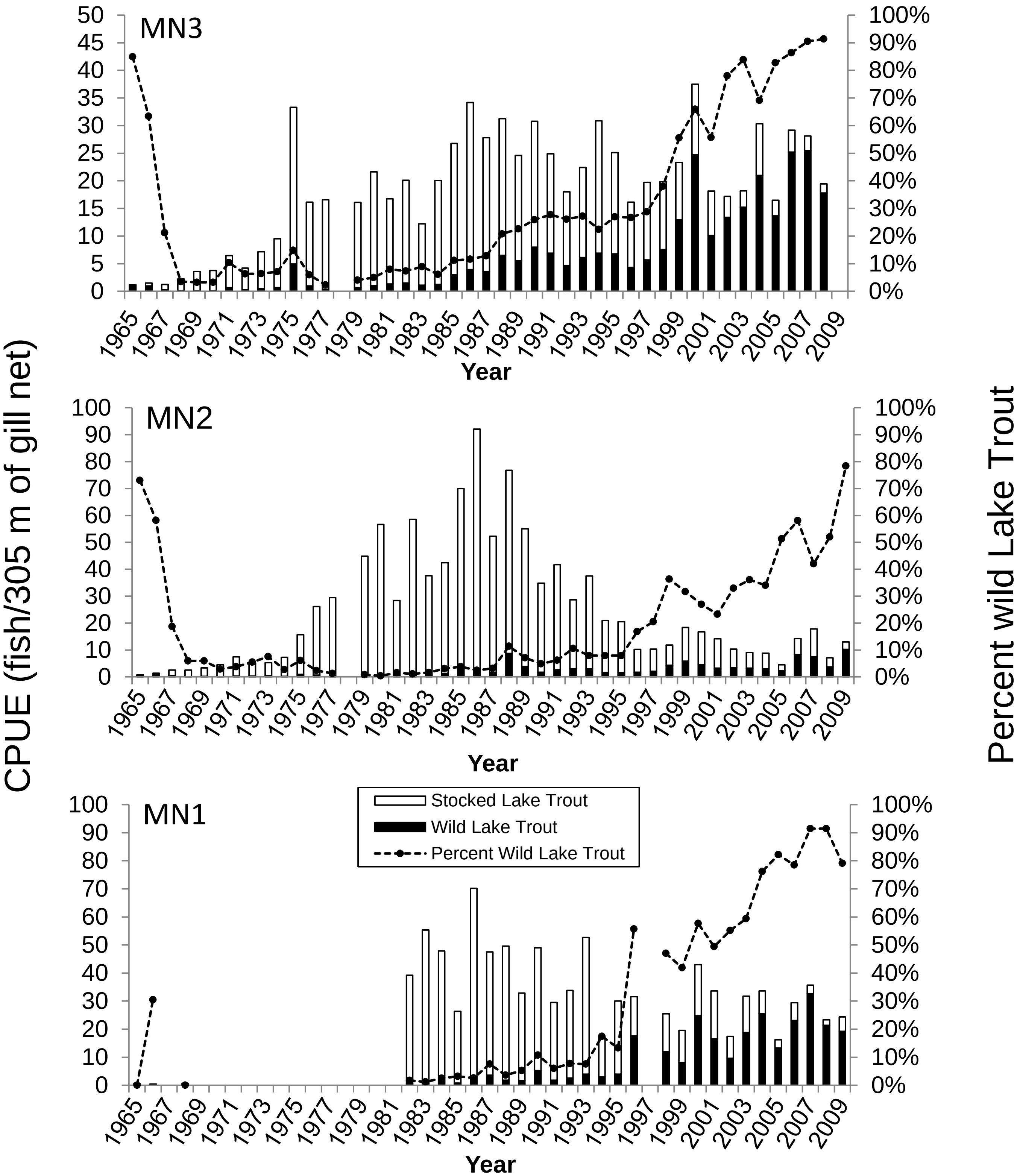


FIGURE 17. Percent wild and mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout by management zone in fall assessment surveys from 1965-2009. No fall assessment surveys were reported for MN-1 from 1965-1981 and in MN-3 the fall assessment was discontinued in 2009.

Sea Lamprey wounding rates, lengths at age 7, and the size/age distribution of Lake Trout captured in the fall assessment were also compared to those observed in the spring assessment. The lower Sea Lamprey wounding rate in the fall (Figure 12) occurred because most transformers (newly migrating parasitic phase Sea Lamprey) had not yet left the streams, and adult Sea Lamprey had entered the streams in the spring, spawned and died. The average size at age-7, and the population structure in fall was similar to the spring, with the population structure skewed slightly more to the right in the fall due to the higher capture of mature pre-spawning individuals (Lake Superior Area files).

Water temperatures in the fall assessment are much more variable than in the spring, which influences the Lake Trout distribution and netting locations. As the fall water temperatures cool, Lake Trout tend to migrate into shallower near-shore water. However, in some years, fall near-shore water temperatures can remain relatively high causing Lake Trout stocks to remain offshore in deeper water. Over the last 50 years, fall water temperatures have generally trended higher causing permit netters to fish in much deeper water to capture Lake Trout. In some of the most recent years, the timing of the fall assessment tended to approach the spawning assessment (mid-October) if the same depths and temperatures were targeted as in previous fall surveys. In addition, by-catch of large walleye in MN-1, before temperatures decreased, was extremely high, and efforts were made to avoid netting during this period.

In 2010, the need for a fall Lake Trout assessment was reevaluated based on the cost of the survey, increasing trend of warmer fall water temperatures and the implementation of the Expanded Assessment Lake Trout fishery. After extensive review and discussion, the decision was made to discontinue the fall assessment. Staff time, effort and expenses were reallocated toward fall hydoacoustics assessments, a targeted cisco netting assessment, and increased migratory fisheries work (Knife and French River trap operations). Because Minnesota was the only Lake Superior agency that had conducted a fall assessment, comparisons of fall collected Lake Trout data among agencies was not a concern. In addition, the Expanded Assessment Lake Trout fishery that was reinstated in 2007 (MN-3) and 2010 (MN-2) included the same month (September) as the traditional fall assessment. Most of the operators who were involved in the traditional fall assessment later participated in the Expanded Assessment. Therefore, commercial operators fishing in September were given special instructions, and encouraged to increase their netting activity so that some trends in the fall Lake Trout assessment could be tracked if desired.

Small Mesh Assessment (Summer)

The small mesh or summer assessment in Minnesota targets juvenile Lake Trout (<43 cm (17 in)), but also captures a variety of coregonids. The purpose of the assessment is to determine recruitment of wild juvenile Lake Trout and early survival of stocked Lake Trout, predict Lake Trout year class strength, and monitor general trends in abundance of coregonids. Prior to a standardized juvenile Lake Trout assessment in 1970, MNDNR staff rode with commercial Chub *Coregonus hoyi* netters to observe by-catch of small Lake Trout in bottom set gill nets measuring 5.7-7.0 cm (2.25-2.75 in) stretch mesh. This was the only method available to monitor survival of recently stocked hatchery-reared Lake Trout and determine percent wild of juvenile Lake Trout at the time.

Methods

The small mesh assessment formally began in 1970 and has only been conducted by MNDNR staff. The assessment is normally conducted from early July through the second week in August. Small mesh netting locations span from Duluth to Grand Portage and the number of sampling sites ranged from 8-10 between 1970 and 1984, and from 10-12 between 1985 and 1990. In 1991, the number of small mesh locations was standardized at 13 where it remains to date (Figure 8). Bottom set gangs of various sized gill nets that ranged from 1.3-7.6 cm (0.5-3.0 in) stretch mesh were used. Although mesh sizes of gill nets within gangs were not completely consistent over the years, most gangs included 5 panels 61 m (200 ft) long each of 3.8, 4.4, 5.0, 5.7, and 6.4 cm (1.5, 1.75, 2.0, 2.25 and 2.5 in) stretch mesh. Length of each sized panel that made up a gang varied in some of the early years, but has generally been consistent since the early 1990s. The 5.7 cm (2.25 in) mesh was included since it was the mesh size most used in the early Chub fishery.

Small mesh gill nets are set cross-contour with most near-shore anchors deployed at 36.6 m (120 ft) and offshore depth ranging from 55 m (180 ft) to over 91.5 m (300 ft) depending on location. Sampling this range of depths is based on early observations by MNDNR personnel that most juvenile Lake Trout by-catch occurred at this range rather than in the deeper Chub nets. Most small mesh net locations have a connection to both stocking sites and commercial large mesh permit netting activity. Small mesh assessment nets are set for two nights at two stations per location, except for the Hovland site which is normally set for one night. More detailed information on methods used in the contemporary small mesh assessment can be found in Geving (2010).

Results

Most Lake Trout captured in the small mesh assessment are less than 43 cm (17 in) and 6 years of age or younger. Strong year classes and trends in percent wild juvenile Lake Trout in the small mesh assessment have generally been noted a few years later in the spring assessment indicating good correlation between these surveys. Shorewide CPUE has varied annually, peaking in the 1980s with high stocking levels and good survival of stocked fish. However, wild fish have consistently replaced stocked fish in the catch, with the rate of change increasing significantly beginning in the mid-1990s (Figure 18; Appendix 6-5). CPUE has varied by location, but was generally lowest in MN-1, moderate in MN-2 and highest in MN-3 (Figure 19; Appendix 6-6). However, by the late 2000s CPUE in all management zones were at similar levels. As expected, increasing trends in percent wild in the small mesh assessment was identified earlier than in the spring and fall assessments, but tended to follow the same general patterns. Natural reproduction exceeded 50% beginning in 1995 in MN-3, 1997 in MN-2 and 2000 in MN-1 (Figure 19; Appendix 6-6). Average percent wild Lake Trout shorewide has exceeded 70% annually since 2001, 80% since 2008, and over 90% since 2012 (Figure 18; Appendix 6-5).

Coregonids are a by-catch in the small mesh assessment, and data have been compiled to monitor long term trends of the various species. CPUE of Cisco has varied over the years, but similar to juvenile Lake Trout, strong year classes captured in the small mesh assessment generally correlate well with high abundance of adults in the commercial fishery a few years later.

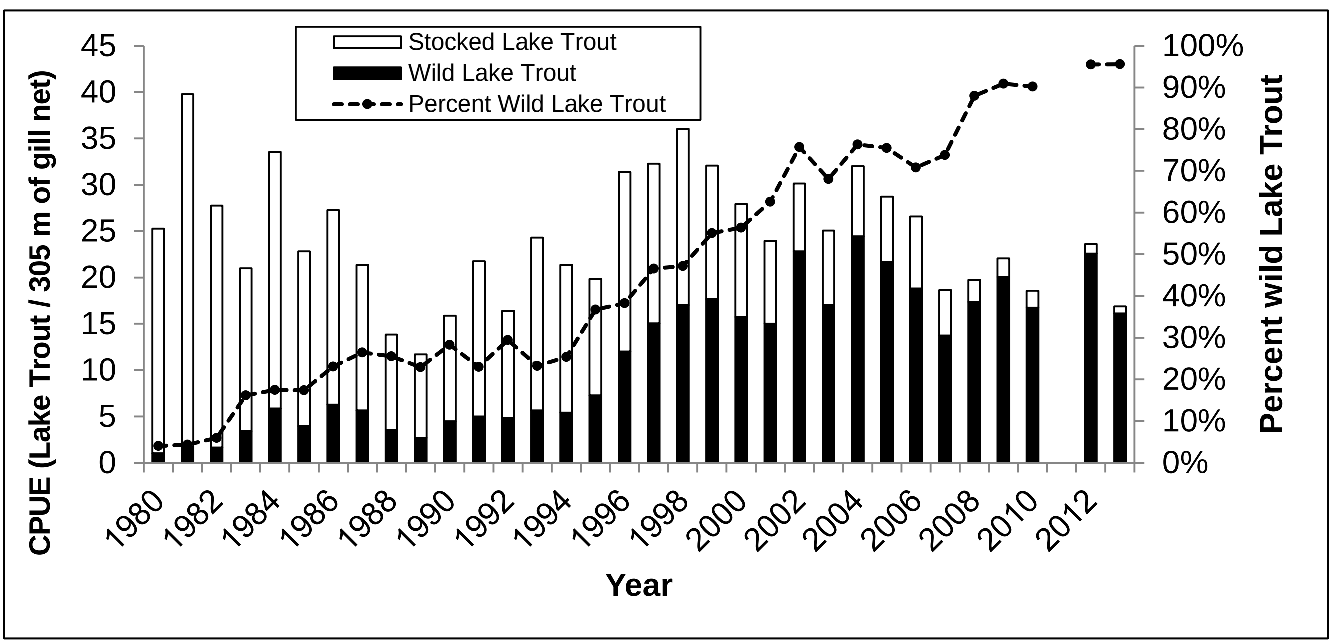


FIGURE 18. Percent wild and CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild juvenile Lake Trout (< 43cm (17 in)) in small mesh assessment surveys shorewide, 1980-2013. Small mesh assessments prior to 1980 are not yet available in electronic format and the 2011 survey was not conducted due to a State of Minnesota government shutdown.

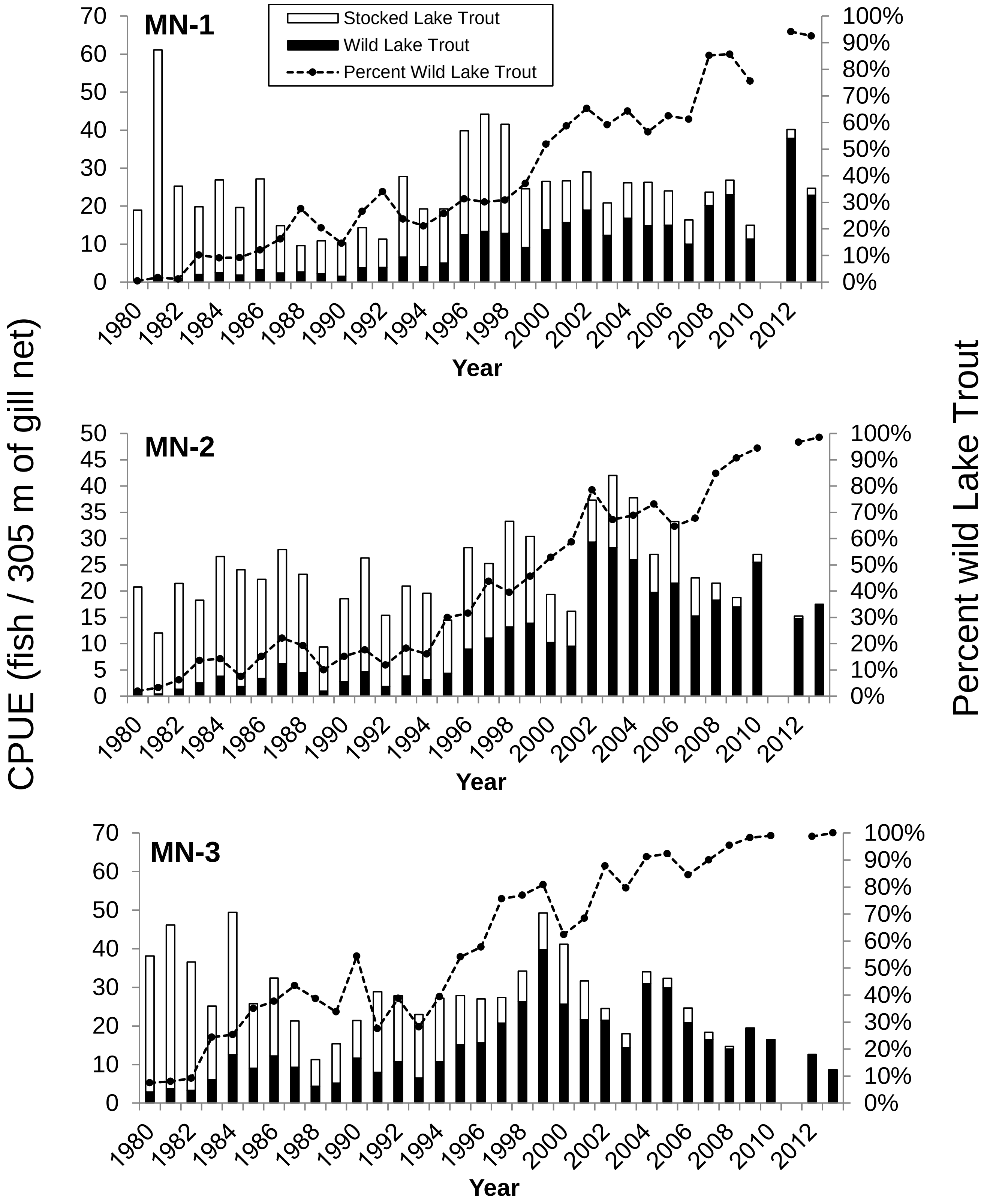


FIGURE 19. Percent wild and CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild juvenile Lake Trout (< 43cm (17 in)) in small mesh assessment surveys by management zone, 1980-2013. Small mesh assessments prior to 1980 are not yet available in electronic format and the 2011 survey was not conducted due to a state shutdown.

Spawning Assessment

Commercial netters were utilized as early as 1947 to provide Lake Trout eggs to the hatchery system for rehabilitation efforts. In 1962, the commercial fishery for Lake Trout was closed, but up to 20 permits could still be issued to commercial netters for spawn taking operations. The Lake Trout spawning assessment was initiated to monitor the expected increase in spawning Lake Trout over time, the increase in wild spawners, the contribution of stocked Lake Trout to the spawning population, the amount of Sea Lamprey wounding on the larger fish, and to determine the location of spawning stocks. Beginning in the early 1970s, as Lake Trout rehabilitation advanced and spawning Lake Trout became more abundant, some commercial netters continued to participate in an early form of a Lake Trout spawning assessment under MNDNR permit. In 1985, the Lake Trout spawning assessment became more formalized, and data similar to that collected in the spring and fall assessments were also collected from spawning Lake Trout. Since 1991, MNDNR staff conducted the spawning assessment in MN-1, while one commercial netter has been permitted to participate in the spawning assessment in each of zones MN-2 and MN-3. Unfortunately, the early Lake Trout spawning records in Minnesota are sparse and lack significant detail, while more complete records were kept beginning in 1985.

Methods

Initial data collection for the Lake Trout spawning assessment began in 1968. These assessments were conducted intermittently until 1985 when the spawning assessment became more formalized and changed to bi-annual sampling. The spawning assessment was initially conducted in three locations by commercial netters operating under special permit from MNDNR. These locations included Grand Portage and Grand Marais in MN-3 and Split Rock River area in MN-2. The spawning assessment in the Grand Portage area was discontinued in 1989. In 1985 the MNDNR initiated a Lake Trout spawning assessment in MN-1. Since 1985 each management zone has maintained at least one spawning assessment location. All gill nets used in the spawning assessment were set on the bottom in relatively shallow water (<30.5 m (100 ft)). Mesh size varied in the early years from 14.0-16.5 cm (5.5 - 6.5 in), but since 1985, 14.0 cm (5.5 in) stretch mesh has been the predominant size used. Spawners are generally sampled from mid-October through mid-November. Data collected from individual Lake Trout captured include total length, weight, Sea Lamprey wounds, tags, fin clips, scales, sex, stage of maturity, and in later years, sub-samples of stomachs, otoliths, and occasionally egg skeins were taken to determine number of eggs/female.

Results

The CPUE of wild Lake Trout in the spawning assessment has increased significantly in each management zone from 1968–2014. The percentage of wild Lake Trout in the spawning assessment increased from less than 5% in all zones in 1985 to over 90% in MN-3, over 80% in MN-2, and approximately 40% in MN-1 by 2013 (Figure 20; Appendix 6-7). Because the spawning assessment focuses on larger, older fish in the population, evidence of rehabilitation lagged behind that found in the other assessments. The percent wild Lake Trout in the spawning assessment increased first in MN-3, followed by MN-2 and then MN-1. The rate of increase in wild spawners in MN-3 suggests that remnant stocks of wild fish may have made significant early contributions. Sea Lamprey control was critical to reestablishing spawning populations, and it took about 10 years before adequate numbers of stocked Lake Trout survived to reproduce naturally in all three zones (Selgeby et al. 1995a).

Males first entered the spawning population around age- 8, while females first entered at age-9 based on otolith-aged fish (Lake Superior Area files). Annual sex ratio in the spawning assessment varied greatly, but appeared to be more dependent on sample timing than on the actual sex ratio in the population. Males tend to congregate in spawning areas for a much longer period of time than females, which tend to move onto the spawning site, drop their eggs within 1-2 days, and then depart. Data collected from egg traps set in MN-1 suggested that nights with heavy wave action stimulated spawning more than calm or moderate periods of wind/wave action. In MN-1, the peak spawning period from 1990-1992 was October 15–25, based on egg captures, but specific dates were heavily dependent on water temperatures and wind velocity (Schreiner 1995).

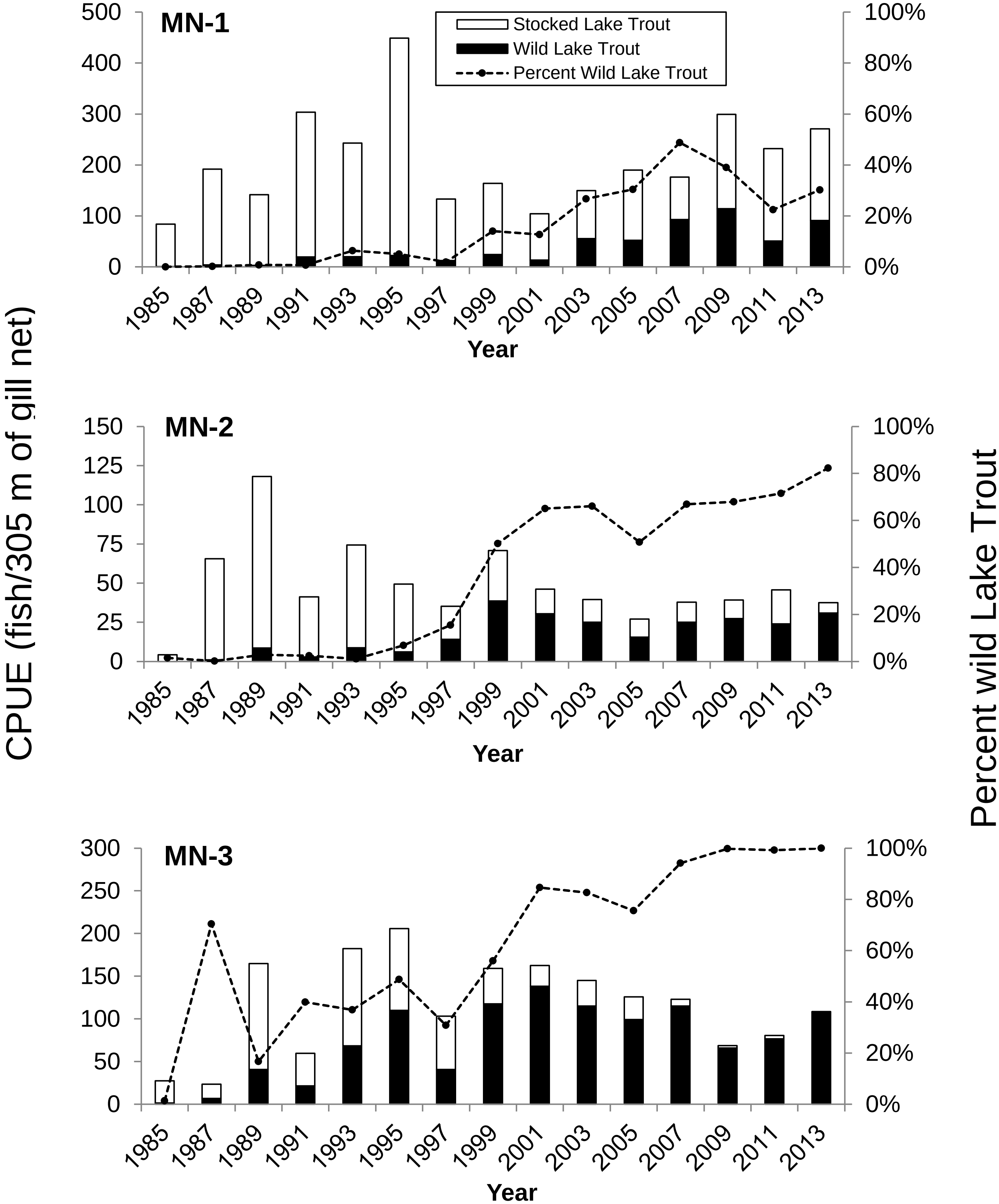


FIGURE 20. Percent wild and CPUE (number of fish/305 m (1,000 ft) gill net) of stocked and wild Lake Trout in spawning assessment surveys by management zone, 1985-2013. Spawning assessments are conducted in odd numbered years.

A minimal amount of tagging on the spawning population was conducted in the 1980s in MN-1, and recaptures showed a significant amount of site fidelity by stocked fish. Rehabilitation of wild stocks in MN-1 as measured in the spawning assessment has lagged behind the other two zones considerably, despite high densities of stocked fish on the spawning grounds and heavy egg deposition along the rip-rap at both the Superior and Duluth entries, the old dock pilings in the Lake Walk area, and on or near Fitger's artificial reef. Factors that may have influenced the lag in the percentage of wild spawners in MN-1 are continued heavy predation on larger fish by Sea Lamprey, relatively high stocking rates by both Minnesota and Wisconsin in the far western arm that increased contribution of stocked fish to the detriment of wild fish, high exploitation in the sport fishery, and general lack of suitable spawning habitat, especially in the immediate area of Duluth and along the far south-western Wisconsin shoreline.

Commercial Fishery

The state commercial fishery for Lake Trout was closed in 1962, so it was not a good method to monitor restoration between the mid-1960s and late 2000s. However, important data was collected from the commercial coregonid fishery when Lake Trout were harvested as bi-catch. In addition, the Grand Portage Band of Chippewa reported commercial and subsistence Lake Trout harvest beginning in 1988. An Expanded Assessment Lake Trout fishery was reopened in 2007 in MN-3, and 2010 in MN-2. Recent data collected from the newly Expanded Assessment fishery are not yet extensive enough to create a time series that is meaningful in monitoring trends in Lake Trout abundance.

Methods and Results

All commercial operators are required to report Lake Trout by-catch in their Cisco fishing operations. Dead Lake Trout greater than 43 cm (17 in) can be retained as long as they have a MNDNR incidental tag affixed through their gill and out the mouth. Each commercial operator is provided with 20 incidental Lake Trout tags at the beginning of each season and each can request more if they exhaust the original distribution. If incidental Lake Trout catch is excessive, commercial operators may be asked to change netting locations, or discontinue fishing for the season. Most operators do not use the entire incidental tag allocation, and all unused tags must be returned at the end of the season. Incidental harvest has increased as Lake Trout rehabilitation has progressed, and varies among management zones (Figure 21). Since 2007, incidental harvest has consistently been highest in MN-1 where no commercial fishery is allowed for Lake Trout.

The Grand Portage Band must report all commercial and subsistence harvest of Lake Trout taken from the Grand Portage commercial zone in pounds on an annual basis as described in the MOA (Minnesota Department of Natural Resources 1988). Reporting has occurred intermittently (Lake Superior Area files) and the Grand Portage commercial harvest of Lake Trout has never exceeded the quota agreed to in the Memorandum of Agreement of 12,247 kg (27,000 lb). All commercially caught Lake Trout sold off the Grand Portage Reservation must have a MNDNR issued Grand Portage tag affixed in a similar manner as incidentally caught Lake Trout.

An Expanded Assessment fishery was reinstated in 2007 in MN-3, and in 2010 in MN-2 (Schreiner et al. 2006). All commercial netters must report information similar to that reported in the assessment fishery for both net sets and Lake Trout captured. Operators must apply annually for permits that specify netting locations, and the number of Lake Trout they are allowed to harvest. The MNDNR distributes commercial tags to successful applicants, and all Lake Trout taken in the fishery must be tagged. Harvest trends are limited since the fishery was reinstated less than 10 years ago (Figure 22). However, as the time series increases, we expect the Expanded Assessment to serve as a surrogate for a limited commercial Lake Trout fishery and provide important information on the status of Lake Trout in Minnesota's portion of Lake Superior.

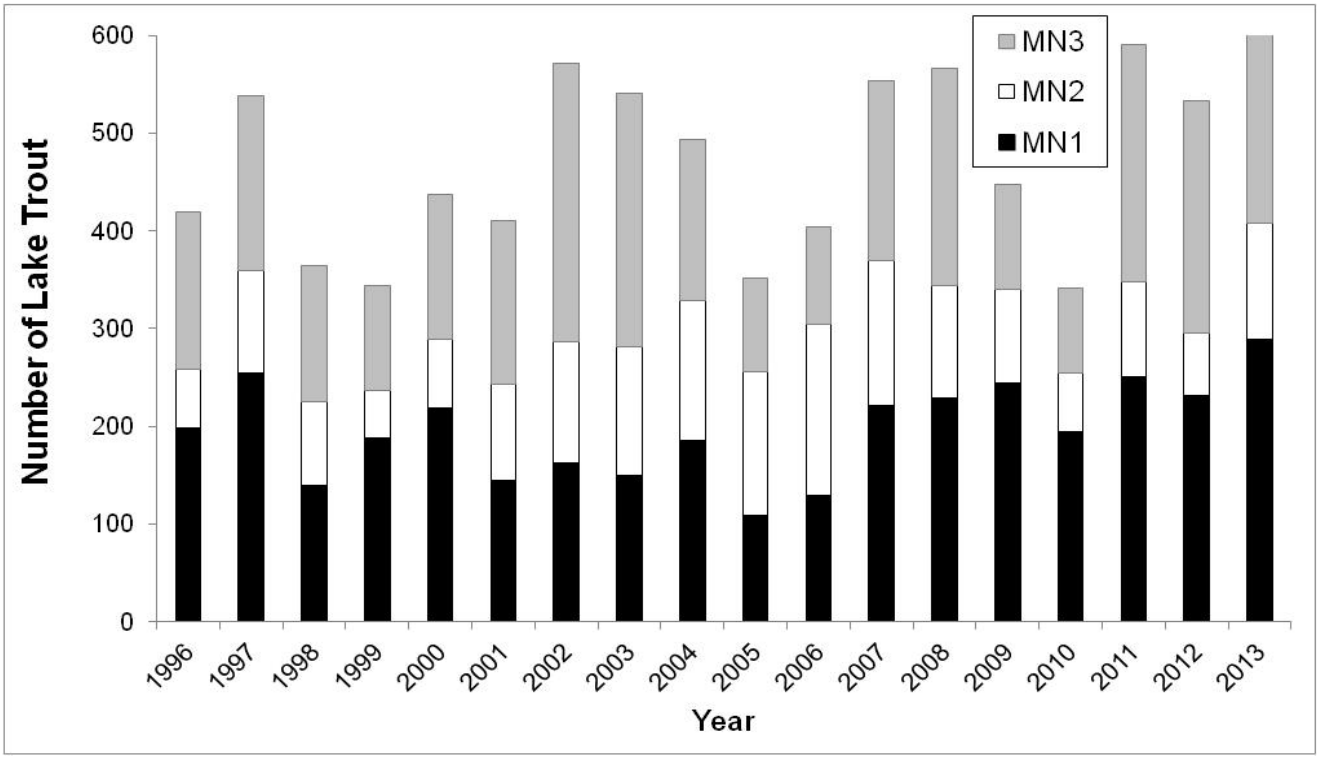


FIGURE 21. Incidental harvest of Lake Trout in the commercial fishery, 1996-2013.

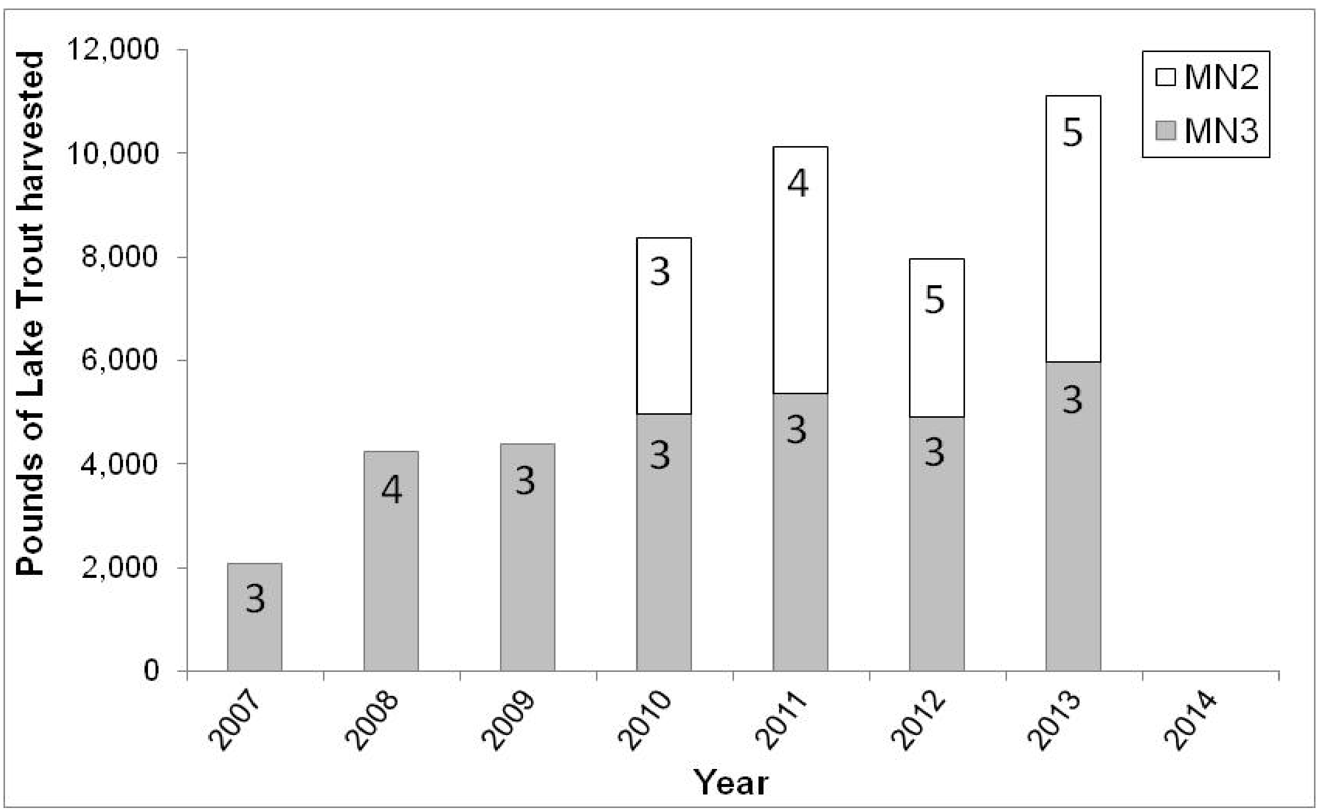


FIGURE 22. Lake Trout yield from the Expanded Assessment by management zone, with number of commercial operators shown within each bar.

Sport Fishery

The sport fishery in Minnesota's portion of Lake Superior is monitored using a summer creel survey that has routinely focused on Lake Trout and to a lesser extent Pacific Salmon. However, early creel surveys in the 1960s also included information on anglers targeting the spring Rainbow Trout *Oncorhynchus mykiss* fishery. In most cases this information can be separated based on the location (shore or lake) and months surveyed (April-May for Rainbow Trout and June – September for Lake Trout). Creel survey information is critical for monitoring Lake Trout rehabilitation in Minnesota since the Lake Trout sport harvest has far exceeded the commercial and tribal harvest over most of the last 40 years. Annual creel survey reports are on file in the MNDNR Lake Superior Area office and more recent reports can be found on the MNDNR website, under the Lake Superior Area link.

Methods

Annual summer creel surveys began at one access in 1969, expanded to four to six accesses in 1972-1976, expanded to between 22 and 24 accesses during 1983-1993, and was reduced to 11 high-use accesses beginning in 1994. The reduction in access sites surveyed enabled more focus on the boat fishery where approximately 90% of the angling pressure was directed.

Important information gained from creel surveys on Lake Trout includes angling pressure in hours, number and weight (yield) of Lake Trout harvested, and an index of abundance or CPUE (no. of Lake Trout harvested/angler hour). Specific creel survey methods have varied slightly over time (Schupp 1964; Morse 1984; Halpern 1995; Bindman and Mach 1997). Removing excess stations in 1994 led to an average (1988-1992) angling effort decline of 12.24% and a Lake Trout catch decline of 6.83%. The stations eliminated were mostly in streams, near stream mouths, and in state parks where Lake Trout are caught infrequently. For most of the past 30 years, summer creel surveys that focused on Lake Trout extended from Memorial Day weekend to September 30. Typically, two clerks were employed, one to survey the upper shore from Silver Bay (now Twin Points) to Hovland, and one to survey the lower shore from Two Harbors to Duluth. Approximately 70-80% of the angling pressure was located between Duluth and Two Harbors, so the lower clerk conducted far more interviews, even though a smaller geographical area was covered.

The summer creel survey is access based and uses complete trip interviews. Average number of anglers in the party and average trip length was determined during interviews. Counts of empty boat trailers at public access sites and/or boats out at marinas at pre-determined randomly chosen times were expanded to estimate the number of trips. The estimated number of trips and the information on trip length and party size gained from angler interviews were used to determine overall angling pressure throughout the survey season. The summer creel survey uses a stratified random design and strata include month, location or cluster, weekday vs weekend, and early vs late days. In the summer creel survey a set of stations the clerk could access efficiently in a day is referred to as a cluster. In most years each clerk visited one of two clusters daily. The cluster visited was chosen at random from a schedule that apportioned more effort to the busier clusters. Angling effort was adjusted to correct for non-uniform probability sampling of clusters. Angler interviews were conducted between counts to collect: anglers per boat, trip length, number of lines, species caught, length, fin clips, scale samples, Sea Lamprey wounds and other information. In some years questions were asked to gain specific information such as species preference, angler demographics, preferred regulations, etc.

Results

Creel survey results that track the status of Lake Trout rehabilitation are similar to those in the assessment fishery. The creel survey was not originally designed based on Lake Trout management areas. However, the area referred to as the "lower shore" in the summer creel survey generally refers to the area covered by MN-1 and the "upper shore" covers MN-2 and

MN-3 combined. Results reported in the summer creel survey will use "lower shore" (MN-1) and "upper shore" (MN-2 and MN-3) when referring to specific geographic areas. During the 1970s, geographic areas were not analyzed separately so they will be reported as "combined".

The lower shore supports 70-80% of the fishing pressure and harvest of Lake Trout in Minnesota waters and this area has a strong influence on the overall creel results. Fishing pressure increased sharply from 1972-1983 when it peaked at about 450,000 angler hours, pressure then declined gradually until about 1993 where it has stabilized at around 150-200,000 angler hours (Figure 23). The allocation of fishing pressure has been relatively consistent between upper and lower shore areas, however slight increases in pressure from the upper shore were reported in the late 1990s and early 2000s after the Safe Harbor Program was implemented (Figure 23). New and better protected public access sites were constructed along the upper shore, increasing angler opportunity, especially in the Silver Bay – Taconite Harbor area where pressure showed the largest increase.

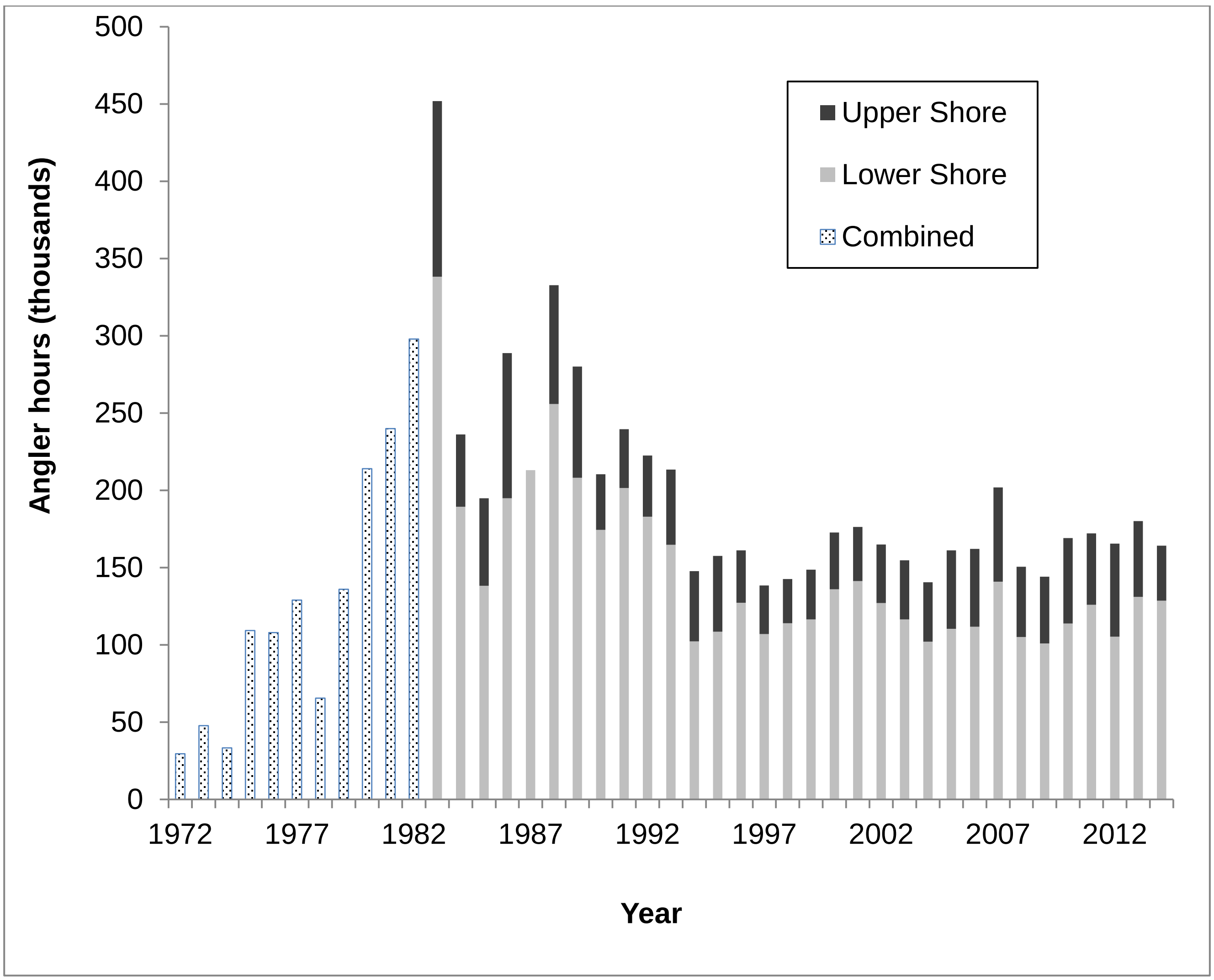


FIGURE 23. Pressure (angler hours) from summer creel survey in Minnesota waters of Lake Superior, 1972-2014.

Lake Trout have made up about 80% of the anglers' catch in the summer sport fishery since the early 1980s (Figure 24). The number of Lake Trout harvested by sport anglers increased from less than 5,000/year in the early 1970s to a mean of about 22,000/year from 1980–1990, declined to approximately 10,000/year in 1992-1994, then increased steadily to a mean of about 23,000/year between 2000 and 2014 (Figure 25). Although the mean annual number of Lake Trout harvested in the 1980s is similar to that harvested during the 2000s, the harvest in the more recent period has been much more consistent on an annual basis. Unlike pressure, Lake Trout harvest has increased significantly in the upper shore since the early 2000s. As expected, Lake Trout yield generally tracked harvest in the sport fishery with a peak of about 53,000 kg (116,850 lb) in 1983, followed by a gradual decline to about 17,000 kg (37,480 lb) in the early 1990s and then increasing to an average of about 40,000 kg (82,000 lb) annually over the last 15 years (Figure 26). The allocation of Lake Trout yield from the upper shore sport fishery also increased significantly when compared to the lower shore beginning in the early 2000s. Mean length of Lake Trout in the angler catch averaged about 57 cm (22.5 in) from 1987 to 2014, with no significant trend noted over that period (Figure 27).

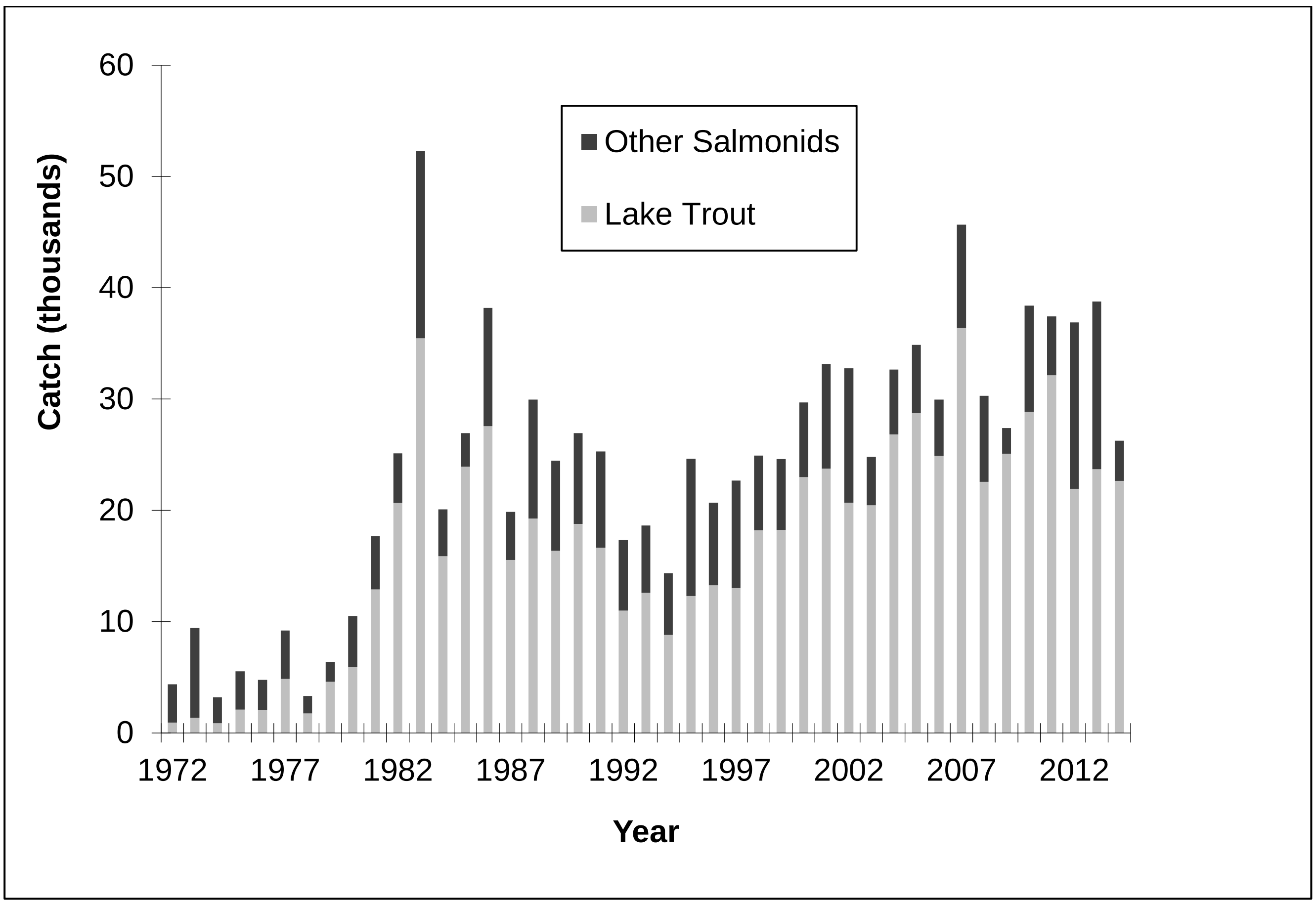


FIGURE 24. Catch of Lake Trout and other salmonids (Pacific Salmon and Rainbow Trout) from summer creel survey in Minnesota waters of Lake Superior, 1972-2014.

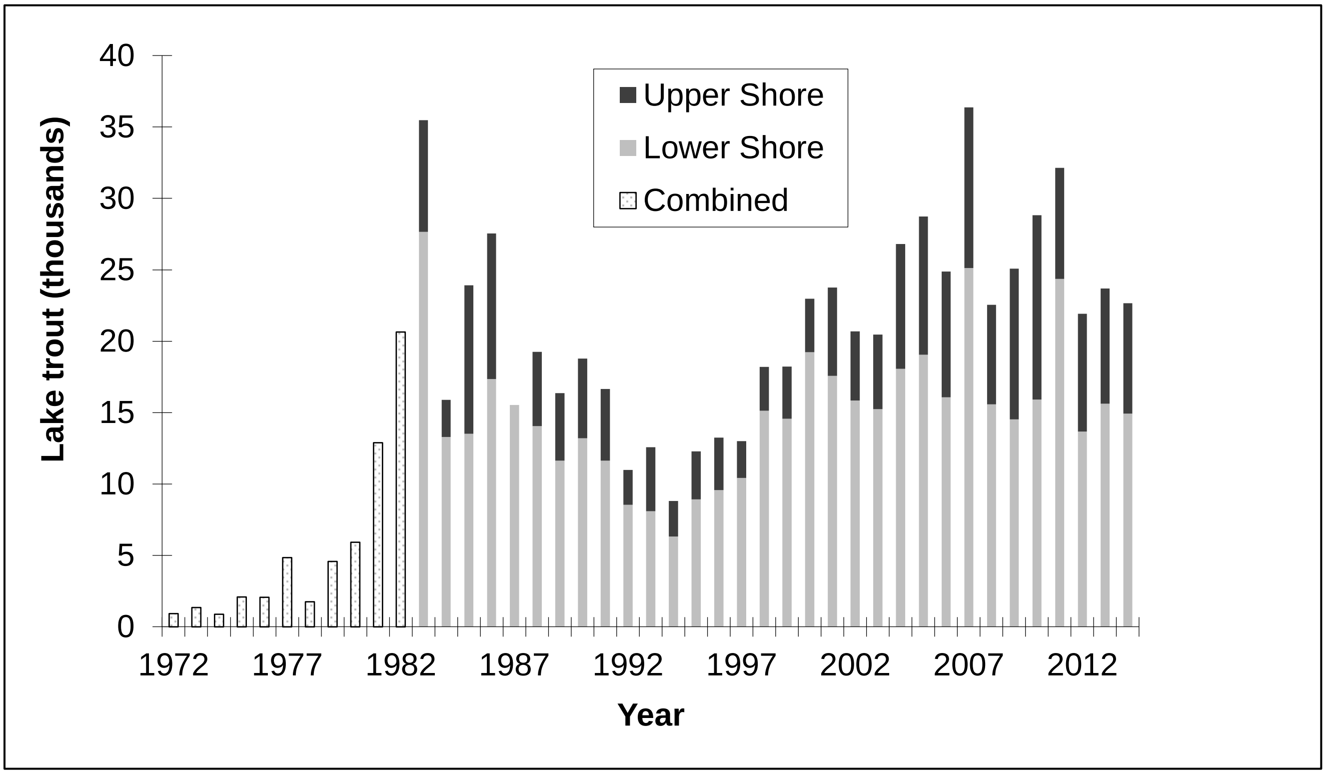


FIGURE 25. Catch of Lake Trout from summer creel survey in Minnesota waters of Lake Superior, 1972-2014.

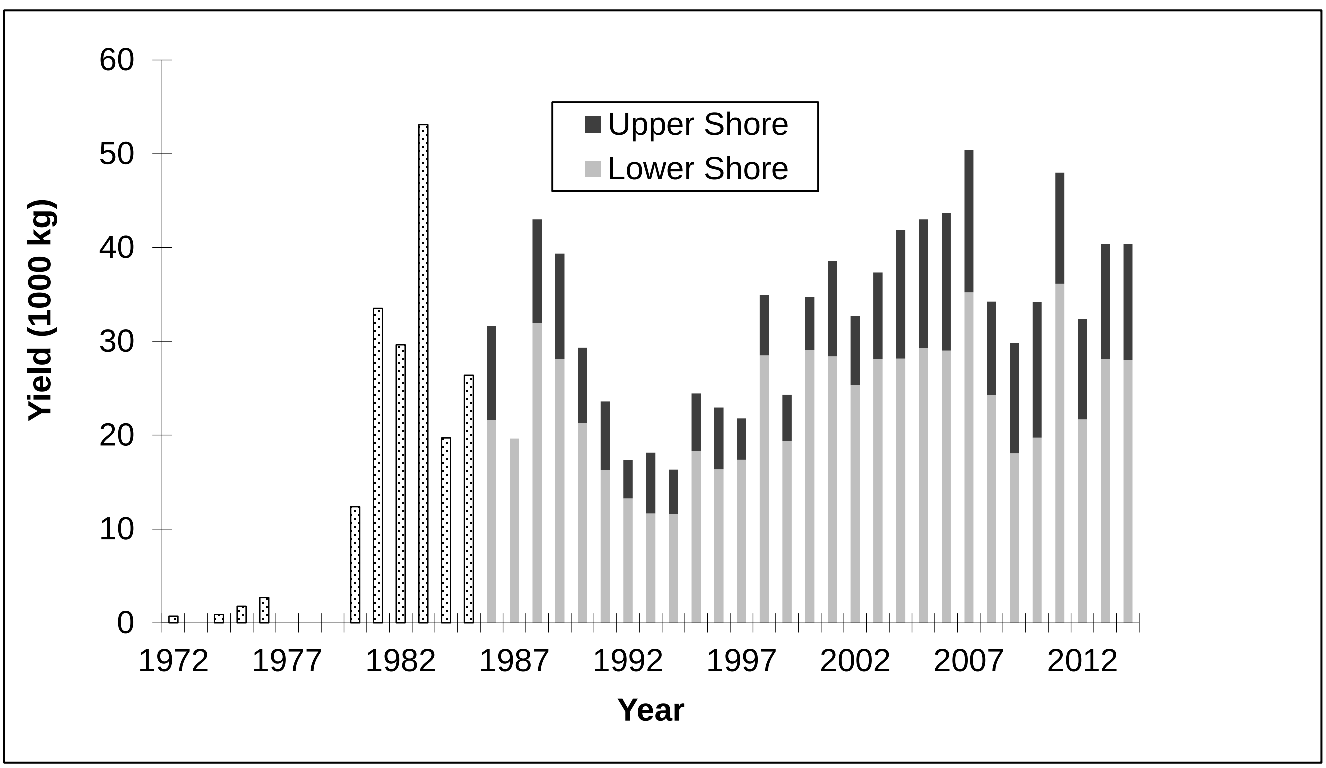


FIGURE 26. Yield of Lake Trout harvested from summer creel survey in Minnesota waters of Lake Superior 1972-2014.

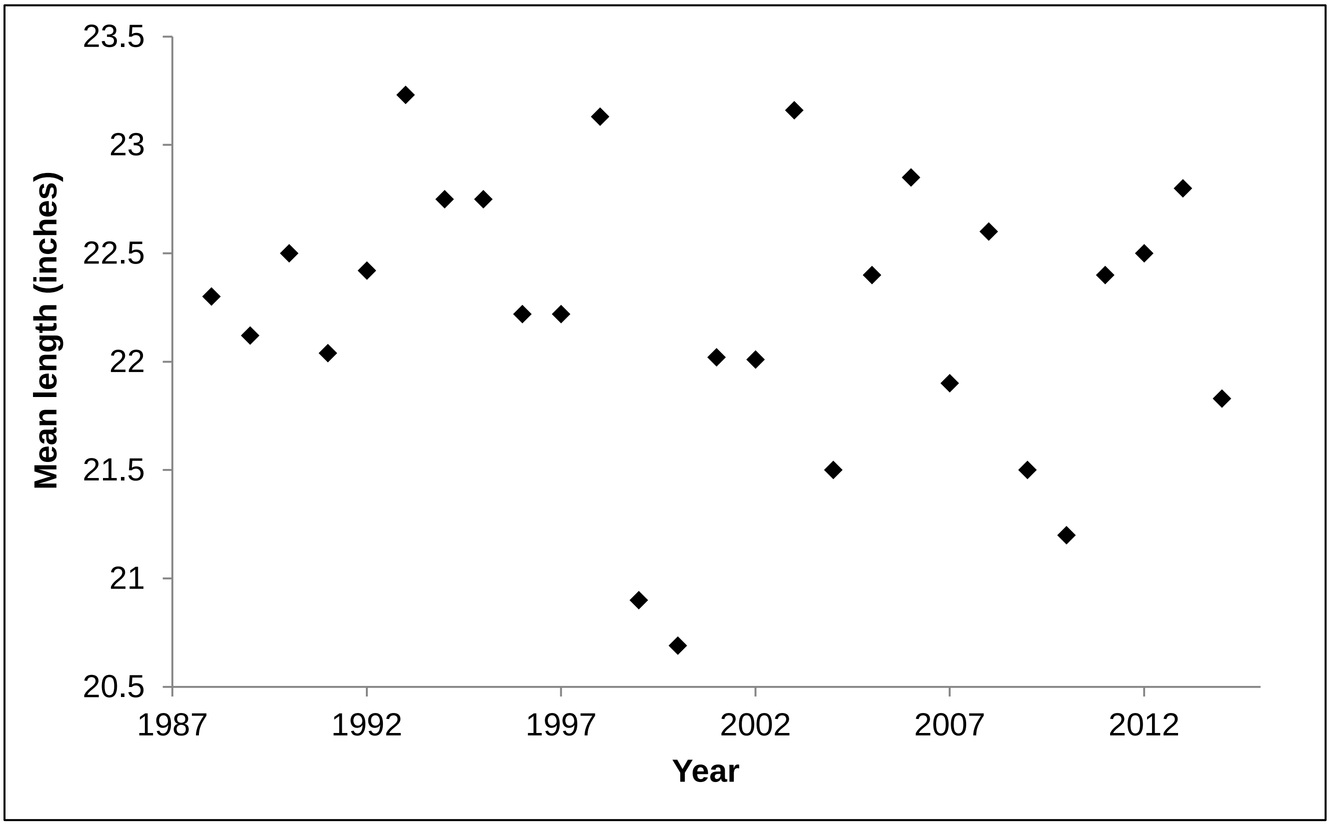


FIGURE 27. Average length of lake Trout harvested from summer creel survey in Minnesota waters of Lake Superior, 1987-2014.

Total CPUE of Lake Trout increased from 0.027 fish per angler hour in 1972-1976 to an average of about 0.16 fish per angler hour since 2004 (Figure 28). Overall CPUE for Lake Trout has consistently been higher in the upper shore fishery, with the contribution of wild fish increasing sooner than that found in the lower shore fishery, which is similar to findings from the spring and fall netting assessments. The recent higher catch rates translated into more fish per boat. In 1983 only 40% of boat trips resulted in a catch of one or more Lake Trout, whereas in 2013 the success rate increased to 55.8%. Fishing success as measured by CPUE is normally greatest along the lower shore in the spring and gets better along the upper shore starting in early July as the water warms. In fall, as Lake Trout began to stage for spawning, fishing success normally increases in all near-shore areas with many large fish harvested in late September, and more recently, early October.

The overall contribution of wild Lake Trout to the sport fishery has increased approximately 8-fold from the early 1980s through 2014 (Figure 29). Wild Lake Trout now comprise over 95% of the Lake Trout harvested from the upper shore and over 75% from the lower shore. The increase in percent wild Lake Trout along the lower shore has lagged behind the upper shore, but in about 2000, wild fish surpassed the percent of stocked fish in the angler's catch. Possible explanations for the slower increase in wild fish along the lower shore include: limited spawning habitat, much higher rates of stocking, significantly higher angler exploitation, higher Sea Lamprey wounding of older native Lake Trout and higher total mortality. Based on the results of the assessment fishery, wild fish are expected to continue their increase in the lower shore sport fishery.

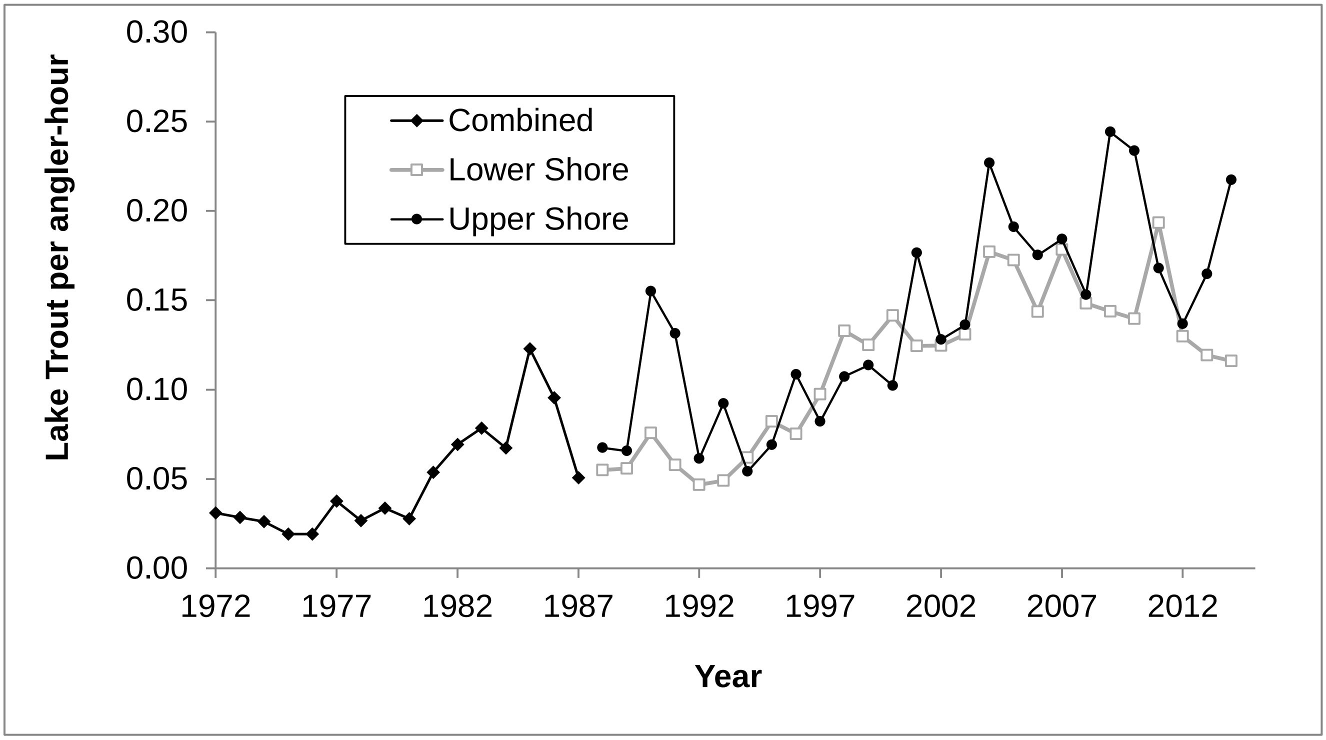


FIGURE 28. Catch rate of Lake Trout (fish/angler hour) from summer creel survey in Minnesota waters of Lake Superior, 1972-2014.

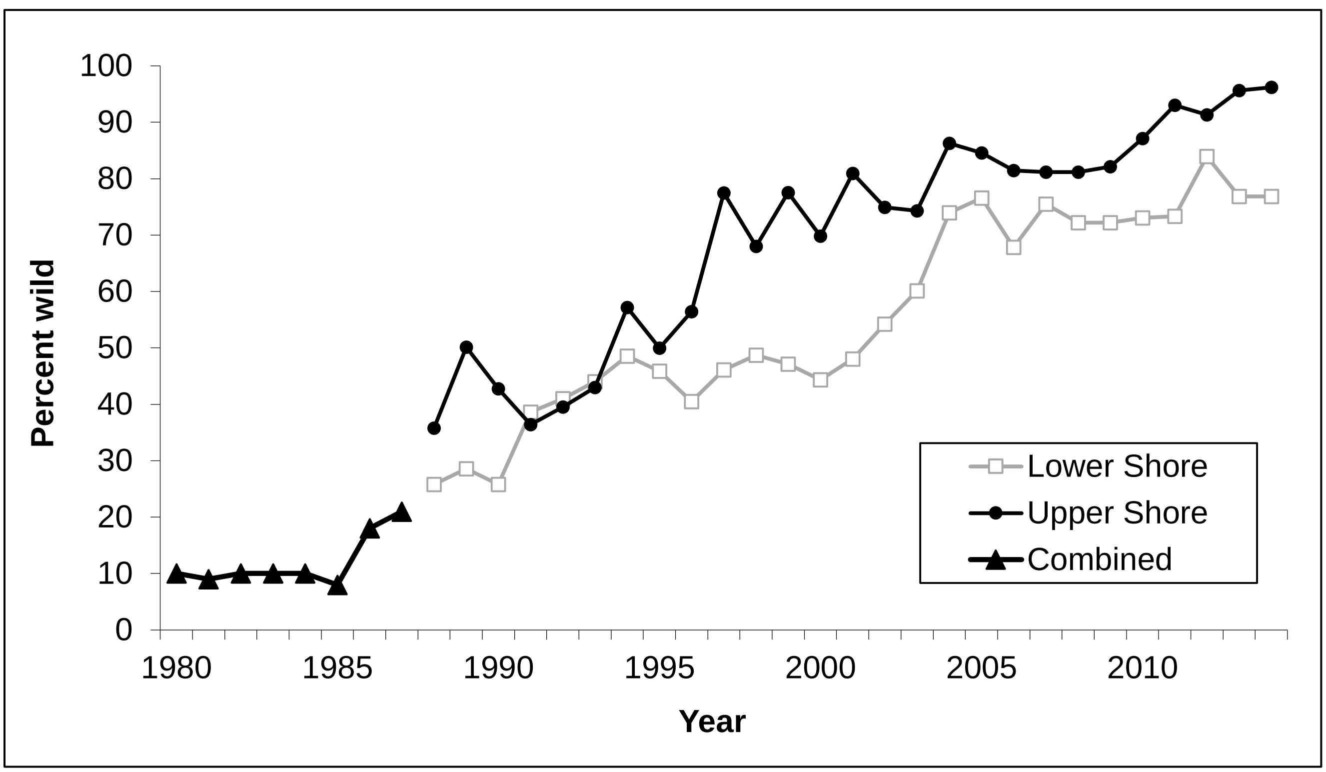


FIGURE 29. Percent wild Lake Trout from summer creel survey in Minnesota waters of Lake Superior, 1980-2014.

Charter Fishery

Sea Lamprey control, the subsequent rehabilitation of the Lake Trout fishery and the introduction of Pacific Salmon during the 1970s all increased interest in the Lake Superior sport fishery. This renewed interest, and the desire for larger vessels to fish further offshore, drove the introduction of the Minnesota Lake Superior charter fishery. The charter fishery formally began in 1985 when a state license administered by the MNDNR was required to guide anglers for compensation when fishing on Lake Superior and in the St. Louis River. In addition, the U.S. Coast Guard also requires each charter captain to be licensed and pass a vessel inspection. All charter captains must file catch reports on a monthly basis as a condition of their license. The catch reports are summarized annually by the Lake Superior Area and provide an indication on the status of Lake Trout, and other species harvested in the charter fishery.

Methods

Charter captains are required to file a monthly catch report as a condition of their license. Reports must be filed by the 10th day of the month following the month in which fishing occurred. Reports must be filed from April – October whether or not fishing occurred. Information requested includes: trip dates, length of trip in hours, number of anglers in party, number of lines, number and species of fish harvested and/or released, tags or fin clips noticed, and any other information the charter captain choose to share. Annual Charter Fishing Reports (e.g. Reeves 2014) are prepared over the winter for distribution to each charter captain and posting on the Lake Superior Area website.

Results

The number of licensed Lake Superior charter captains in Minnesota increased sharply from 25 in 1985 to 89 in 1990. Over the next ten years the number of licensed charter captains declined steadily to about 40 in 2000. Since 2000, the number of charter captains has stabilized at about 40 per year and the number of charter trips has ranged from 1,000-1,500 per year (Figure 30). Results from the charter fishery are included in the summer creel survey, so results should not be added. Pressure from the charter fishery normally accounts for about 25% of the annual sport angling pressure in Minnesota's portion of Lake Superior, and has ranged from a low of 18,000 angler hours in 1985 to a relatively consistent effort of around 35-40,000 hours annually since 2000 (Figure 31). Most of the pressure occurs along the lower shore; however, similar to the sport fishery, pressure has increased slightly along the upper shore since about 2000.

Lake Trout comprised about 78% of the salmonid harvest in the charter fishery from 1985-2014 (Figure 32). The catch of Chinook Salmon *Oncorhynchus tshawytscha* and Coho Salmon *O. kisutch* vary annually between species, but the average long-term proportion of each in the charter catch is about 10% (Figure 32). In general, total harvest of Lake Trout increased until about 2000 where it stabilized at around 7,000-8,000 fish per year. Since 2005, the contribution of Lake Trout from the upper shore had increased and at times makes up over 30% of the total annual harvest (Figure 33). CPUE of Lake Trout in the charter fishery has steadily increased since about 1990 as rehabilitation has progressed, with the highest catch rates consistently occurring along the upper shore (Figure 34). When the salmon catch is high, charter captains normally reduce effort targeted at Lake Trout, which decreases the Lake Trout catch rate as was noted in 2012 and 2013 (Figure 34). Similar to the summer creel survey, the Lake Trout catch in the charter fishery is now composed predominately of wild fish, especially along the upper shore (Figure 35).

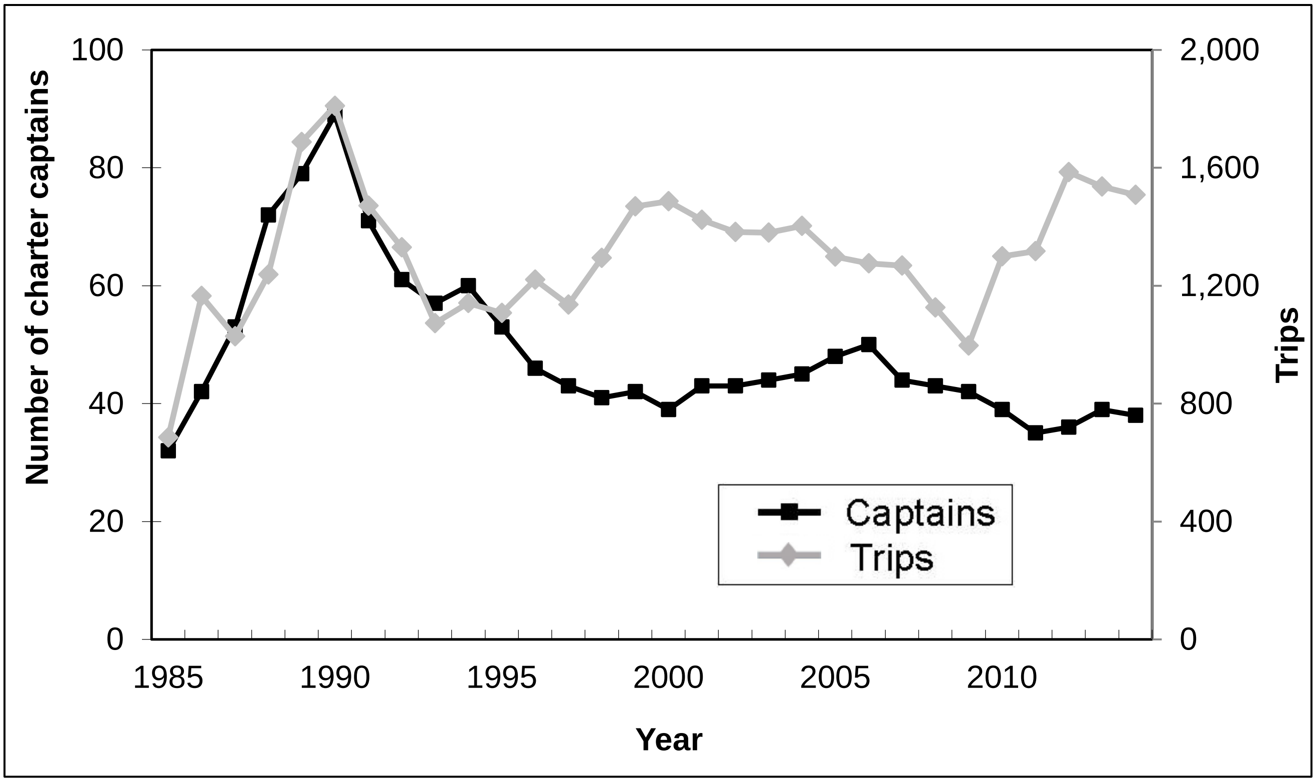


FIGURE 30. Number of licensed charter captains and charter trips reported in Minnesota waters of Lake Superior, 1985-2014.

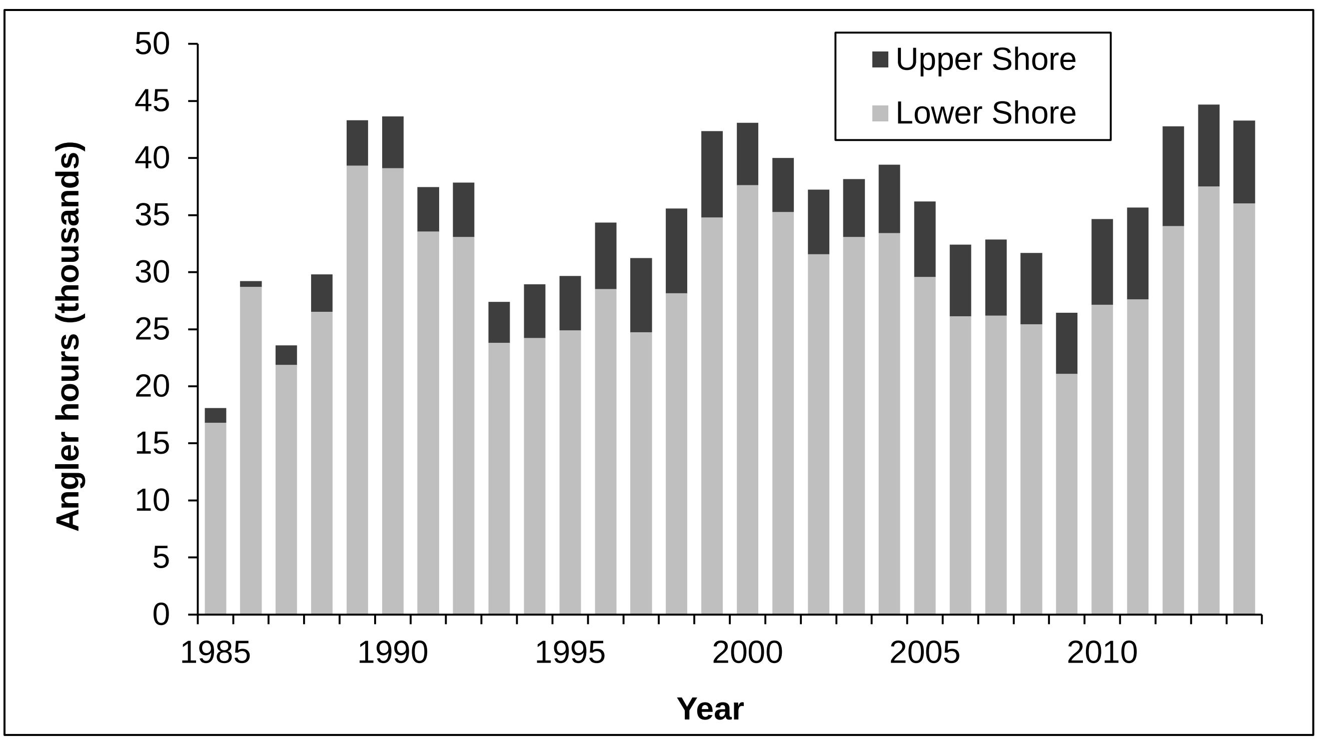


FIGURE 31. Pressure (angler hours) from charter fishery in Minnesota waters of Lake Superior, 1985-2014.

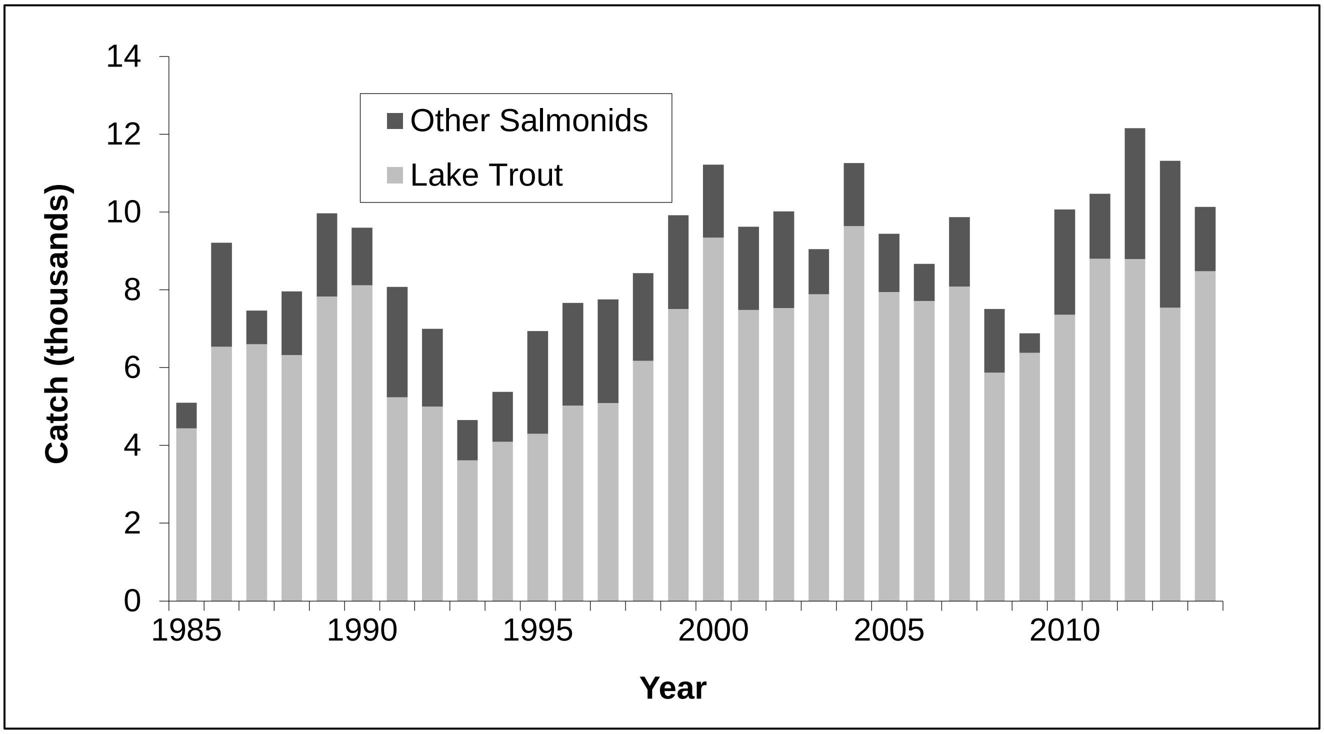


FIGURE 32. Catch of Lake Trout and other salmonids from charter fishery in Minnesota waters of Lake Superior, 1985-2014.

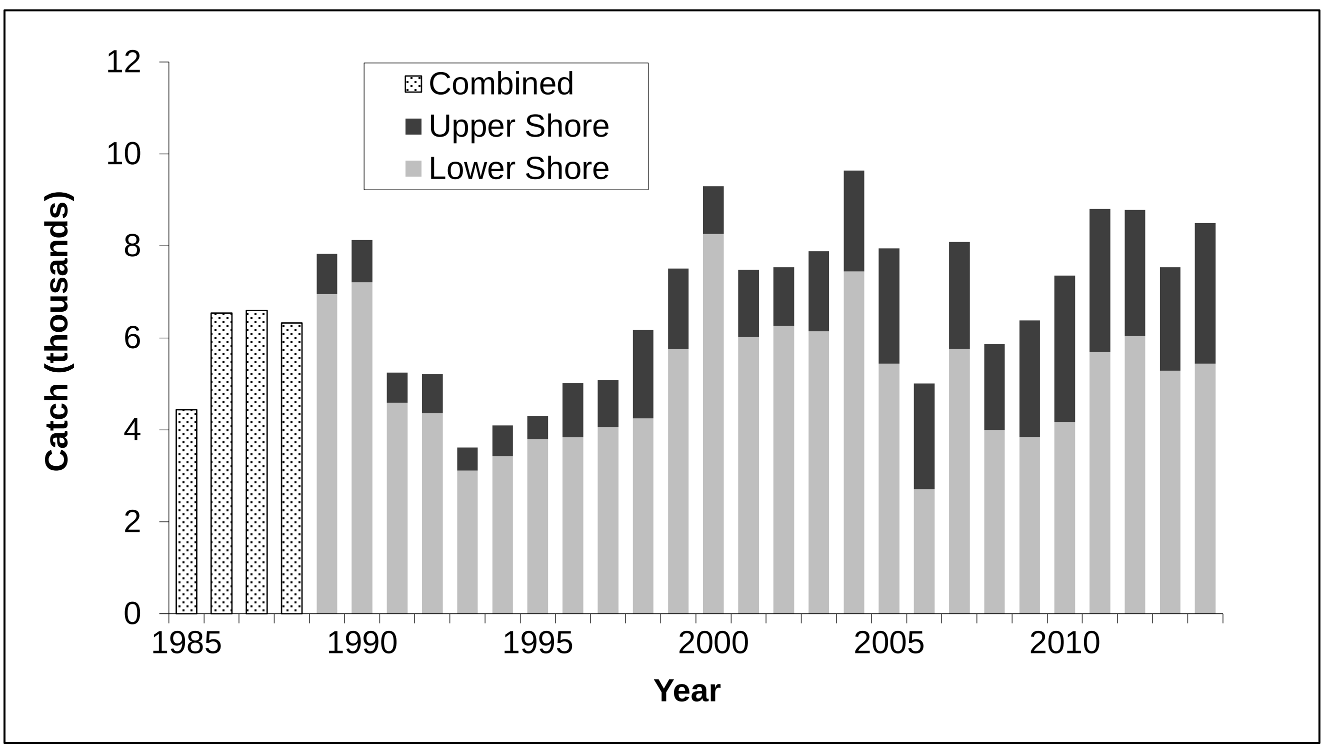


FIGURE 33. Catch of Lake Trout from charter fishery in Minnesota waters of Lake Superior, 1985-2014.

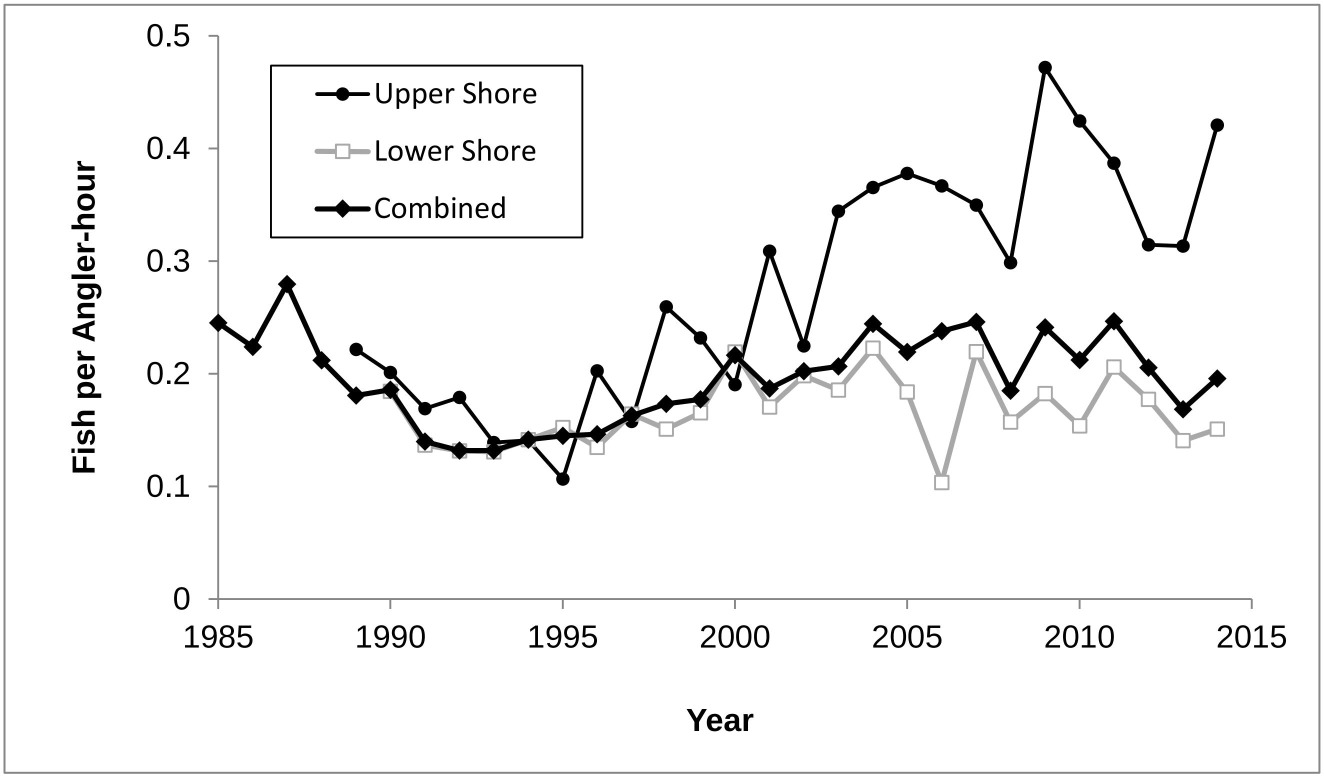


FIGURE 34. Catch rate of Lake Trout (fish/angler hour) from charter fishery in Minnesota waters of Lake Superior, 1965-2014.

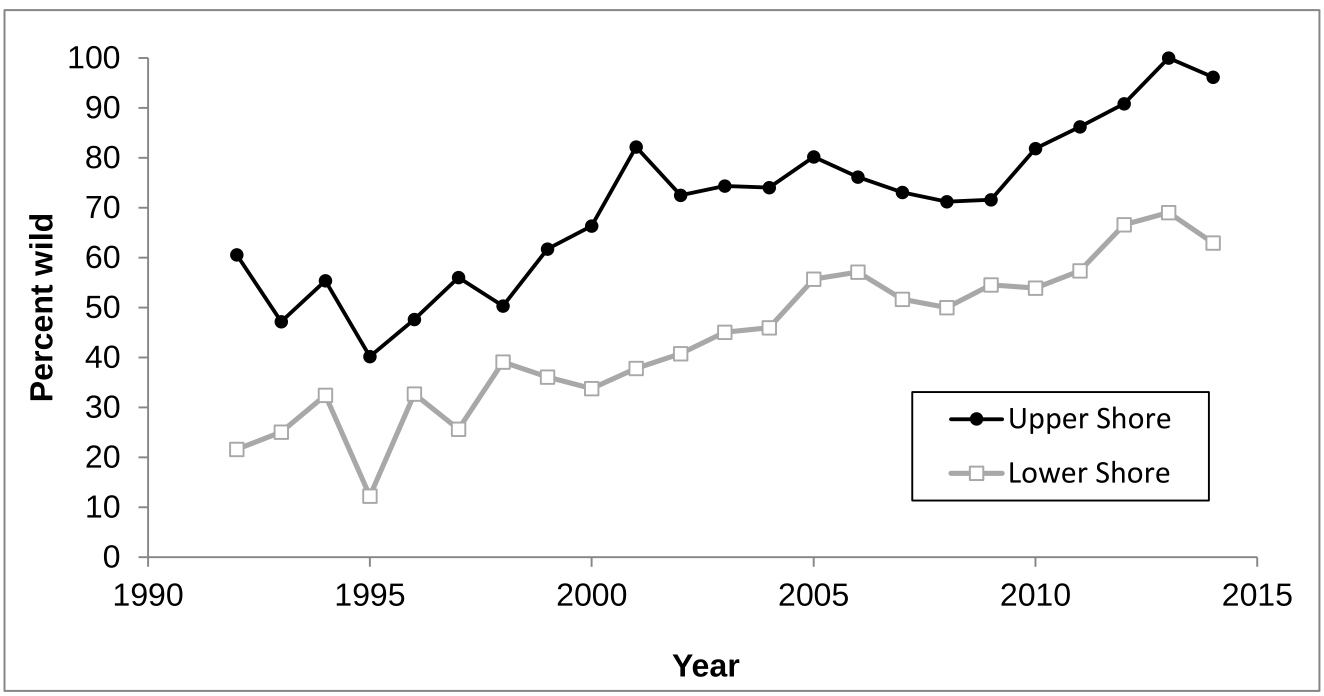


FIGURE 35. Percent wild Lake Trout harvested from charter fishery in Minnesota waters of Lake Superior, 1992-2014.

Present Status of Lake Trout Stocks

Rehabilitation Goals and Targets

Rehabilitation goals for Lake Trout in Lake Superior have evolved as the fish community and types of fisheries have changed. The rehabilitation goal stated in the 1990 Fish Community Objectives (Busiahn 1990) and more specifically in "A Lake Trout Restoration Plan for Lake Superior" (Hansen 1996) was to restore self-sustaining stocks of Lake Trout that could support an annual harvest of 2 million kg (4.4 million lb), based on the average annual yield from the commercial fishery between 1929-1943. This is a relatively simplified goal since it depends only on commercial yield. Since the commercial fishery is now heavily regulated and the sport harvest in many areas of Lake Superior surpasses the commercial harvest, the previous goal requires modification. Rather than comparing historical to present yield in the commercial fishery, it would be more informative to compare CPUE as an index of Lake Trout abundance. This, of course, depends on the availability of historical CPUE information, which is lacking for the appropriate time periods in most areas of Lake Superior.

Hansen (1996) suggests that another method to determine progress toward restoration should be measured as the number of recruits produced by the spawning stock in each management zone. Given a natural mortality rate of approximately 0.12 (Ebener et al. 1989), modern Lake Trout stocks must produce approximately 3.6 million recruits lake-wide to reach the goal of 2 million kg of Lake Trout available for harvest. To determine this on a jurisdictional basis, the number of recruits in each management zone must be estimated with a stock-recruitment relationship (Ricker 1975) or with statistical catch at age (SCAA) models (Bence and Ebener 2002). Even with adequate levels of recruitment, Lake Trout rehabilitation may not reach historical abundance levels if Sea Lamprey induced mortality does not decline further, or if Cisco stocks do not recover to levels that will support a high level of self-sustaining Lake Trout stocks. Competition with Siscowet and Pacific Salmon for scarce forage in some areas of the lake may also inhibit complete restoration of Lake Trout stocks. Bioenergetics and fish community models can be used to investigate these concerns, and used together with stock-recruitment and SCAA models may help to develop a more realistic goal for Lake Trout restoration (Negus et al. 2008).

Historical versus Present Yield - In Minnesota, the average annual yield of Lake Trout reported in the commercial fishery from 1929-1943 was 164,000 kg (361,000 lb). The present commercial Lake Trout yield is approximately 5,000 kg (11,000 lb), far short of the goal published in 1990 (Busiahn 1990). However, if the total yield of Lake Trout from the sport, commercial, tribal, and assessment fisheries are combined the total annual yield over the last 5 years has averaged approximately 60,000 kg (132,000 lb). In addition, potential average Lake Trout yield removed by Sea Lamprey induced mortality over the last 5 years is estimated at approximately 45,500 kg (100,000 lb), similar to that harvested in the sport fishery. The potential average yield of Lake Trout displaced by introduced Pacific Salmon over the last 5 years averages approximately 7,000 kg (15,000 lb). If the historical commercial yield of Lake Trout from 1929-1943 included some portion of Siscowet, as described by Wilberg et al. (2003) for Michigan waters of Lake Superior, overall harvest of lean Lake Trout would be reduced. Based on Wilberg et al. (2003), and discussions with older commercial netters in Minnesota, harvest of Siscowet in the reported historical commercial Lake Trout harvest was estimated at approximately 25%. When adjusted for Siscowet harvest, the yield of lean Lake Trout in the historical commercial Lake Trout harvest in Minnesota from 1929-1943 is approximately 122,500 kg (270,000 lb). If all harvest estimates from the sport, commercial, tribal, and assessment fisheries; along with potential Lake Trout yield consumed by Sea Lamprey induced mortality, and displacement by Pacific Salmon are totaled, the average contemporary harvest over the last 5 years is approximately 112,500 kg (247,000 lb). When contemporary Lake Trout harvest is compared to the adjusted historical commercial Lake Trout harvest (excluding estimated Siscowet yield) contemporary harvest is only about 10% below the historical harvest target in Minnesota. Although many assumptions were made to modify historical Lake Trout harvest and calculate contemporary Lake Trout harvest, the estimates indicate that the annual Lake Trout fishery in Minnesota is approaching the target harvest level established in the 1990 Fish Community Objectives for Lake Superior (Busiahn 1990).

Stock Recruitment - Density dependence in fish populations is a good indicator that stocks have reached their maximum abundance (carrying-capacity) based on the conditions in the fish community at the time (Ricker 1975). In the Great Lakes, determining the peak of the stock-recruitment curve can be used to evaluate the status of Lake Trout restoration (Bronte et al. 1995a; Richards et al. 2004; Corradin et al. 2008). In addition, for true rehabilitation to occur it is important to determine if the recruits originate from wild or stocked parents. The stock-recruitment method of measuring Lake Trout rehabilitation in Lake Superior may be preferable to the historical yield method since it assimilates the many changes that have taken place in the Lake Superior fish community since the historical commercial yield was determined.

Analysis of stock-recruitment relationships in the western arm of Lake Superior indicate density dependence and that Lake Trout rehabilitation in much of Minnesota is approaching or exceeds the level that the current fish community can support (Corradin et al. 2008; Negus et al. 2008). Management zones MN-3 and MN-1 showed recruitment was at a level that could sustain the present spawning population, while MN-2 produced slightly below the number of recruits required to replace the spawning population. However, since MN-2 has such a limited amount of Lake Trout spawning and nursery habitat, and there is evidence of significant Lake Trout movement in and out of the area, the model may not truly reflect the current stock-recruitment relationship in MN-2 (Corradin et al. 2008). In addition, the majority of recruits in all management zones were produced by wild parents, with no significant contribution from stocked parents.

Mortality Targets - Total annual Lake Trout mortality is used as an important criterion to control overexploitation by the fishery, although it has not specifically been used as a measure to determine if rehabilitation has occurred. Total annual mortality of Lake Trout is composed of natural, fishing and Sea Lamprey induced mortality. Healey (1978) suggested that a Lake Trout population would decline when experiencing more than 50% total annual mortality. In *A Lake Trout Restoration Plan for Lake Superior* (Hansen 1996) and in the *Fisheries Management Plan for the Minnesota Waters of Lake Superior (*Schreiner 1995, Schreiner et al. 2006), the maximum target level was reduced to 45% total annual mortality in Lake Superior because the simulated abundance of Lake Trout spawners in the statistical catch at age (SCAA) model declined when mortality exceeded 45%, but increased at levels less than 45% total annual mortality (Ebener et al. 1989).

More recently, Nieland et al. (2008) suggest that a total annual mortality rate of 42% would be adequate to sustain recovering Lake Trout stocks in eastern Wisconsin waters of Lake Superior. The authors recommended that management decisions about sustainable levels of total annual mortality rate and fishing mortality rates consider both age-4+ (recruit) and age-8+ (spawner) abundance since mortality rates on different segments of the population can significantly affect spawner abundance. They also strongly recommended that a threshold management strategy that sets a minimum for spawning stock biomass be implemented as a way to avoid low spawner abundance and to protect self-sustaining stocks of Lake Trout in Lake Superior.

In the *Fisheries Management Plan for the Minnesota Waters of Lake Superior* (Schreiner 1995, Schreiner et al. 2006) a major objective for Lake Trout rehabilitation was to suppress total annual Lake Trout mortality in each management zone to less than 45%. Total annual mortality below 45% should increase the speed of Lake Trout rehabilitation. An evaluation of total annual Lake Trout mortality in 2005 by management zone, using SCAA models, showed the 45% level has not been exceeded in MN-2 and MN-3 since 1980, but total mortality in MN-1 had been at or near 45% for a number of years (Schreiner et al. 2006). A criterion was established in the 2006 LSMP that states, "if total average mortality exceeds 45% for five consecutive years, or the average exceeds 50% for three consecutive years, sport harvest of Lake Trout will be reduced" (Schreiner et al. 2006). In 2006, the fishery had only approached this criterion in MN-1, however, total annual mortality was recalculated in 2014 using a new variation of the SCAA model (see next section) and the results suggested that total annual mortality may have been slightly higher in MN-2 and MN-3, so annual monitoring should be continued to make sure the 45% criterion level is not exceeded in the future.

Statistical Catch at Age Models (SCAA)

In 2005, a stock assessment model for lean Lake Trout was developed for Minnesota waters of Lake Superior. This was an important new tool for assessing the status and trends of Lake Trout stocks, determining how Lake Trout mortality compares to target rates, and for estimating future population size as one factor to consider when setting harvest levels in Minnesota waters. Similar models are used to inform Lake Trout management in Wisconsin and Michigan waters of Lakes Superior, along with Michigan waters of Lake Michigan and Lake Huron (Linton et al. 2007; Caroffino and Lenart 2010).

Model Description

An age-structured integrated stock assessment model that follows the general procedures of statistical catch-at-age (SCAA) analysis (Sitar et al. 1999; Schreiner et al. 2006; Linton et al. 2007) was developed for the Lake Trout population in each of the three Minnesota management zones of Lake Superior. Advantages of SCAA models include estimation of age-specific abundance and exploitation over time, flexibility, and the ability to include both measurement error and process error (Fournier and Archibald 1982). The time series modeled began in 1982 in MN-1 and 1980 in MN-2 and MN-3. For each management zone, data for stocked and wild Lake Trout are included but modeled separately. The ratio of stocked to wild fish is used as a component in the objective function to help anchor the model since the number of fish stocked into each zone is known. Lake Trout harvest and effort are obtained from recreational and commercial (expanded assessment) fisheries in Minnesota waters of Lake Superior. Lake Trout age distribution and CPUE from MNDNR spring and summer assessments are used to provide fishery independent indices of relative abundance for the SCAA. The spring surveys in MN-2 and MN-3 are conducted by permit netters; to account for changes in netters over time, an index of CPUE is generated using a mixed model that incorporates grid, depth category (shallow, intermediate, deep), and year as fixed effects, and treats the interaction of year and cooperator as a random effect. Lake Trout ages have been estimated by otoliths since 1994. Prior to that scales were used to estimate age. Fin clips are also used to assist in age estimation of stocked fish by assigning a potential age based on the clip and the probability of that age given fish length. Prior to 1999, a pooled age-length key was created using ages estimated by scales or otoliths from multiple assessments across years. Annual age-length keys have been constructed since 1999. Survey and year-specific age-length keys are used to expand estimated ages to the entire catch. Age-length keys derived from the spring assessment are used to expand estimated ages to the entire creel harvest. Recruitment of stocked Lake Trout is based on known stocking rates and model estimated survival of the stocked fish. A migration matrix is applied to the model to account for post-stocking movement of stocked fish between zones.

The model tracks stocked fish ages 1 to 16+. Recruitment of wild fish is estimated by the model from catch of age-3 fish in the juvenile assessment. The model tracks wild fish ages 3 to 16+. The SCAA is used to estimate age-specific abundance, recruitment, mortality, and fishery selectivity for stocked and wild Lake Trout by management zone in Minnesota waters of Lake Superior during 1980-2013 by fitting predicted fishery harvest, survey CPUE, and age distributions to observed data.

Age-specific fishery harvest, which is primarily from the recreational fishery, is estimated by Baranov's catch equation (Ricker 1975):

$$Harv_y = \sum_a N_{y,a} \cdot \frac{F_{y,a} \cdot (1 - S_{y,a})}{Z_{y,a}} \; .$$

Corresponding age and length compositions of angler harvest in numbers were calculated for each year by dividing the angler harvest in each age and length bin by the total harvest. Abundance was calculated using the exponential population equation (Ricker 1975; Quinn and Deriso 1999),

$$N_{y+1,a+1} = N_{y,a} \cdot e^{-Z_{ya}} \; ,$$

for years after 1980 and all ages greater than 3. Total instantaneous mortality was partitioned into natural mortality, Sea Lamprey induced mortality, and fishing mortality:

$$Z_{y,a} = M + M_{Ly,a} + F_{y,a} \cdot$$

Background natural mortality was held constant at 0.16 based on Pauly's equation (Pauly 1980). Sea Lamprey mortality is estimated by a logistic model based on the number of wounds as a function of Lake Trout length (Rutter and Bence 2003). Separate Sea Lamprey mortality estimates are made for stocked and wild Lake Trout. Fishing mortality is estimated as the product of fishing effort, selectivity, and catchability.

Model Results and Discussion

In general the SCAA model suggests declines in the number of stocked Lake Trout and increases in the number of wild Lake Trout in all management zones (Figure 36). However after 2008 steep increases in the number of wild fish age 7 and older appear to be increasing at unrealistically high rates in all 3 zones, suggesting some systematic issue (e.g. model assumption not met). Therefore using these current estimates of absolute abundance to set harvest quotas should be avoided until these issues can be resolved. As the wild Lake Trout population has increased and as rehabilitation proceeds, additional Lake Trout status indicators that consider spawning stock biomass are being developed.

Total annual mortality is an important criteria used to monitor Lake Trout status in Lake Superior (Hansen 1996; Schreiner et al. 2006). Natural mortality is a major contributor to total Lake Trout mortality in Minnesota waters of Lake Superior (Figure 37). Background natural mortality and modeled Sea Lamprey induced mortality generally make up the largest proportion of total mortality. The SCAA model estimates of mortality suggest that total annual mortality targets have not been reached in any of the management zones (Figure 38).

Several sources of uncertainty exist in the SCAA model that are derived from two general types of error (observation error and process error). The uncertainty resulting from the way in which data were collected (observation error), includes the variability in gill net catches, age estimation errors, variability associated with estimates of creel catch and effort, and so forth. The primary source of uncertainty dealing with the true variation that exists in the estimated population is process error. It includes variation in recruitment and the factors that may influence that variation. SCAA models are capable of accounting for both types of uncertainty; however errors in the magnitude or distribution of the assumed errors can have large effects on model results, requiring the need for caution and thought in interpreting model output.

While a model is a useful tool to inform management, the absolute estimates derived from models like the Lake Trout SCAA model should be carefully reviewed and interpreted. It is important to consider a variety of population attributes in addition to the model output to more accurately judge the health of the Lake Trout populations. When considering the uncertainty in model output it is wise to favor a more conservative approach that will protect recovering Lake Trout stocks in Minnesota. There are several immediate concerns that should be considered in the Minnesota SCAA Lake Trout models. Harvest is quite low in Minnesota waters of Lakes Superior and in order for SCAA models to function they require sufficiently high levels of harvest (Linton et al. 2007). Additionally, as stocking has ceased in most of the zones, dealing with stocked fish in the models needs to be addressed. Finally, the current versions of the SCAA models for Lake Trout in Minnesota waters of Lake Superior lag behind in the use of new analytical techniques (e.g. time varying parameters, age-length transition matrices instead of raw keys) when compared to other SCAA Lake Trout models used in some other Great Lakes jurisdictions.

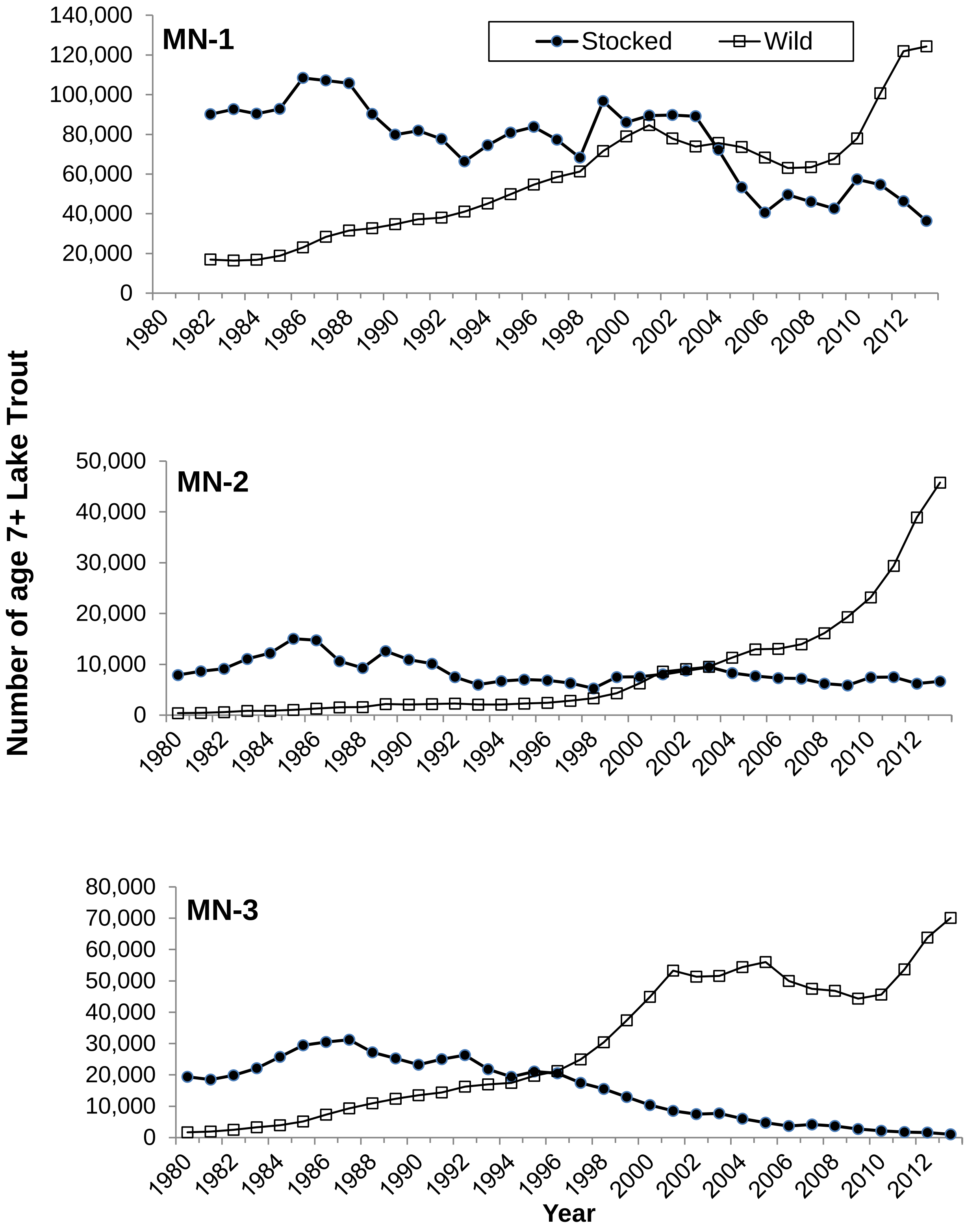


FIGURE 36. Number of age 7 and older Lake Trout by management zone in Minnesota waters of Lake Superior estimated by SCAA models, 1980-2013.

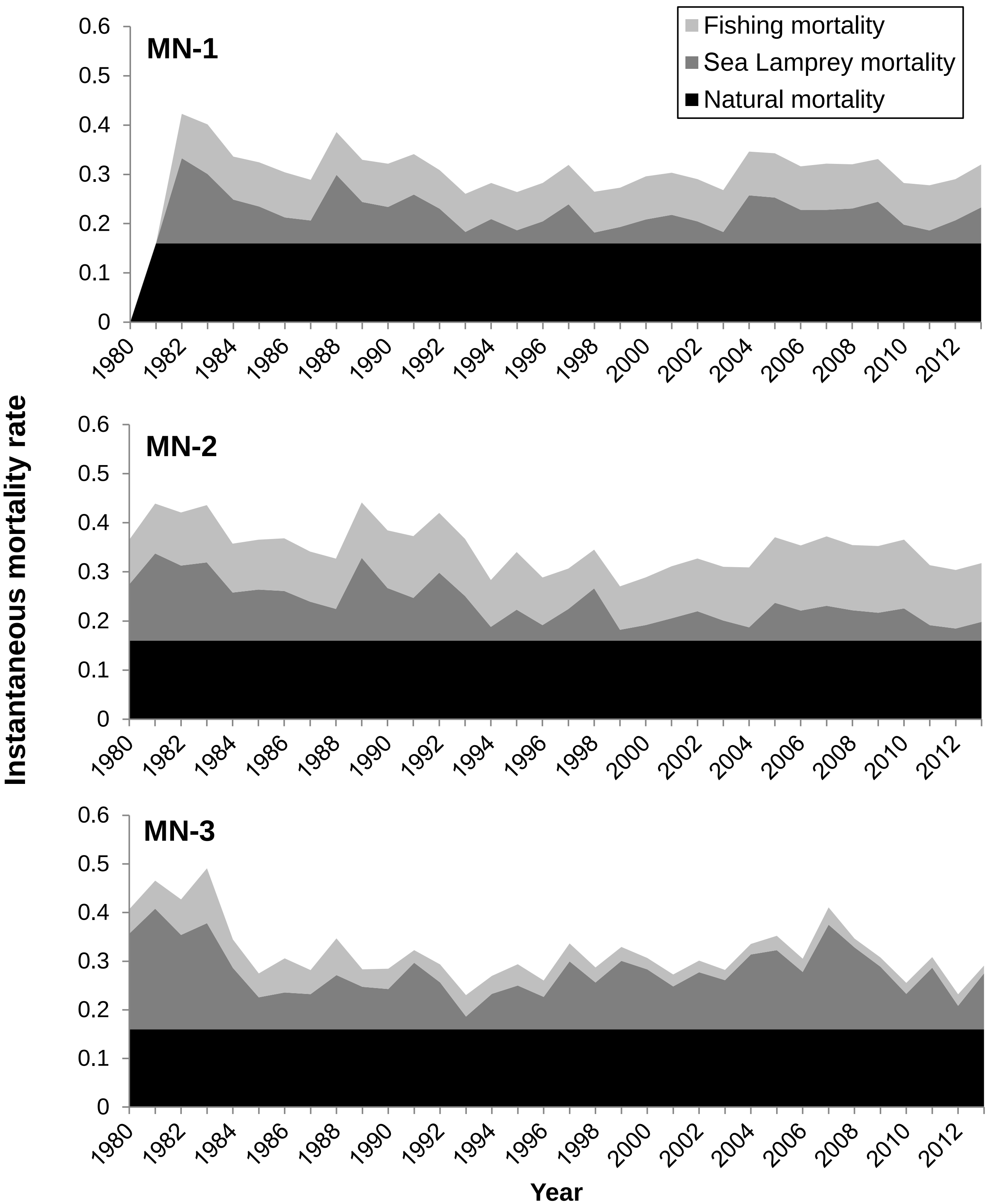


FIGURE 37. Instantaneous mortality rates of Lake Trout (combined stocked and wild), by management zone, in Minnesota waters of Lake Superior estimated by SCAA models, 1980-2013.

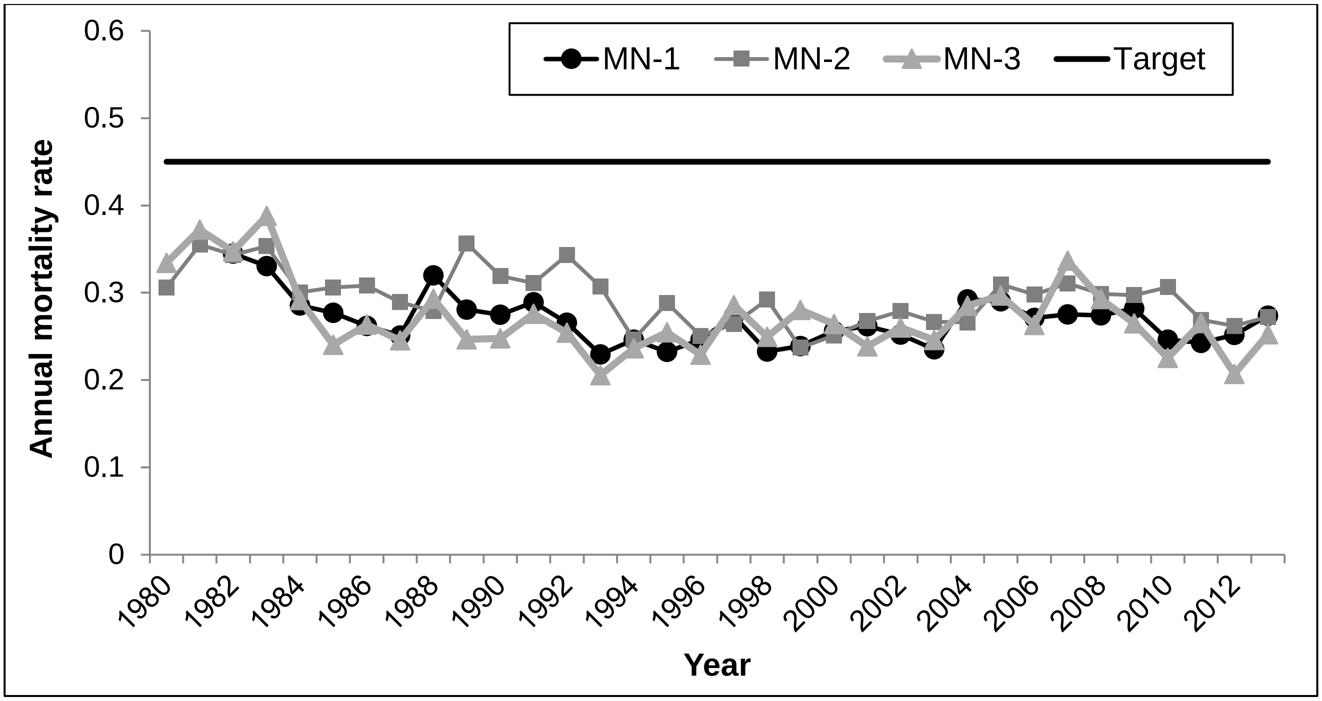


FIGURE 38. Total annual mortality rate by management zone for Lake Trout in Minnesota waters of Lake Superior estimated from an SCAA models, 1980-2013.

Bioenergetics Model (Fish Community)

Two bioenergetics studies were conducted on the Lake Superior fish community in Minnesota approximately 10 years apart (Negus 1995; Negus et al. 2008). Bioenergetics models can be used to estimate the energy flow between trophic levels of the food chain, and determine if the predator and prey are in balance. The Wisconsin bioenergetics model (Hanson et al. 1997) was used in both studies and balances the energy consumed with energy expended by the predator fish. The hierarchy of energy allocation is an important component of this modeling approach. Consumed energy is first allocated to catabolic processes (maintenance and activity metabolism), and then to waste losses (feces, urine and specific dynamic action) with any remaining energy allocated to somatic storage (body growth and gonad development):

Energy Consumed = Respiration + Waste + Growth

The Wisconsin model uses the kinds of data most frequently collected by biologists. For predator fish this includes: the habitat that is occupied by the predators (thermal history); size at age (growth curves); stomach contents (diet); size or age at sexual maturity; and size or age related mortality rates. The models assemble individuals of each species into age or size based cohorts, so that population size, mortality rates, diet categories, and temperatures occupied by each cohort reflect the trophic ontogeny that occurs throughout the lifespan of each species.

In the 1995 bioenergetics study, Negus (1995) applied bioenergetics models to fisheries data from Minnesota waters in 1989 to quantify predator consumption relative to prey supply. The study resulted in consumption estimates that exceeded prey supply levels. This imbalance suggested that more and better data were needed to estimate forage biomass. The study also indicated the need for better predator population estimates which has been addressed by use of SCAA models described in the previous section of this report. The estimates of inadequate forage were used to justify hydroacoustics studies of forage populations in the Western Arm of Lake Superior (Johnson et al. 2004; Mason et al. 2005; Hrabik et al. 2006). Although predator consumption and prey availability did not balance in the 1995 study it nevertheless served to identify areas for future research.

The second study utilized the new sources of prey data called for in the 1995 study, and consumption by predator species was compiled from near-shore and offshore regions within Minnesota waters for 2004 (Negus et al. 2008). Detailed tables of compiled data can be found in Negus et al. (2007). The results of the 2008 study indicated that the fish community in Minnesota waters was at or near its carrying capacity for predators. Estimated predator demand was about one-half the annual biomass plus production of Coregonine prey, but slightly exceeded the biomass plus production of Rainbow Smelt, possibly because the Rainbow Smelt population is underestimated in shallower near-shore areas, and possibly because predator diets were somewhat outdated due to recent shifts in response to changes in the prey base. Lean Lake Trout were responsible for most of the consumption of these prey fish, while the deep-water Siscowet form ranked second. Slight reductions in growth of lean Lake Trout, and density-dependent survival in some areas of the lake also indicate that competition for prey is intense (Corradin et al. 2008).

Lake Trout do not appear to be as sensitive to reductions in prey availability as Chinook Salmon, possibly because the Lake Trout are more efficient predators, and are able to sustain high predation rates at low prey densities. Thus, reduced prey availability may not equate to reduced rations for Lake Trout. Lake Trout diets in spring assessment surveys are predominately Rainbow Smelt, but change to more coregonids during the summer and fall (Conner et al. 1993; Ray et al. 2007). Wild Lake Trout populations have increased through natural reproduction to levels that justified a reduction or cessation of stocking in most areas of the lake (Schreiner and Schram 1997; Bronte et al. 2003; Ebener 2007).

Use of bioenergetics models to periodically re-examine the relationship between predator demand and prey supply would be helpful in the management of Lake Superior fisheries, for allocation of resources to various interest groups, and to understand lake production and community dynamics. Collection of data that directly affect predator numbers and food quality (i.e., population estimates, mortality rates, growth, and prey caloric densities) will have the greatest impact on bioenergetics model output, according to sensitivity analyses (Negus 1992).

Because Lake Trout and Siscowet are the most abundant predators in Lake Superior, continued refinement of the bioenergetics model for these species should be undertaken to increase the accuracy of model predictions. The development of bioenergetics models for the different life stages of Lake Trout, and analysis of the sizes of prey fish utilized by different Lake Trout life stages, may assist in determining where bottlenecks exist in both predator and prey populations. Continued use of hydroacoustic sampling to monitor the prey base in different seasons will provide needed perspective on these populations and assist in the calculation of realistic production:biomass (P:B) ratios.

Human Dimensions

Public involvement in Lake Superior Lake Trout management in Minnesota began early and was likely driven by the need for reduced harvest in the commercial fishery, and later by the invasion of the Sea Lamprey. In the early 1880s, when Lake Whitefish stocks, and later other species began to decline, commercial netters were already advocating for hatcheries to be built at both the Lester (federal) and French (state) River sites in Minnesota. By the late 1940s, commercial netters had volunteered to assist with Lake Trout egg takes from wild fish, where they were fertilized, transferred, and reared in the hatchery for stocking. Once Sea Lamprey arrived and Lake Trout stocks had declined to extremely low levels, most commercial netters could no longer make a living fishing and expressed their concerns and recommendations to their respective management agencies. In the 1950s, the GLFC created citizen advisory groups for each lake, composed of commercial and sport fishers, which made suggestions and significant contributions on how the fishery should be managed. These committees still exist and continue to participate at a variety of management levels.

The closure of Minnesota's commercial Lake Trout fishery (except under permit) in 1962 meant that commercial operators had to sacrifice in the interest of Lake Trout rehabilitation. Commercial netters who were willing to conduct assessments under MNDNR issued permit provided valuable information on the status of the recovering Lake Trout stocks for the MNDNR. As Lake Trout abundance increased, so did the interest in the sport fishery. In the early 1970s and again in 1980 the MNDNR attempted to communicate Lake Superior fisheries management to the citizens of Minnesota. Unfortunately, the early plans had very few specific recommendations, and a limited amount of public participation from only a few select user groups (Minnesota Department of Natural Resources 1974; Minnesota Department of Natural Resources 1980).

The first comprehensive Lake Superior fisheries management plan for Minnesota was written in the early 1990s, and incorporated significant public participation through the newly formed Lake Superior Advisory Group (Schreiner 1995). The need for a mutually agreed-upon plan for fisheries in Lake Superior was driven by the extremely diverse perspectives of the many user groups that were focused on individual species management. Much of the demand for fisheries management was driven by the desires of various groups that did not seriously consider the biological constraints which limit the fish community that the Lake Superior ecosystem can support.

Work began on drafting a comprehensive fisheries management plan for Lake Superior with the Lake Superior Advisory Group in the early 1990s and culminated in the publication of the *Fisheries Management Plan for the Minnesota Waters of Lake Superior* (LSMP) (Schreiner 1995). The LSMP took over two years to complete, with major input from the Lake Superior Advisory Group that met monthly during the fall and winter months of 1993 and 1994. Three large meetings that focused on input from the general public were also held to obtain comments on the draft plan. Although not every group represented on the Lake Superior Advisory Group agreed with the final outcome, all understood that no single group could obtain every request they submitted. The discussion process and examination of various recommendations enlightened the advisory group on the constraints within the Lake Superior ecosystem that limit the fish community. Once completed, the strategies in the LSMP were implemented and much progress, especially toward Lake Trout rehabilitation, was made. The LSMP had a pre-determined life of 10 years.

In 2004, the process began again to revise and update the Fisheries Management Plan for the Minnesota Waters of Lake Superior, since the 10 year life time of the initial plan was ending. Once again, significant public input was sought, and deemed critical to the success of the planning process. One major change was that the planning process began with a one day conference open to the general public where MNDNR staff and other fisheries experts provided information on strategies that were implemented from the first plan, the results of those actions, and the present status of the Lake Superior fishery in Minnesota. A major objective was to solicit public input on important concerns that the conference participants had about the Lake Superior fishery, and how those concerns might be addressed in the revised LSMP. Issues were discussed in small break-out groups, and a list of the most important concerns was compiled to serve as the basis for revising the plan. As with the 1995 plan, a Lake Superior Advisory Group was formed that included all interested organizations, and meetings were held over a two year period while the plan was drafted. Many of the members on the 1995 Lake Superior Advisory Group also served on the 2004 group. Again, three meetings were held with the general public to review the draft plan and collect public comment on the proposed recommendations. The final plan was published early in 2006 (Schreiner et al. 2006), and has been implemented over the last 8 years. Work on the next plan revision began in late 2014.

Lake Trout management was a major focal point in the 2006 plan because rehabilitation had progressed from the rebuilding stage to the maintenance stage. Significant management changes for Lake Trout included reduced stocking in MN-1, elimination of stocking in MN-2 and MN-3, the implementation of an Expanded Assessment fishery in MN-2 and MN-3, a lengthening of the sport fishing season by approximately 1 week in the fall, and increased emphasis on protection of wild Lake Trout spawners.

Management Considerations

A variety of management issues and strategies that contributed to the successful rehabilitation of Lake Trout stocks in the Minnesota waters of Lake Superior have been described in this synthesis. Below is a short summary of the most important issues:

1. Sea Lamprey control is critical and must be continued at the present level, or increased if possible, so that as Sea Lamprey induced mortality is reduced, fishing mortality can be increased. In Minnesota, continued monitoring of the St. Louis River estuary for any increase in Sea Lamprey production will be essential as efforts to increase both water quality and fisheries habitat become realized. The St. Louis River estuary has the potential to produce large numbers of parasitic Sea Lamprey, and the cost to treat this large area will be onerous. The removal and/or relocation of the dam on the Black Sturgeon River that flows into Black Bay in northwest Ontario also has great potential to increase Sea Lamprey abundance and impact Lake Trout stocks in Minnesota. As the GLFC and the Lake Superior Committee has recommended, reconstruction of the deteriorating dam in the same location, rather than 50 km (31 mi) upstream, would avoid an increase in Sea Lamprey spawning habitat, and continue to protect Lake Trout in Minnesota and other portions of Lake Superior from potential increased predation by Sea Lamprey.

2. Criteria to discontinue Lake Trout stocking for the purpose of rehabilitation have been met in MN-1 and review of the Lake Trout stocking program will take place during the 2015/16 LSMP revision process. Given that Lake Trout abundance in MN-2 and MN-3 has not shown a significant decline since stocking was discontinued, a large decrease in Lake Trout abundance in MN-1 is not expected.

3. SCAA models are a common stock assessment technique used in the Great Lakes to calculate total annual mortality rates and estimate population abundance of Lake Trout stocks. However, extreme caution should be used when relying on abundance estimates from SCAA models to set harvest levels. A thorough understanding of model inputs, calculations, assumptions and output is critical for proper model use.

4. Spawning stock biomass estimates can be determined using SCAA models and other applicable biological information. Establishing criteria for spawning stock biomass can help guide harvest levels. Spawning stock biomass can be based on stock-recruitment relationships by determining the minimum number of spawners to produce the number of recruits required to sustain the fishery at target levels or levels of density dependence. Conservative criteria for both spawning stock biomass and total annual mortality should protect the present Lake Trout stocks from overexploitation and promote continued self-sustainability.

5. The prey base is an important consideration for Lake Trout management in Lake Superior. Conservative allocation of total allowable catch quotas for Cisco is likely the best management tool available to ensure adequate prey for self-sustaining Lake Trout populations.

6. Monitoring Siscowet populations will be important to determine whether a large expansion in abundance of Siscowet (increased competition), or a major decline in the abundance of Siscowet (which could adversely impact an important energy shunt from deep-water to shallow water) could negatively affect lean Lake Trout abundance. Managing for a balanced fish community should be the long term goal for a sustainable Lake Superior fishery in Minnesota.

7. Bioenergetics and fish community models (e.g. ecopath-ecosim) are important methods to describe energy flow through the present fish community. They can also provide techniques to simulate realistic scenarios concerning Sea Lamprey control, changes in harvest regulations of various species, different stocking strategies, and potential effects of changes in habitat, invasive species and climate change (Kitchell et al. 2000). Use of these models will provide managers with important information on Lake Trout sustainability.

Conclusions

Lake Trout rehabilitation in the Minnesota waters of Lake Superior and in Lake Superior overall, has been an undeniable success, and is one of the few positive examples world-wide of a fishery returning to high levels of production after an almost total collapse. Shared management initiatives implemented by state, federal and tribal agencies, with support from commercial fishers, sport anglers and the general public all contributed to this success.

Many biological and human based factors contributed to successful Lake Trout rehabilitation in Lake Superior. One important factor was a relatively pristine environment in Lake Superior where critical Lake Trout habitat remained intact. Control of exploitation in both the commercial and sport fisheries during the early stages of recovery was critical, and the patience and willingness of the commercial netters and anglers to forgo harvest allowed stocks to recover more quickly. The existence of remnant wild Lake Trout stocks and the use of these stocks as brood fish for hatchery production likely increased the rate of Lake Trout recovery and buffered wild stocks from Sea Lamprey attacks. Undeniably, the most critical factor in recovery of Lake Trout in Lake Superior was the control of Sea Lamprey. Sea Lamprey control remains the cornerstone of Lake Trout rehabilitation not only in Lake Superior, but is the basis for productive fisheries throughout the Great Lakes. Lake Trout recovery in Minnesota's portion of Lake Superior has taken over half a century. We are just now realizing the benefits of a rehabilitated Lake Trout fishery. Ironically, apathy toward recovered Lake Trout stocks is widespread and seems to be increasing among the general public. Many citizens already take the recovery of Lake Trout in Lake Superior for granted. Few individuals in the general public are even aware that Sea Lamprey still pose a major threat to the Great Lakes fishery. As has been the case in fisheries for centuries, citizens react only after fish stocks have undergone major declines. It would benefit us as fishery biologists, anglers, commercial netters and interested citizens to manage Lake Trout stocks conservatively and remind the general public about the amount of time, effort, sacrifice, and cost that went into the Lake Trout rehabilitation program and how quickly this success could be reversed.

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Appendices

Appendix 1. Commercial Lake Trout harvest in Minnesota waters, 1885 to 2014. All weights are dressed weights of Lake Trout with a conversion factor to round weight of 1.25. From 1962-1985, weights include incidental Lake Trout harvest in the commercial fishery for other species, and Lake Trout harvested in the assessment fishery. Commercial harvest of Lake Trout from 1986-1995 was less than 1,000 kg/yr and only included incidental harvest, so was not reported in this publication. Details are available at the Lake Superior Area fisheries office. From 1996-2006, weights include incidental Lake Trout harvest in the commercial fishery for other species, and Lake Trout harvest from the Grand Portage Band when reported. From 2007-2014, weights include incidental Lake Trout harvest in the commercial fishery for other species, harvest from the Grand Portage Band, and the Expanded Assessment fishery that was implemented in 2007.

Year	Thousands of lbs	Thousands of kgs	Year	Thousands of lbs	Thousands of kgs
1885	1,376	624.1	1912		
1886			1913	150	68.0
1887			1914	105	47.6
1888			1915	86	39.0
1889	1,099	498.5	1916	137	62.1
1890	138	62.6	1917	125	56.7
1891			1918	223	101.2
1892			1919	242	109.8
1893	619	280.8	1920	238	108.0
1894			1921	383	173.7
1895			1922	236	107.0
1896			1923	253	114.8
1897	394	178.7	1924	371	168.3
1898			1925	345	156.5
1899	247	112.0	1926	333	151.0
1900			1927	324	147.0
1901			1928	391	177.4
1902			1929	322	146.1
1903	489	221.8	1930	294	133.4
1904			1931	536	243.1
1905			1932	532	241.3
1906			1933	227	103.0
1907	400	181.4	1934	270	122.5
1908	215	97.5	1935	379	171.9
1909			1936	393	178.3
1910			1937	354	160.6
1911			1938	463	210.0

Appendix 1 (continued on next page)

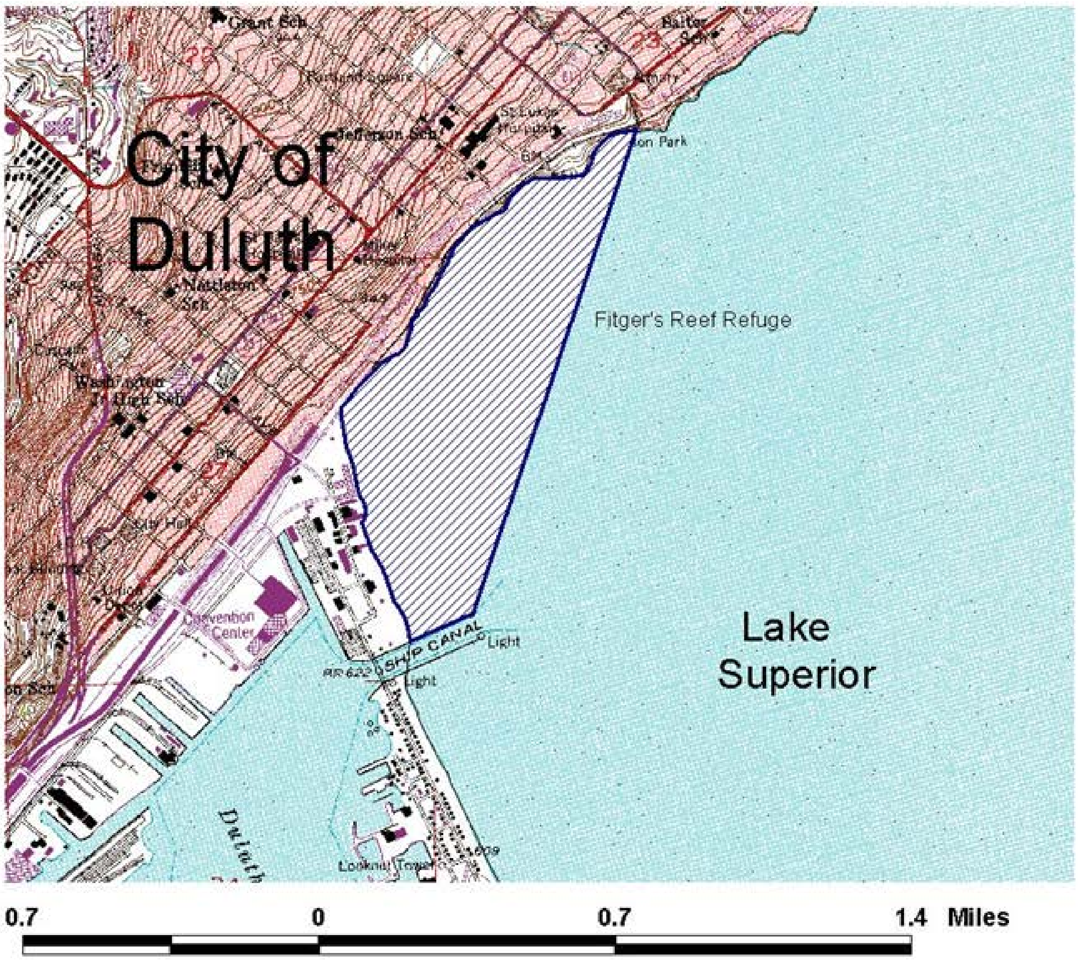
Appendix 1. (continued)

Year	Thousands of lbs	Thousands of kgs	Year	Thousands of lbs	Thousands of kgs
1939	349	158.3	1972	14	6.4
1940	321	145.6	1973	25	11.3
1941	353	160.1	1974	27	12.2
1942	277	125.6	1975	35	15.9
1943	347	157.4	1976	32	14.5
1944	332	150.6	1977	36	16.3
1945	234	106.1	1978	35	15.9
1946	316	143.3	1979	36	16.3
1947	219	99.3	1980	35	15.9
1948	240	108.9	1981	35	15.9
1949	270	122.5	1982	35	15.9
1950	202	91.6	1983	37	16.8
1951	233	105.7	1984	7	3.2
1952	243	110.2	1985*	26	11.8
1953	217	98.4	1996	4	1.8
1954	211	95.7	1997	6	2.7
1955	170	77.1	1998	4	1.8
1956	109	49.4	1999	4	1.8
1957	55	24.9	2000	7	3.2
1958	33	15.0	2001	2	0.9
1959	11	5.0	2002	3	1.4
1960	2	0.9	2003	3	1.4
1961	1	0.5	2004	2	0.9
1962	1	0.5	2005	2	0.9
1963	2	0.9	2006	2	0.9
1964	2	0.9	2007	3	1.4
1965			2008	5	2.3
1966	5	2.3	2009	5	2.3
1967	5	2.3	2010	8	3.6
1968	9	4.1	2011	10	4.5
1969	13	5.9	2012	8	3.6
1970	20	9.1	2013	11	5.0
1971	21	9.5	2014		

* Commercial harvest of Lake Trout from 1986-1995 was less than 1,000 kg/yr and only included incidental harvest, so was not reported in this publication. Details are available at the Lake Superior Area fisheries office.

Appendix 2. Map of Fitger's Reef.

Fitger's Reef Refuge

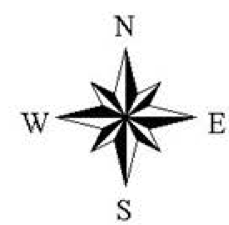


This area is closed to fishing from boats

The dates of closure are from October 1 to November 30.

When November 30 falls on a Saturday, the closure extends to the following Sunday.

Fishing is allowed only from shore in this area during the dates of closure.



Appendix 3. Yearling and fingerling Lake Trout stocked in Minnesota's portion of Lake Superior, 1962 – 2014 (fall fingerlings are in parentheses).

Year Planted	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
Location/Clip	**(D)**	**(LF)**	**DRR (D)**	**ABR (RF)**	**RF (DLF)**	**LFRR (LFLR)**	**DRR (RF)**	**DLF**	**A**
MN-1									
Duluth									
Brighton Beach									
Pumping Station									
Clifton									
French River									
Stoney/Palmers									
Blue Bird					9,979	21,208	24,205	57,160	70,960
Stoney Point				(16,099)	(22,425)		(24,585)		
				(39,825)	9,979	19,955	48,532		
Knife River					(47,828)	(11,890)			
								19,504	19,210
Two Harbors									
Agate & Burlington									
Flood Bay									
Gooseberry/Lind's									
MN-2									
Split Rock				25,645	17,146	18,653	56,807	19,988	18,540
				(66,235)	(22,540)	(16,920)	(27,930)		
Beaver Bay/Silver Bay		(174,820)	(15,412)	25,645	17,146	18,654			
				(27,360)					
Little Marais	(76,559)					(17,100)	(36,494)	16,440	17,670
Tofte									
Lutsen									
MN-3									
Grand Marais			90,000	25,223	27,036	74,984	47,784	38,700	49,810
			(22,434)		(34,270)	(58,680)	(44,764)		
Good Harbor Bay									
5 Mi. Rock/Durfee									
Paradise									
Hovland			92,000	25,223	27,035	73,830	45,805	64,588	50,000
					(24,416)	(49,140)	(19,240)		
Grand Portage									
Cannonball Bay									
Hollow Rock									
TOTAL YEARLINGS			182,000	101,736	108,321	227,284	223,133	216,380	226,190
TOTAL FALL FINGERLINGS	(76,559)	(174,820)	(37,846)	(149,519)	(151,479)	(153,730)	(153,013)		

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	1971	1972	1973	1974	1975	1976	1977	1978	1979
Location/Clip	**RF**	**LR**	**A**	**LFRR**	**LF**	**RF**	**RR**	**A**	**LR ARF***
MN-1									
Duluth									
Brighton Beach			80,150	100,000	99,995	83,450		86,020	
Pumping Station		58,065							
Clifton									
French River									
Stoney/Palmers									
Blue Bird	54,274								
Stoney Point			30,091	38,812	28,992		80,151		80,022
Knife River									
Two Harbors	70,088	73,218	30,782						
Agate & Burlington									
Flood Bay						78,630		80,565	
Gooseberry/Lind's									
MN-2									
Split Rock	40,680	30,123	** 29,895	83,461			85,005		59,986
								80,515	
Beaver Bay/Silver Bay		34,960	30,008		79,990				
Little Marais	50,047	28,885	29,994	82,039		82,511			59,149
Tofte	40,088	40,017	23,759		80,480		84,993		65,017
Lutsen									
MN-3									
Grand Marais	25,044	24,996	28,991						
Good Harbor Bay						50,043	50,001		
5 Mi. Rock/Durfee								59,900	
Paradise								47,731	50,000*
Hovland					47,160				
Grand Portage									
Cannonball Bay						50,142	50,211		
Hollow Rock									
TOTAL YEARLINGS	280,221	290,264	283,670	304,312	336,617	344,776	350,361	354,731	314,174
TOTAL FALL FINGERLINGS									

* indicates yearlings stocked with alternate clip **stocked by boat

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	1980	1981	1982			1983	1984		
Location/Clip	**LF RFLR***	**RF ARR[4*] (ABR)**	**ALR (D)[1]**	**(DLR)**	**RR (DA)**	**A ARF[1]***	**DRF[2] (ARR)[1]**	**LFRR[3*] (LF)**	**LR**
MN-1									
Duluth									
Brighton Beach	41,107								51,024
Pumping Station									
Clifton					87,938				
French River									
Stoney/Palmers									
Blue Bird									
Stoney Point		49,991		(39,000)		82,050		(54,000)	
Knife River									
Two Harbors			48,448				21,290	26,669*	
Agate & Burlington									
Flood Bay	87,100		51,480						
Gooseberry/Lind's									
MN-2									
Split Rock		50,809				43,740 50,009*	(39,600)		
Beaver Bay/Silver Bay	111,093	(75,580)			49,900 (33,155)				52,789
Little Marais		49,932				82,950			
Tofte		21,400*			25,144	75,000			
Lutsen		21,400*							
MN-3									
Grand Marais									
Good Harbor Bay	61,500	21,500*	(50,025)	(39,040)	25,002	58,120*			
5 Mi. Rock/Durfee		21,500*							
Paradise									
Hovland									
Grand Portage									
Cannonball Bay									
Hollow Rock	49,900*								60,499
TOTAL YEARLINGS	350,700	236,532	99,928		187,954	391,869	21,290	26,669	164,312
TOTAL FALL FINGERLINGS		(75,580)	(50,025)	(78,040)	(33,155)		(39,600)	(54,000)	

[1] Isle Royale strain [2] red pigment [3] green pigment [4] stocked on offshore reefs *indicates yearlings stocked with an alternate clip

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	1985		1986	1987	1988	1989	1990	1991	1992
Location/Clip	**ARR[1]**	**LF (RF)**	**RF**	**RR**	**A**	**LR (ALR)**	**LF**	**RF**	**RR**
MN-1									
Duluth									
Brighton Beach			46,305					69,999	58,920
Pumping Station		(17,100)							
Clifton		(27,463)	27,698		14,005	15,033	42,784	31,142	58,778
French River					50,200				
Stoney/Palmers									
Blue Bird		51,954					9,585		67,024
Stoney Point		43,016		43,978		149,759	85,890	66,966	65,041
Knife River									
Two Harbors	31,350	25,490	74,610			69,272	63,698	109,081	58,812
Agate & Burlington									
Flood Bay	25,650	20,925							
Gooseberry/Lind's			74,503		50,000				
MN-2									
Split Rock						17,550	20,930		
						(53,991)			
Beaver Bay/Silver Bay			55,002		26,304			89,901	44,944
Little Marais		20,241	22,200			30,013			
Sugar Loaf									32,222
Tofte		20,241	22,025		21,600		32,759	44,681	
Lutsen									
MN-3									
Grand Marais		17,601	42,561			33,450		65,250	59,059
							51,506		
Good Harbor Bay		17,602		47,008					
5 Mi. Rock/Durfee									
Paradise	24,016	18,212			49,996				
Hovland	24,017	18,072					53,566		32,221
Grand Portage			31,711			54,940		65,216	22,508
Cannonball Bay									
Hollow Rock			11,610						
TOTAL YEARLINGS	105,033	253,354	408,225	90,986	212,105	370,017	360,718	542,236	499,529
TOTAL FALL FINGERLINGS		(44,563)				(53,991)			

[1] Isle Royale strain, and all fish stocked after 1987

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	1993	1994	1995	1996	1997	1998	1999	2000	2001
Location/Clip	**A****	**LR**	**LF + Adults**	**RF + Adults**	**RR**	**A**	**LR**	**LF**	**RF**
MN-1									
Duluth									
Brighton Beach		192,069	93,016	100,550	91,246	61,513	41,139	38,400	60,891
Pumping Station									
Clifton		37,320	38,220						
French River									
Stoney/Palmers									
Blue Bird		14,509							
Stoney Point		58,628	37,800	57,432	48,283		37,893	38,870	80,820
Knife River									
Two Harbors									
Agate & Burlington	346,065**	4,707	123,594	104,830	79,992	43,242	72,192	70,073	89,891
Flood Bay									
Gooseberry/Lind's									
MN-2									
Split Rock									
Beaver Bay/Silver Bay	85,009	53,998	58,407	38,950	15,000	37,978		45,818	41,571
Little Marais									
Tofte		23,056	28,995	46,118	49,400		43,443		45,031
Lutsen									
MN-3									
Grand Marais	54,054	48,160	53,979	52,000	49,170	39,993	50,224	45,904	39,828
Good Harbor Bay									
5 Mi. Rock/Durfee									
Paradise									
Hovland			53,955	52,008	30,000				
Grand Portage	54,443	64,946							
Cannonball Bay									
Hollow Rock									
TOTAL YEARLINGS	539,571	497,393	487,966	451,888	363,091	182,726	244,891	239,065	358,032
TOTAL FALL FINGERLINGS									

** 1993 Size at stocking survival study - ARR - 107,802 @12.64/lb, ALR - 99,273 @12.67/lb, ALF - 100,000 @32.40/lb, ARFLR - 25,137 @5.25/lb, ARF - 13,853 @4.80/lb. Hatchery brood culled: 227 adults at Silver Bay in July of 1995, 716 adults at Two Harbors in February of 1996.

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	2002	2003	2004	2005	2006	2007	2008	2009	2010
Location/Clip	**RR**	**A**	**LR**	**LF**	**RF**	**RR**	**A**	**LR**	**LF**
MN-1									
Duluth									
Brighton Beach	77,360	77,791	62.360	81.424	85,996	72,868	8,718	92,230	83,086
Pumping Station				14.492					
Clifton/Lakewood				13,746	35,180				
French River									
Stoney/Palmers									
Blue Bird	79,905	64,377							
Stoney Point			72,484	38,339			50,611		
Nokomis						36,039			
Knife River									
	71,306	68,191							
Two Harbors			68,942	56,934	72,367	65,501		84,230	
Agate & Burlington									88,587
Flood Bay									
Gooseberry/Lind's									
MN-2	50,508								
Split Rock		31,749							
			34,119	38,373	38,683				
Beaver Bay/Silver Bay									
Little Marais		30,780							
Taconite Harbor			34,560	28,575	38,844				
Tofte	73,006								
Lutsen									
MN-3									
Grand Marais									
Good Harbor Bay									
5 Mi. Rock/Durfee									
Paradise									
Hovland									
Grand Portage									
Cannonball Bay									
Hollow Rock									
TOTAL YEARLINGS	352,085	272,888	272,465	271,883	271,070	174,408	59,329	176,460	171,673
TOTAL FALL FINGERLINGS									

Appendix 3 (continued on next page)

Appendix 3. (continued)

Year Planted	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Location/Clip	**RF**	**RR**	**A**	**LR**	**LF**	**RF**	**RR**	**A**	**LR**
MN-1									
Duluth	83,781	38,433		43,478					
Brighton Beach									
Pumping Station									
Clifton/Lakewood									
French River									
Stoney/Palmers									
Blue Bird			43,414						
Stoney Point									
Nokomis									
Knife River									
Two Harbors		74,880	95,094	50,800					
Agate & Burlington	44,144								
Flood Bay									
Gooseberry/Lind's									
MN-2									
Split Rock									
Beaver Bay/Silver Bay									
Little Marais									
Taconite Harbor									
Tofte									
Lutsen									
MN-3									
Grand Marais									
Good Harbor Bay									
5 Mi. Rock/Durfee									
Paradise									
Hovland									
Grand Portage									
Cannonball Bay									
Hollow Rock									
TOTAL YEARLINGS	127,925	113,313	138,508	94,278					
TOTAL FALL FINGERLINGS									

Appendix 4. Total number and summary of requirements for Lake Trout permit netters in the Minnesota waters of Lake Superior, 1962-2014. (NR – Not Required).

	Number of Permits		Dates					Quota (Spring & Fall combined)	
Year	MN-2	MN-3	Spring	Fall	Combined	Net Length	Mesh Size	Number	Pounds
1962	1	1			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1963	1	2			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1964	1	2			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1965	1	4			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1966	1	5			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1967	2	5			Mar.-early Oct.	NR	4.5 - 5.5	NR	NR
1968	5	7			3/25 - 10/10	6,000	4.5 - 5.5	NR	NR
1969	4	6			4/10 - 10/10	6,000	4.5 - 5.5	NR	NR
1970	4	6			4/15 - 10/10	6,000	4.5 - 5.5	NR	NR
1971	4	6	5/1 - 6/30	9/1 - 9/30		3,000	4.5 - 5.5	NR	NR
1972	4	6	5/1 - 6/30	9/1 - 9/30		3,000	4.5 - 5.5	NR	NR
1973	4	6	5/1 - 6/30	9/1 - 9/30		3,000	4.5 - 5.5	NR	NR
1974	4	6	5/1 - 6/15	9/1 - 9/30		3,000	4.5 - 5.5	NR	NR
1975	4	6	5/1 - 5/31	9/1 - 9/30		3,000	4.5 - 5.5	600	3,000
1976	4	6	5/1 - 5/25	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000
1977	4	6	5/1 - 5/25	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000
1978	4	6	5/1 - 5/25	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000
1979	4	6	5/1 - 5/31	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000

Appendix 4 (continued on next page)

Appendix4. (continued)

	Number of Permits		Dates					Quota (Spring & Fall combined)	
Year	MN-2	MN-3	Spring	Fall	Combined	Net Length	Mesh Size	Number	Pounds
1980	4	5	5/6 - 5/31	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000
1981	4	6	5/11 - 5/31	9/10 - 9/30		3,000	4.5 - 5.5	600	3,000
1982	4	5	5/12 - 5/31	9/10 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1983	4	5	5/11 - 5/31	9/10 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1984	4	5	5/10 - 5/31	9/4 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1985	4	5	5/10 - 5/31	9/4 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1986	4	5	5/7 - 5/31	9/3 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1987	4	5	5/6 - 5/31	9/9 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1988	3	5	5/4 - 5/31	9/7 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1989	4	5	5/9 - 5/31	9/7 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1990	4	5	5/5 - 5/31	9/6 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1991	4	5	5/5 - 5/31	9/7 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1992	4	5	5/2 - 5/31	9/5 - 9/30		3,000	4.5 (>50%) - 5.5	600	3,000
1993	4	4	5/3 - 5/31	9/6 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
1994	4	4	5/4 - 5/31	9/4 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
1995	4	3	5/1 - 5/31	9/5 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
1996	3	3	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
1997	4	2	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
1998	3	2	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000

Appendix 4 (continued on next page)

Appendix 4. (continued)

	Number of Permits		Dates					Quota (Spring & Fall combined)	
Year	MN-2	MN-3	Spring	Fall	Combined	Net Length	Mesh Size	Number	Pounds
1999	3	2	5/1 - 5/31	9/7 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
2000	3	2	5/1 - 5/31	9/5 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
2001	2	2	5/1 - 5/31	9/4 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
2002	2	2	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
2003	2	2	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	4,000
2004	2	2	5/1 - 5/31	9/1 - 9/30		3,000	4.5 (>50%) - 5.5	600	NR
2005	2	1	5/1 - 5/31	9/1 - 9/30		3,000	4.5	600	NR
2006	2	1	5/1 - 5/31	9/1 - 9/30		3,000	4.5	600	NR
2007	2	1	5/1 - 5/31	9/1 - 9/30		3,000	4.5	600	NR
2008	2	1	5/1 - 5/31	9/1 - 9/30		3,000	4.5	600	NR
2009	2	1	5/1 - 5/31	9/1 - 9/30		3,000	4.5	600	NR
2010	2	1	5/1 - 5/31	Discontinued		3,000	4.5	600	NR
2011	2	1	5/1 - 5/31			3,000	4.5	600	NR
2012	2	1	5/1 - 5/31			3,000	4.5	600	NR
2013	2	1	5/1 - 5/31			3,000	4.5	600	NR
2014	2	1	5/1 - 5/31			3,000	4.5	600	NR

Appendix 5. Summary of Lake Trout netting locations and codes by permit netter and year in the Minnesota waters of Lake Superior, 1962-1995.

Initials	Permit name	Zone	Site	Site name	Grid	Years sampled
ES	Ernest Spry	MN-3	AOC	Albert Olsen's Cabin	715	ES in 83
JK	John Koss	MN-3	BBY	Big Bay	714	JK in 64-66, KK in 67-79 & RE in 81
ES	Ernest Spry	MN-3	BHE	East of Booth Rock East	716	ES in 79
ES	Ernest Spry	MN-3	BHR	Booth Rock	716	ES in 72,74-76,78-86; GS in 89-93
ES	Ernest Spry	MN-3	BHT	Booth Foot	716	ES in 86
NK	Nassau Koss	MN-3	BLP	Black Point	811	NK in 80
GS	Gerald Spry	MN-3	BLR	Blank's Rock	716	GS in 91
JC	Jack Scott	MN-3	BRB	Brule Bay	813	JC in 63
ES	Ernest Spry	MN-3	BRE	Boot Rock East	716	ES in 79-81,86
ES	Ernest Spry	MN-3	BRW	Booth Rock West = BHR	716	ES in 81; GS in 88
ES	Ernest Spry	MN-3	BTR	Boot Rock	716	ES in 74,76-78,80-85; GS in 94
NK	Nassau Koss	MN-3	CAR	Cascade River	811	NK in 68
GS	Gerald Spry	MN-3	CBB	Cannonball Bay	715	GS in 91
ES	Ernest Spry	MN-3	CLB	Clark's Bay	716	ES in 74; GS in 88
TE	Thomas Eckel	MN-3	CPB	Coast Guard Point & Powder Bay	811	TE in 87
NK	Nassau Koss	MN-3	CPK	Cascade Park	811	NK in 66,69,77-78,80
NK	Nassau Koss	MN-3	ECR	East of Cascade River	811	NK in 66-67
NK	Nassau Koss	MN-3	EGB	Egro Bay	811	NK in 68-81; CK in 82-92 & KK (should be NK) in 73
TE	Thomas Eckel	MN-3	EGM	East of Grand Marais=GME	812	TE in 66-67,71,86,88,92
LH	Lloyd Hendrickson	MN-3	EHP	East of Hat Point	716	LH in 63,64,66; ES in 78, 85
TE	Thomas Eckel	MN-3	EPB	East Powder Bay	811	TE in 87
ES	Ernest Spry	MN-3	EPI	East of Portage Is.	716	ES in 73-74,80
LH	Lloyd Hendrickson	MN-3	FIB	Frances Is.	716	LH in 67,84,87,88,91,93
TE	Thomas Eckel	MN-3	GMA	Grand Marais	812	TE in 65,68-86,88-95
TE	Thomas Eckel	MN-3	GME	East of Grand Marais=EGM	812	TE in 87
TE	Thomas Eckel	MN-3	GMG	Grand Marais, General	812	TE in 88
TE	Thomas Eckel	MN-3	GMR	Grand Marais, Rosebush	811	TE in 89-90,94

Appendix 5 (continued on next page)

Appendix 5. (continued)

Initials	Permit name	Zone	Site	Site name	Grid	Years sampled
ES	Ernest Spry	MN-3	GPB	Grand Portage Bay	716	LH in 64-68; JH in 69; ES in 68-76,80,83; GS in 88
ES	Ernest Spry	MN-3	GPC	Grand Portage Cannonball/Pie Is.	715	ES in 70
LH	Lloyd Hendrickson	MN-3	GPI	Grand Portage Is.	716	LH in 68; ES in 70; GS in 91-93
TE	Thomas Eckel	MN-3	GRC	Grand Marais, Rosebush=GMR	811	TE in 90
LH	Lloyd Hendrickson	MN-3	GRP	Grand Portage	716	LH in 94
RE	Richard Eckel	MN-3	HOV	Hovland	714	JK in 65; RC (listed as JH) in 81; RE in 81-95
LH	Lloyd Hendrickson	MN-3	HPT	Hat Point=HTP	716	LH in 63-66,69-76,78,80,81,90-92; ES in 73-75,77-83,86; GS in 89
LH	Lloyd Hendrickson	MN-3	HTP	Hat Point	716	LH in 67,68,83; ES in 84
JH	John Hendricks	MN-3	HWR	Hollow Rock	715	JH in 65-81; ES in 84; GS in 88-89
JH	John Hendricks	MN-3	HWT	Hollow Rock=HWR	715	JH in 74
JC	Jack Scott	MN-3	KBC	Kimball Creek	813	JC in 63; JS in 68
KK	Kenneth Koss	MN-3	KK= BBY	Big Bay	714	KK in 76
NK	Nassau Koss	MN-3	LUT	Lutsen	910	NK in 66-67,69
ES	Ernest Spry	MN-3	OHP	Outside Hat Point	716	ES in 76,78; LH in 78
ES	Ernest Spry	MN-3	OPB	Outside Picnic Bay	716	ES in 77
ES	Ernest Spry	MN-3	OPI	Outside Portage Is. = GPI	716	ES in 71-75,77-78,86; GS in 87-89, 91
GS	Gerald Spry	MN-3	OPT	Portage Island=GPI+OPI	716	GS in 88
TE	Thomas Eckel	MN-3	PDB	Powder Bay=WGM	811	TE in 87-88
ES	Ernest Spry	MN-3	PGP	Pigeon Point	716	TE in 65; ES in 77; GS in 88
GS	Gerald Spry	MN-3	PHS	Pumphouse	716	GS in 92
ES	Ernest Spry	MN-3	PIC	Picnic Bay	716	ES in 68-78,80,83-84; GS in 87-89,92
ES	Ernest Spry	MN-3	PIG	Pigeon Bay	716	LH in 69; ES in 69,71,75-77; GS in 87-88
CK	Clayton Koss	MN-3	PPP= CPK	Should be Cascade Park=CPK	811	CK in 82
JC	Jack Scott	MN-3	RCB	Red Cliff Bay	813	JC in 63
JH	John Hendricks	MN-3	RED	Red Rock=RRK	715	JH in 81

Appendix 5 (continued on next page)

Appendix 5. (continued)

Initials	Permit name	Zone	Site	Site name	Grid	Years sampled
JH	John Hendricks	MN-3	RRK	Red Rock=RED	715	JH in 81
LH	Lloyd Hendrickson	MN-3	SDW	Sand Bay (Washwonagon Bay)	716	LH in 84,88
LH	Lloyd Hendrickson	MN-3	SHP	South of Hat Point	716	LH in 63,64,66,69,70,74,76,77,79, 80,82,84-89,91,93
ES	Ernest Spry	MN-3	SLI	Susie and Lucille Is.	716	ES in 74
LH	Lloyd Hendrickson	MN-3	SLT	Susie & Lucille Is.	716	LH in 67
ES	Ernest Spry	MN-3	SPL	Spry's Landing	716	ES in 80,82-86; GS in 90
LH	Lloyd Hendrickson	MN-3	SUI	Susie Island	716	LH in 63
ES	Ernest Spry	MN-3	TMP	Tamarack Point	716	ES in 68-69,71-76,78,80,83-84; ES (listed as JH) in 73; GS in 88-94
ES	Ernest Spry	MN-3	TPS	Twin Points =TSP	716	ES in 72-82,84-86; LH in 79; GS in 87-92
ES	Ernest Spry	MN-3	TSP	Twin Points = TPS	716	ES in 74; GS in 93-94
TE	Thomas Eckel	MN-3	WGM	West Grand Marais	811	TE in 66,69,71,73,83,86-87,89,92-93; TE (listed as JK) in 66
ES	Ernest Spry	MN-3	WHP	West of Hat Point	716	ES in 78,85-86
ES	Ernest Spry	MN-3	WPI	West of Portage Is.	716	ES in 73-75,79
LH	Lloyd Hendrickson	MN-3	WSB	Washwonagon Bay	716	LH in 63-70,73-93,95
ES	Ernest Spry	MN-3	WTP	West of Twin Point	716	ES in 84-86
LH	Lloyd Hendrickson	MN-3	WZB	Washwonagon Bay=WSB	716	LH in 81
EN	Ed Ness	MN-2	BAP	Baptism River; Ed Ness Home	1006	EN in 64,74-87
EN	Ed Ness	MN-2	BUR= BRV	Beaver River-should be BRV	1106	EN in 75
RM	Robert Midbrod	MN-2	BVB	Beaver Bay	1106	RM in 89-94
EN	Ed Ness	MN-2	EPL	East of Palisade	1006	EN in 68
EN	Ed Ness	MN-2	ESP	East of Shovel Point	1007	EN in 82
EN	Ed Ness	MN-2	KEN	Kennedy Landing	1007	EN in66-69,71-72,74-75,78
BF	Ben Fenstad	MN-2	LMA	Little Marais	1007	BF in 69-91; DF in 91-95
BF	Ben Fenstad	MN-2	LMR	Little Marais	1007	BF in 89; DF in 94
EN	Ed Ness	MN-2	LUT	Lutsen	910	EN in 63

Appendix 5 (continued on next page)

Appendix 5. (continued)

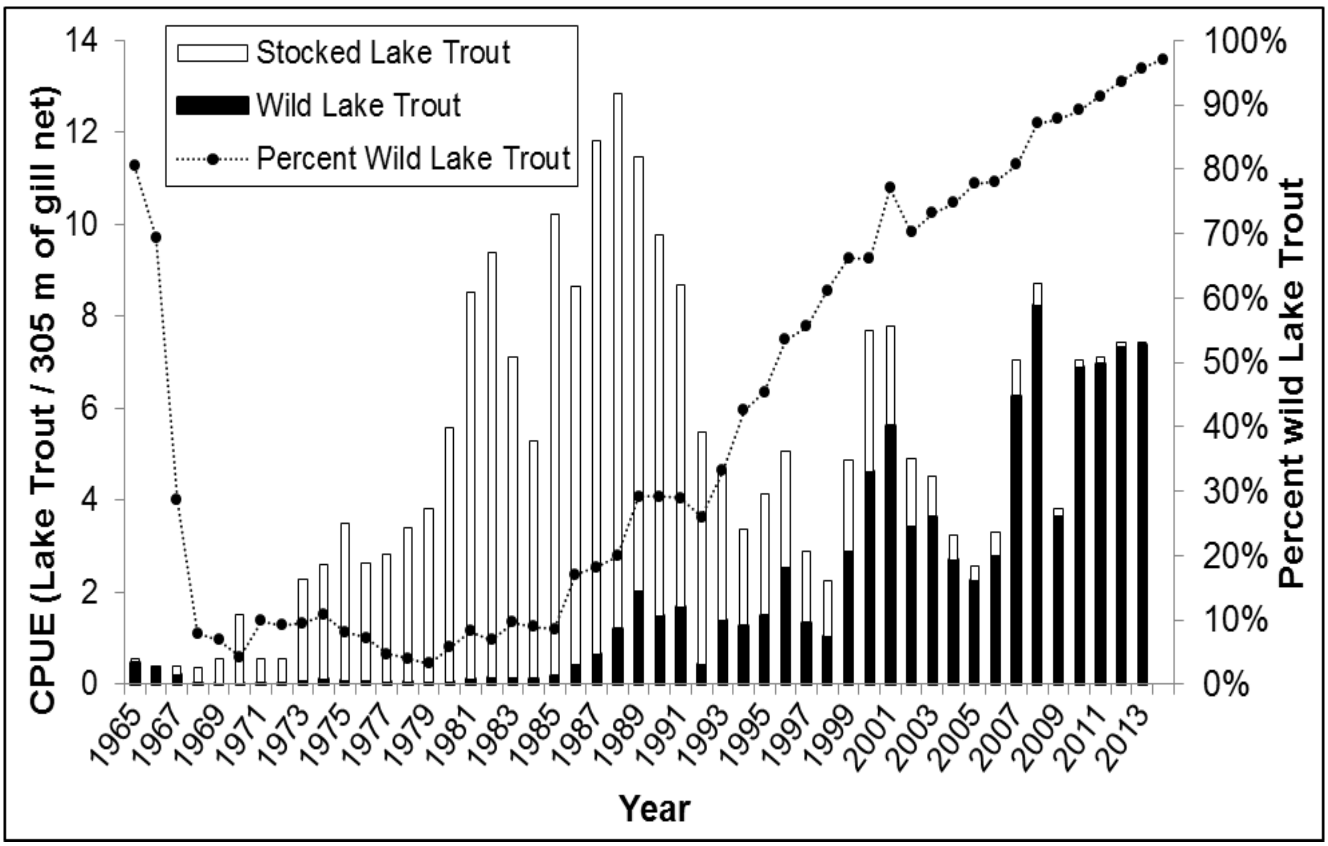
Initials	Permit name	Zone	Site	Site name	Grid	Years sampled
RM	Robert Midbrod	MN-2	MBL	Midbrod Landing	1106	RM in 89
EN	Ed Ness	MN-2	MCL	McIvers Landing	1106	EN in 64,76
RM	Robert Midbrod	MN-2	NML	Ness & Midbrod Landing	1106	RM in 89
EN	Ed Ness	MN-2	NSL	Ness Landing	1006	EN in 67; RM in 89
EN	Ed Ness	MN-2	PAL	Palisade	1006	EN in 63-67,69-70,75-76,78-81; RM in 68; RM (listed as JS) in 68
EN	Ed Ness	MN-2	SBY	Silver Bay	1106	EN in 71,73; RM in 68
TC	Thor Carlsen	MN-2	SGL	Sugarloaf	1008	TC in 77-90; KC in 92-95
RS	Ragnvald Sve	MN-2	SPL	Split Rock = SPR	1106	RS in 73; WS in 89
RS	Ragnvald Sve	MN-2	SPR	Split Rock	1106	RS in 68-81; WS in 82-95
EN	Ed Ness	MN-2	SPT	Shovel Point	1007	EN in 66-69,71-86
EN	Ed Ness	MN-2	STH	South of Taconite Harbor	1008	EN in 66
EN	Ed Ness	MN-2	THB	Taconite Harbor (18 mi SE)	1008	EN in 77
EN	Ed Ness	MN-2	TOF	Tofte	909	EN in 63; CS in 67-76
FR=DNR	French River Crew=MNDNR	MN-1	25A	25th Ave. East	1401	FR in 88
FR=DNR	French River Crew=MNDNR	MN-1	40A	40th Ave. East	1401	FR in 88
FR=DNR	French River Crew=MNDNR	MN-1	45E	45th Ave. East	1401	FR in 89
FR=DNR	French River Crew=MNDNR	MN-1	AGB	Agate Bay	1204	FR in 85
FR=DNR	French River Crew=MNDNR	MN-1	BBS	Between Bluebird and Sucker River = SBW	1302	FR in 83
FR=DNR	French River Crew=MNDNR	MN-1	BUB	Burlington Bay	1204	FR in 85
FR=DNR	French River Crew=MNDNR	MN-1	CGP	Coast Guard Point	1204	FR in 87-91,93; DNR in 94-95
DNR	MNDNR	MN-1	CRR	Croft Reef	1303	DNR in 95
FR=DNR	French River Crew=MNDNR	MN-1	ECI	Encampment Is. = ENC	1204	FR in 89,91-93: DNR in 95
FR=DNR	French River Crew=MNDNR	MN-1	ENC	Encampment = ECI	1204	FR in 93; DNR in 94
CM	Clarence M. Swenson	MN-1	FHR	French River	1302	GT in 63-64; CM in 66; CS=CM in 69; FR in 82-93; DNR in 94
FR=DNR	French River Crew=MNDNR	MN-1	FIT	Fitger's and Moen Tire	1401	FR in 84,86,88,92,93
FR=DNR	French River Crew=MNDNR	MN-1	FLB	Flood Bay	1204	FR in 88
FR=DNR	French River Crew=MNDNR	MN-1	FPT	Fisherman's Point	1204	FR in 82,90-93; DNR in 94-95
DNR	MNDNR	MN-1	FRR	French River = FHR	1302	DNR in 95

Appendix 5 (continued on next page)

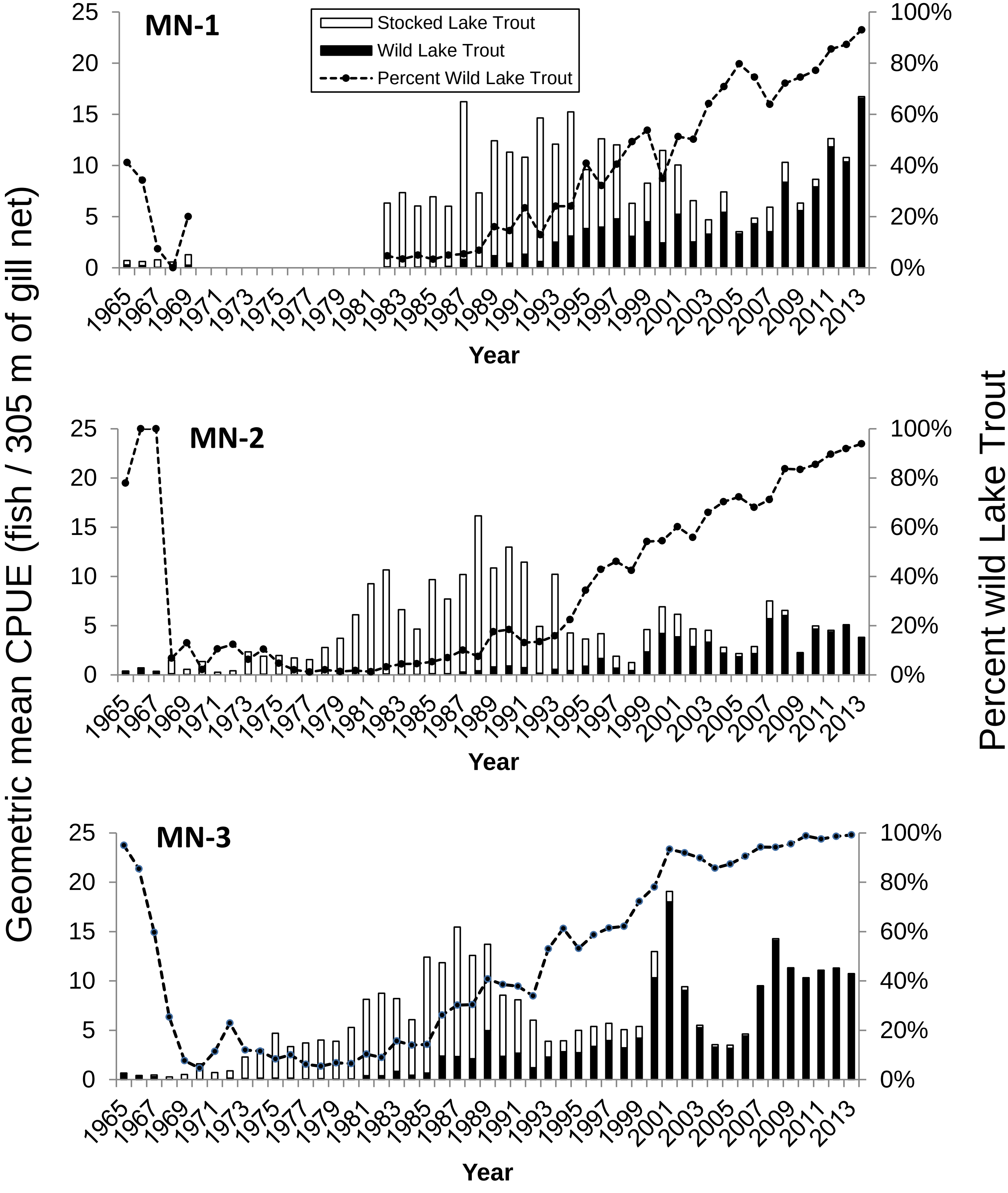
Appendix 5. (continued)

Initials	Permit name	Zone	Site	Site name	Grid	Years sampled
FR=DNR	French River Crew=MNDNR	MN-1	FSR	Fish Scale Reef - Flood Bay (East)	1204	FR in 87
FR=DNR	French River Crew=MNDNR	MN-1	KGC	Kithchi Gami Club - 6th Ave. East	1401	FR in 85
FR=DNR	French River Crew=MNDNR	MN-1	KIP	Knife Island - Parallel	1303	FR in 86
FR=DNR	French River Crew=MNDNR	MN-1	KIR	Knife Island - Perpendicular	1303	FR in 86,89
FR=DNR	French River Crew=MNDNR	MN-1	LAR	Larsmont	1303	FR in 91-93; DNR in 94-95
CM	Clarence M. Swenson	MN-1	LBB	Lester River/Brighton Beach	1302	CM in 66; FR in 90-93; DNR in 94-95
CM	Clarence M. Swenson	MN-1	LWR	Lakewood Road = SBW	1302	CM in 66
FR=DNR	French River Crew=MNDNR	MN-1	NFR	New Fishing Reef=NRE+NRF	1401	FR in 88
GT	George Torgerson	MN-1	NKR	North of Knife River	1303	GT in 66,68
FR=DNR	French River Crew=MNDNR	MN-1	NRE	New Reef - Fitger's = NRF	1401	FR in 89
FR=DNR	French River Crew=MNDNR	MN-1	NRF	New Reef - Fitger's = NRE	1401	FR in 90-91,93
FR=DNR	French River Crew=MNDNR	MN-1	PPP	People's Park - Old Pier	1401	FR in 85-86,88,90,93
CM	Clarence M. Swenson	MN-1	PPS	Pumping Station	1302	CM in 66; CS (=CM) in 69; FR in 89-93; DNR in 94-95
FR=DNR	French River Crew=MNDNR	MN-1	RES	Reef East of Stoney Pt.=CRR	1303	FR in 93
FR=DNR	French River Crew=MNDNR	MN-1	SBE	Sucker Bay East	1303	WJ in 65; FR in 85-86,88-90,93
FR=DNR	French River Crew=MNDNR	MN-1	SBW	Sucker Bay West	1302	FR in 85-89,91-93; DNR in 94
FR=DNR	French River Crew=MNDNR	MN-1	SEP	Superior Entry Pocket	1401	FR in 85
GT	George Torgerson	MN-1	SKR	South of Knife River	1303	GT in 65-67
FR=DNR	French River Crew=MNDNR	MN-1	SPT	Stoney Point = STP	1303	FR in 87
WJ	Walford Johnson	MN-1	SRB	Sucker River Bay = SBW	1302	WJ in 66; FR in 84
JM	John Myrdal	MN-1	SSP	Stoney Point South=STP	1303	JM in 68
FR=DNR	French River Crew=MNDNR	MN-1	STH	South Two Harbors = STP	1204	FR in 93
FR=DNR	French River Crew=MNDNR	MN-1	STP	Stoney Point	1303	FR in 82,88-93; DNR in 94-95
FR=DNR	French River Crew=MNDNR	MN-1	THB	Two Harbors	1204	FR in 86-89,91-93; DNR in 94
FR=DNR	French River Crew=MNDNR	MN-1	THW	Two Harbors West = WTH	1204	FR in 90-91; DNR in 95
FR=DNR	French River Crew=MNDNR	MN-1	WTH	West of Two Harbors	1204	FR in 92-93; DNR in 95
FR=DNR	French River Crew=MNDNR	MN-1	WTS	Witch Tree South = WTH	1204	FR in 87

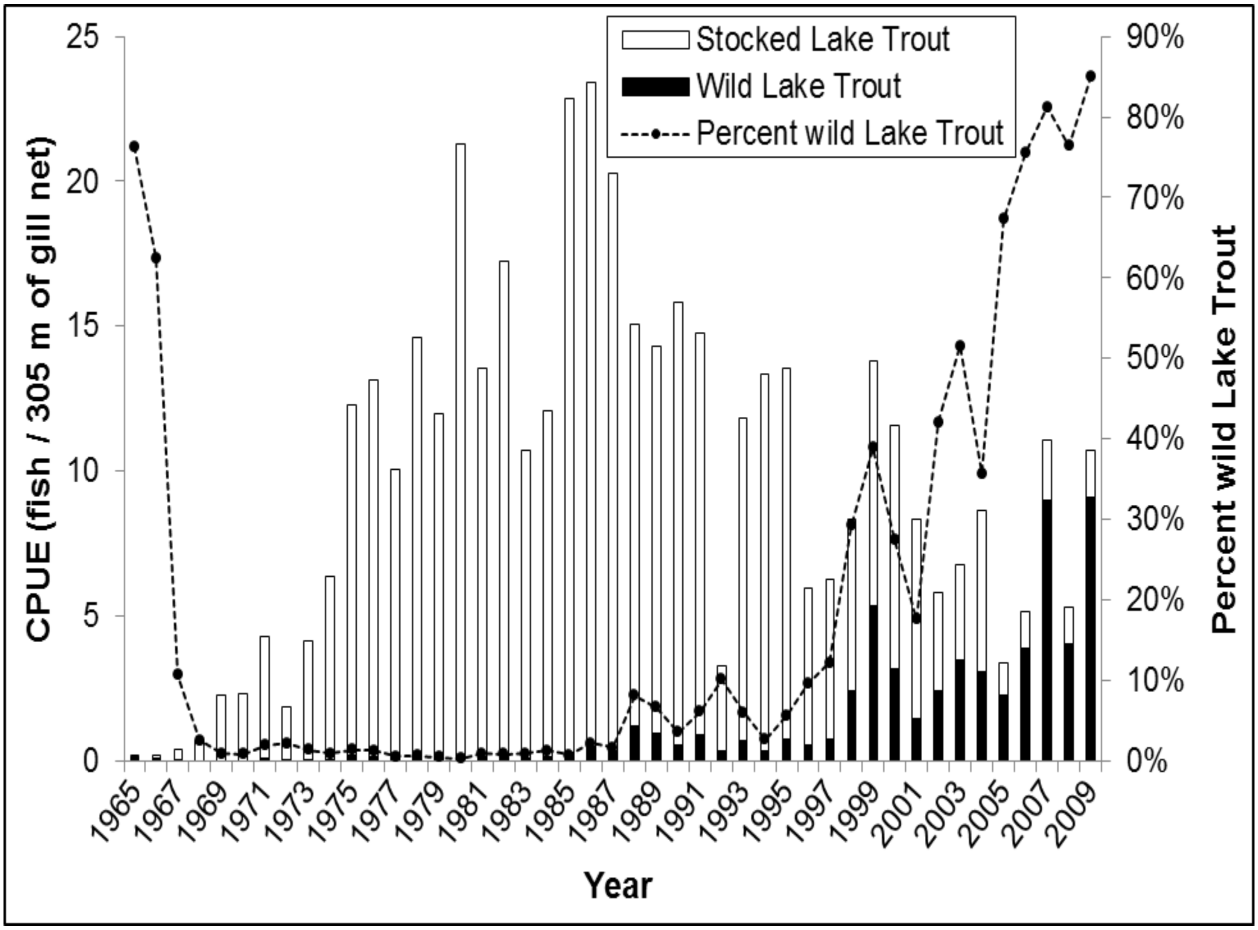
Appendix 6 (6-1 through 6-7). The following figures in Appendix 6 depict CPUE information from the various Lake Trout assessments conducted in Minnesota. The figures in Appendix 6 are similar to the figures depicting CPUE in the main body of the report; however CPUE in Appendix 6 has been calculated using the geometric mean rather than the direct method of determining CPUE (see Abundance Indices sub-section in the Large Mesh Assessment section). The geometric mean calculation is the standard protocol adopted by the LSTC (Ebener 2001), but most of the earlier reports produced by MNDNR have used the direct method to calculate CPUE, which the public has long been accustomed to viewing; therefore we include both methods in this report.



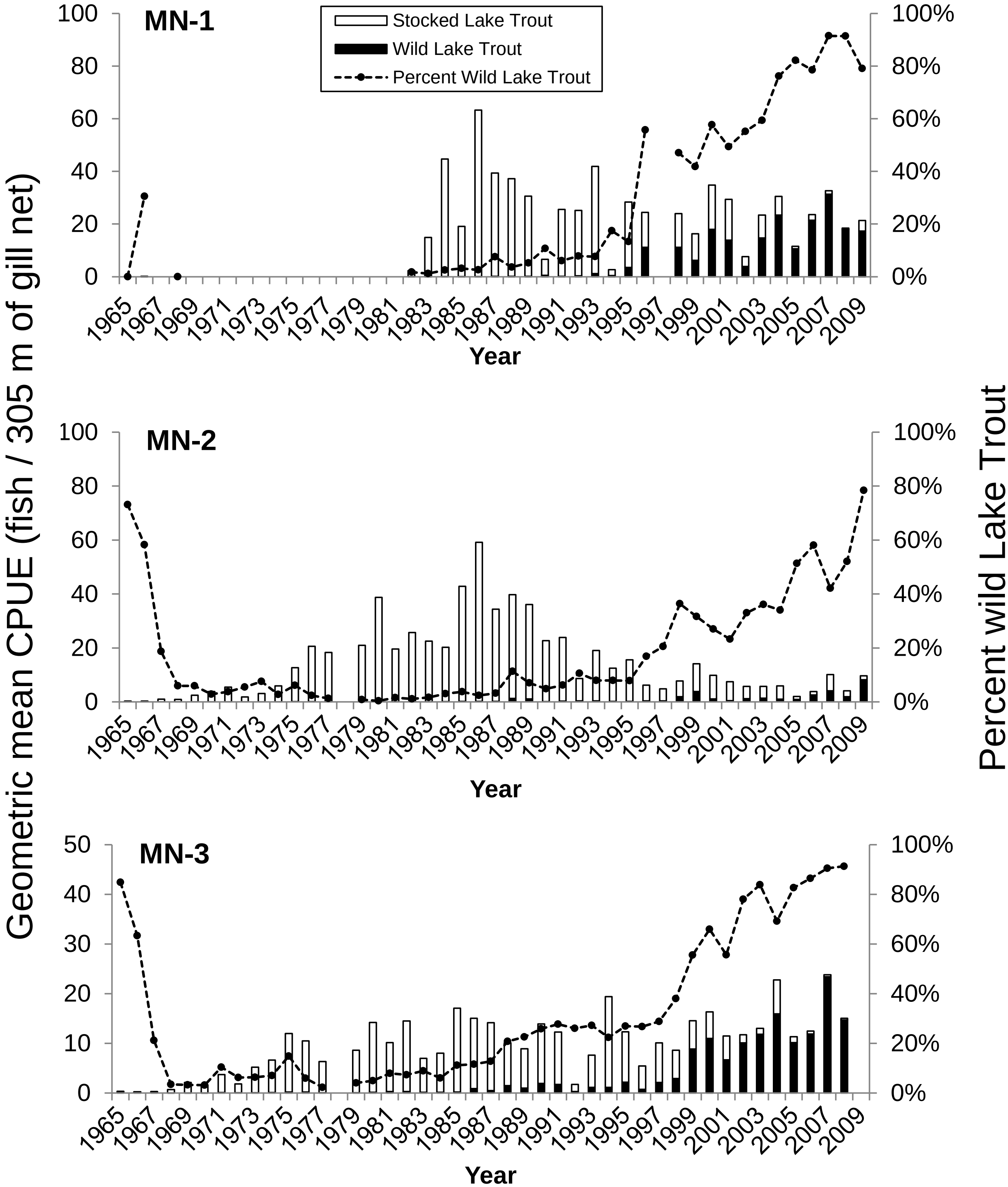
Appendix 6-1. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout shorewide in spring assessment surveys from 1965-2013. No spring assessment surveys were conducted in MN-1 from 1970-1981.



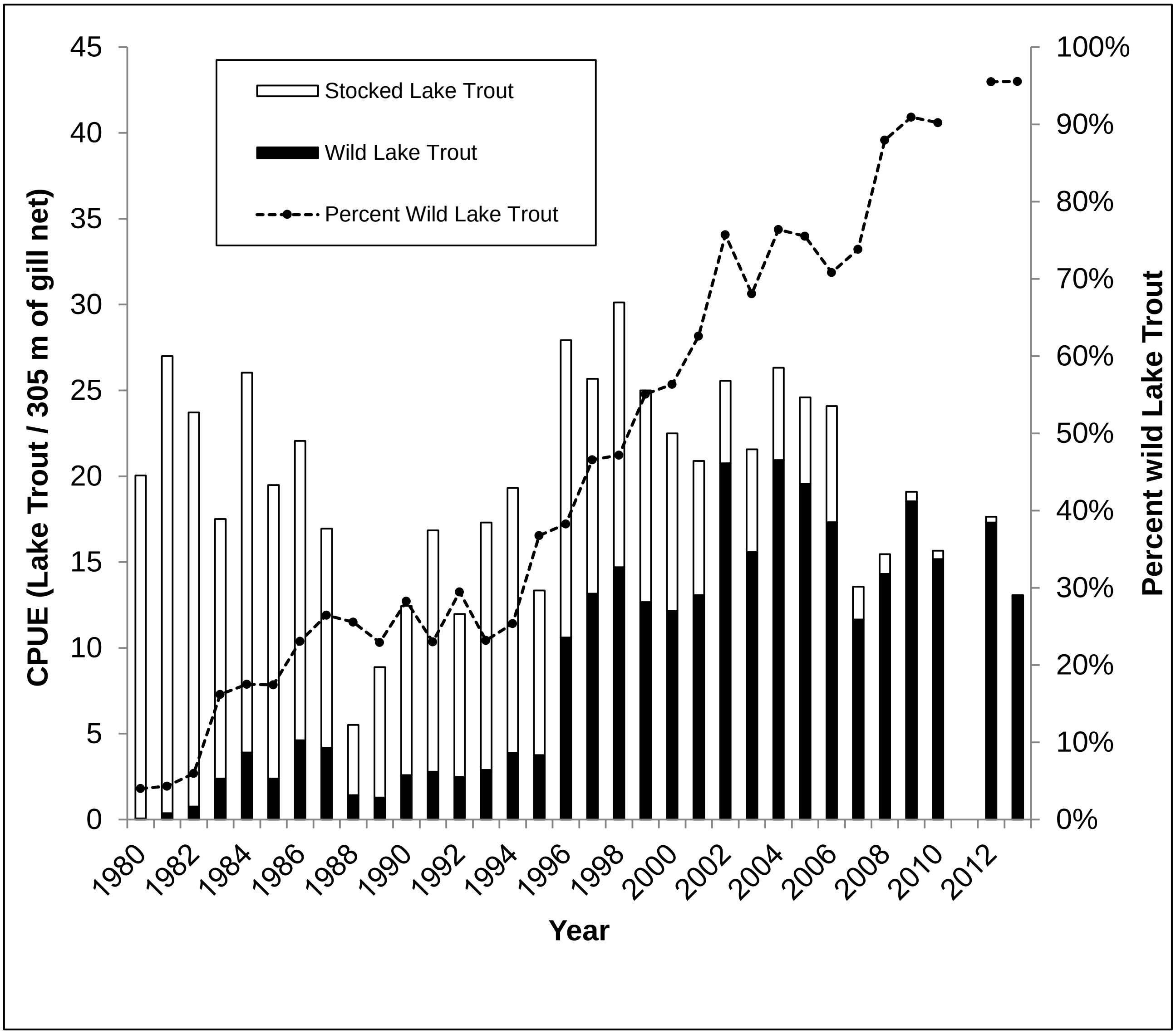
Appendix 6-2. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) gill net) of stocked by management zone in the spring assessment surveys from 1965-2013.



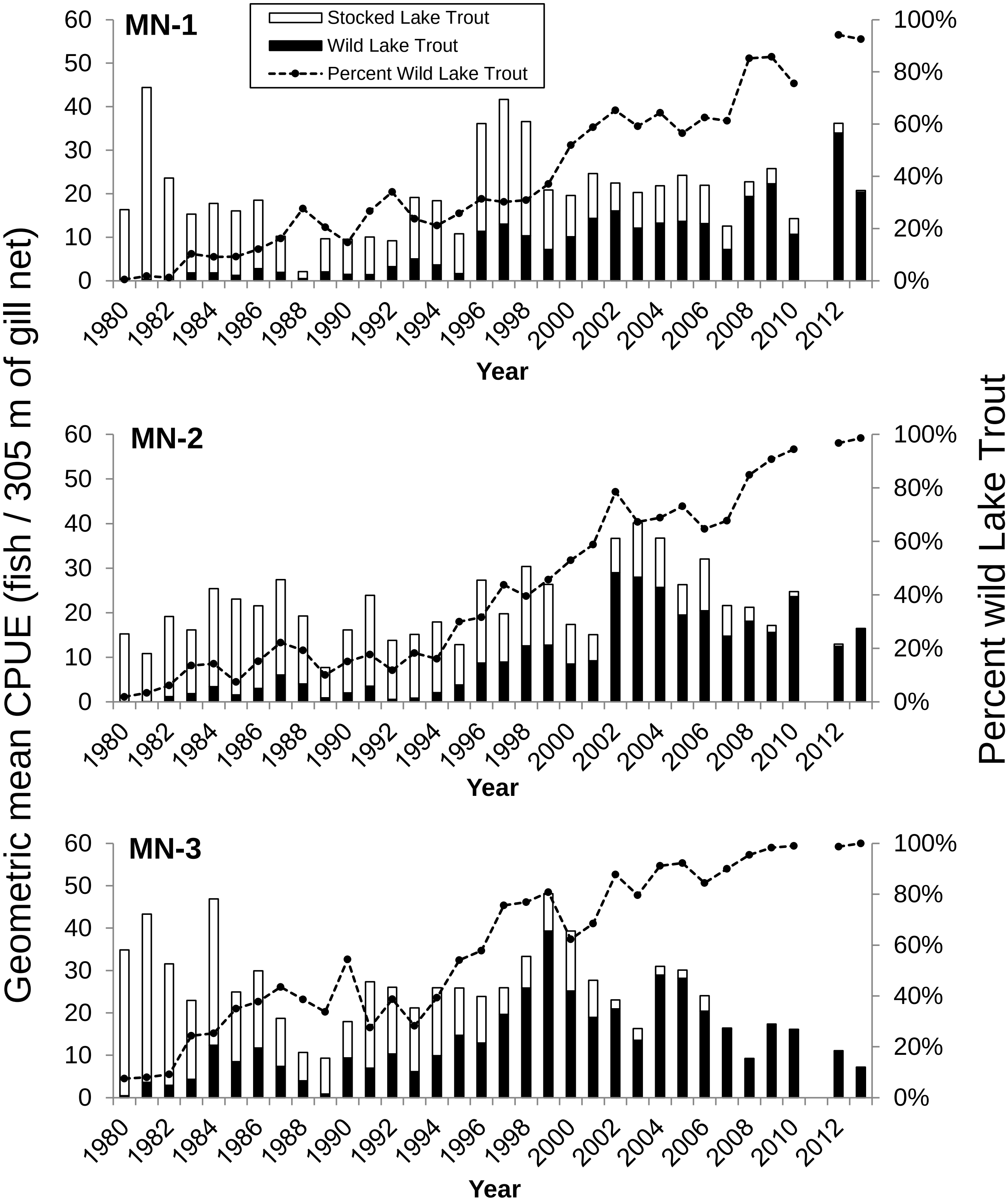
Appendix 6-3. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout shorewide in fall assessment surveys from 1965-2009. No fall assessment surveys were reported for MN-1 from 1965-1981 and in MN-3 the fall assessment was discontinued in 2009**.**



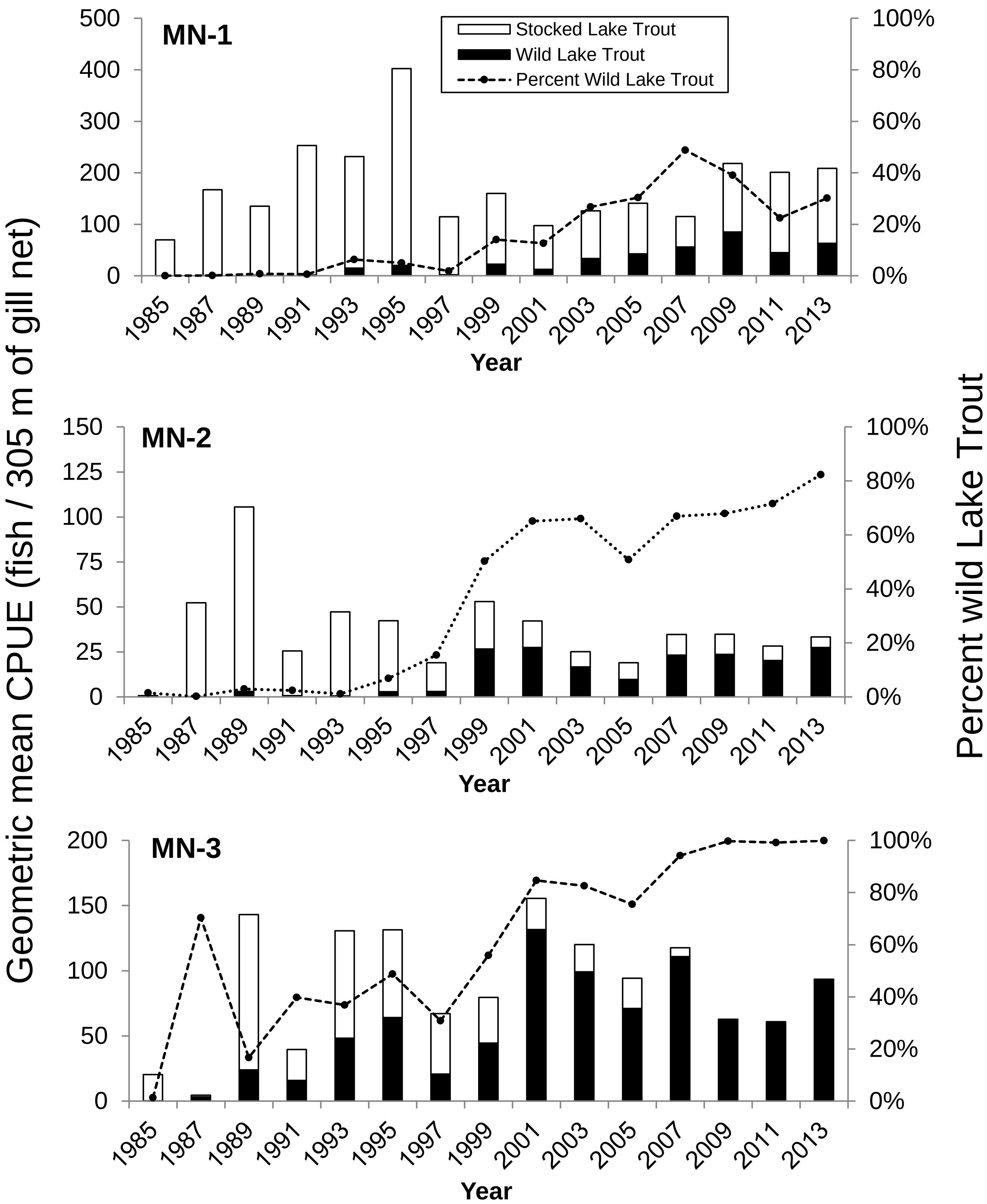
Appendix 6-4. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild Lake Trout by management zone in fall assessment surveys from 1965-2009. No fall assessment surveys were reported for MN-1 from 1965-1981 and in MN-3 the fall assessment was discontinued in 2009.



Appendix 6-5. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) of gill net) of stocked and wild juvenile Lake Trout (< 43cm (17 in)) in small mesh assessment surveys for all of Minnesota waters, 1980-2013. Small mesh assessments prior to 1980 are not yet available in electronic format, and the 2011 survey was not conducted due to a State of Minnesota government shutdown.



Appendix 6-6. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) gill net) of stocked and wild juvenile Lake Trout (< 43cm (17 in)) in small mesh assessment surveys by management zone, 1980-2013. Small mesh assessments prior to 1980 are not yet available in electronic format, and the 2011 survey was not conducted due to a State of Minnesota government shutdown.



Appendix 6-7. Percent wild and geometric mean CPUE (number of fish/305 m (1,000 ft) gill net) of stocked and wild Lake Trout in spawning assessment surveys by management zone, 1985-2013. Spawning assessments are conducted in odd numbered years.