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Chinook Salmon Management in the Minnesota Waters of Lake Superior, 1974-2014

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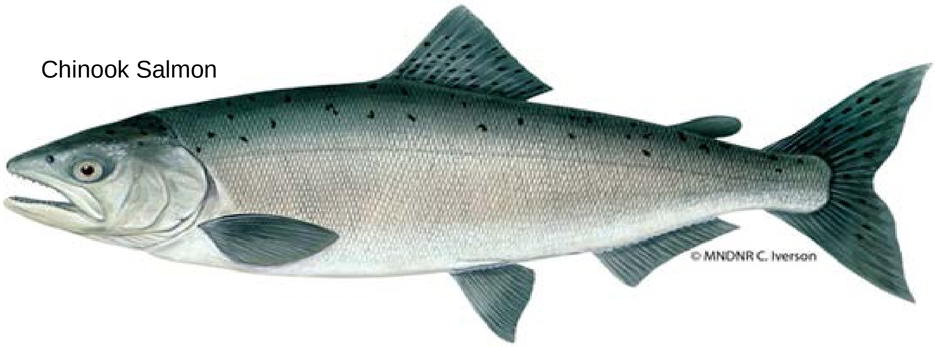

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Abstract

Pacific Salmon were successfully introduced into the Great Lakes in the mid-1960s when the Michigan Department of Natural Resources (MIDNR) established Chinook Salmon *Oncorhynchus tshawytscha* and Coho Salmon *Oncorhynchus kisutch* populations in Lake Michigan. MIDNR introduced Pacific Salmon to diversify the recreational sport fishery after the collapse of Lake Trout *Salvelinus namaycush*, and to attempt control of the non-indigenous Alewife *Alosa pseudoharengus* which had become both a social and ecological concern. Based on the early success of Chinook Salmon introductions in Lake Michigan and on the enthusiastic support of sport anglers, MIDNR introduced Chinook Salmon to Lake Superior in 1967. The Minnesota Department of Natural Resources (MNDNR) soon started a similar program in 1974 to diversify the sport fishery as Lake Trout stocks recovered, utilize the expanding Rainbow Smelt *Osmerus mordax* forage base, provide a fall stream fishery, and develop a feral broodstock (egg source). The program was initially successful, and by the mid-1980s high angler catches were reported in the summer and fall sport fisheries. A feral (self-sustaining) broodstock was also established from returns to the French River trap. However, by the mid-1990s, the survival of hatchery-reared Chinook Salmon began a decline which became so severe that the number of mature Chinook Salmon captured in the French River trap could no longer support a viable hatchery program. Two studies were conducted to investigate the extent of the decline in hatchery-reared Chinook Salmon. The first study was a lake-wide stocking evaluation in which fisheries management agencies that stocked Chinook Salmon applied agency-specific fin clips to each fish prior to stocking into Lake Superior from 1988-1990. The objectives of this study were to evaluate the contribution of hatchery-reared Chinook Salmon to the sport fishery, determine the extent of natural reproduction, and monitor the movement of stocked Chinook Salmon among jurisdictions in Lake Superior. The second study was similar in design to the lake-wide study, but was only conducted by the MNDNR to evaluate the contribution and percent return of marked fish stocked from 1999-2002 in Minnesota's portion of Lake Superior. The results indicated that the contribution of stocked fish to the summer creel survey had declined approximately 7-fold over the ten year period between studies, with wild fish contributing over 95% to the summer harvest in the Minnesota study. Catch of stocked Chinook Salmon in the fall fishery and the French River trap also declined. After four years of an intensive experimental stocking program using Chinook Salmon gametes from Lake Huron, returns of feral broodstock to the French River trap remained so low that a Chinook Salmon hatchery program could not be sustained, and stocking was discontinued in 2007. After stocking was discontinued, Minnesota anglers experienced some of the highest harvest and harvest rates for Chinook Salmon in the summer and charter fishery on record. Natural reproduction now largely supports the Chinook Salmon fishery in Lake Superior, with most of the fish harvested in Minnesota being produced in the larger rivers of other jurisdictions. Maintenance of the Chinook Salmon fishery is desirable to provide diverse opportunities for Lake Superior anglers. Future trends in climate change and population dynamics of the prey fish community in Lake Superior will have a large influence on Chinook Salmon stocks. This report summarizes the management actions and results of the Chinook Salmon program in Minnesota from 1974-2014.

Introduction

Chinook Salmon *Oncorhynchus tshawytscha* is an anadromous fish native to the North Pacific Ocean. It is the largest species of Pacific Salmon and is also commonly called King Salmon. Chinook Salmon are highly prized and sought after by sport anglers for their large size and fighting ability. Historically, the native distribution ranged from California to Alaska in the eastern Pacific, and from northern Japan to the south Arctic Ocean in the western Pacific (Scott and Crossman 1973). Due to commercial overfishing, construction of dams on major spawning tributaries, and other habitat alterations, many North American populations of Chinook Salmon are now listed as endangered, and restoration programs have been established in an attempt to rehabilitate these stocks in the Pacific Northwest.

Chinook Salmon have been introduced to many parts of the world to develop both commercial and sport fisheries. Successful commercial introductions of Chinook Salmon have occurred in New Zealand and Chile where ocean farming supports large commercial aquaculture operations, with approximately 95% of world commercial Chinook Salmon produced in New Zealand and 5% in Chile (FAO 2012). Chinook Salmon were first introduced to the Great Lakes in 1873, with small intermittent stocking events occurring until about the mid-1920s. None of these events were known to be successful (Scott and Crossman 1973).

Introduction of Pacific Salmon into the Great Lakes was again attempted in the mid-1960s, when the Michigan Department of Natural Resources (MIDNR) successfully established both Chinook and Coho Salmon *Oncorhynchus kisutch* populations in Lake Michigan. The goals of the Pacific Salmon introductions were to diversify the recreational sport fishery after the collapse of Lake Trout *Salvelinus namaycush*, and attempt to control the non-indigenous Alewife *Alosa pseudoharengus* which had become both a social and ecological concern (Tanner and Tody 2002). The success of the Pacific Salmon fishery that followed these early introductions by MIDNR is well documented (Tanner and Tody 2002; Kocik and Jones 1999; Bence and Smith 1999; Hansen and Holey 2002) and has been described as an example of a resource miracle (Gale 1987). Sport anglers urged other Great Lakes states and the province of Ontario to also stock Pacific Salmon in their waters to diversify the sport fishery. By the mid-1970s, each of the Great Lakes had established stocking programs for Pacific Salmon, and by the mid-1980s, angler expectations for this exciting fishery were rising to extremely high levels (Goddard 2002; Claramunt et al. 2013).

Based on the early success of Chinook Salmon introductions in Lake Michigan, and the enthusiastic support of sport anglers, the Minnesota Department of Natural Resources (MNDNR) introduced Chinook Salmon into Lake Superior with the following objectives: 1) efficiently utilize Lake Superior's expanding forage base of Rainbow Smelt *Osmerus mordax*; 2) provide a sport fish that would attain a size comparable to Lake Trout, but within a shorter time period; 3) provide a species that returned to spawn at times and locations that facilitated maximum angler opportunity for harvest; 4) develop a self-sustaining broodstock (egg source); and 5) allow for optimum control over abundance (Close et al. 1984). This report is a summary of the management actions and results of the Chinook Salmon program in Minnesota from 1974-2014. The objectives for this report are to: 1) describe the general life history characteristics of Chinook Salmon in the Great Lakes, 2) provide a brief overview of Chinook Salmon management in Lake Superior, 3) summarize the management actions taken to provide a Chinook Salmon fishery in Minnesota, 4) report on the results of the Minnesota Chinook Salmon program, 5) discuss why the Chinook Salmon stocking program was discontinued, and 6) examine the potential future for Chinook Salmon in Lake Superior.

Life History of Chinook Salmon in the Great Lakes

Chinook Salmon, like other Pacific Salmon introduced into the Great Lakes, have a complex life history where they spend the early stages of their life in streams, the adult portion of their life in the lake, and then return to their natal stream to spawn once and die. In ocean systems the migration behavior of Chinook Salmon crosses a saline-freshwater boundary and is referred to as anadromous. The term potamodromous is used to define this migration behavior in freshwater systems such as the Great Lakes. Most adult Chinook Salmon in the Great Lakes enter streams from late August through October to spawn, with egg deposition occurring from late September to early November (Kocik and Jones 1999). The eggs are deposited in gravel nests called redds, which are excavated by the female. Fertilization takes place when one or more males mate with the female and broadcast their sperm as the eggs are released into redds. Eggs normally hatch during late winter (February - March), and when yolk sacs are depleted, fry emerge from late March through May. The young Chinook Salmon, referred to as parr, grow rapidly when feeding begins, and reach about 3 inches in length by June–July. At that time they may begin “smolting” (the physiological transformation that originally acclimated them to salt water), change color to bright silver and begin their migration to the lake. Unlike Coho Salmon, Steelhead *Oncorhynchus mykiss* and Atlantic Salmon *Salmo salar* which spend one to two years in the stream, Chinook Salmon only spend about 9 months in their natal stream (including the egg stage). The abbreviated period of stream residency protects them from having to spend the warmest summer months in the stream, likely increasing survival to the smolt stage. However, when they migrate to the lake, their relatively small size makes them much more vulnerable to predation in the lake than the other salmonid species that spend a longer period in the stream and grow larger. This trade-off may be positive or negative depending on the annual environmental conditions and predator abundance in each of the Great Lakes.

Chinook Salmon smolts may inhabit the near-shore zone for a few weeks after entering the lake, especially where adequate cover, food, and preferred water temperatures are available. From July through September young Chinook Salmon in the lake can range in size from 6 inches to 13 inches and are normally found near the surface in water depths of less than 100 feet. Diet analysis indicates that terrestrial insects, aquatic invertebrates and very young fish are all principal food items. By late fall, young-of-year Alewives in the lower lakes, juvenile Rainbow Smelt, and Cisco *Coregonus artedi* in Lake Superior are major diet items and the adults of each prey species remain so as the Chinook Salmon mature. Upon sexual maturation, normally from age-3 to age-5, mature adults return to tributaries in the fall where they spawn and die, starting the life cycle anew (Kocik and Jones 1999) (Figure 1).

As the common name “King” Salmon implies, Chinook Salmon can grow to a very large size, from record weights of over 40 pounds in Lakes Michigan and Ontario to over 30 pounds in Lake Superior. However, average size more commonly ranges from 15-20 pounds in the lower lakes and from about 7-12 pounds in Lake Superior. Since the mid-2000s, as natural reproduction of Chinook Salmon has increased and Alewife and Rainbow Smelt abundances have declined, average size of Chinook Salmon has also declined, especially in Lake Huron (Johnson and Gonder 2012) and Lake Superior where mature fish are now routinely in the 4-8 pound range (Negus et al. 2008).

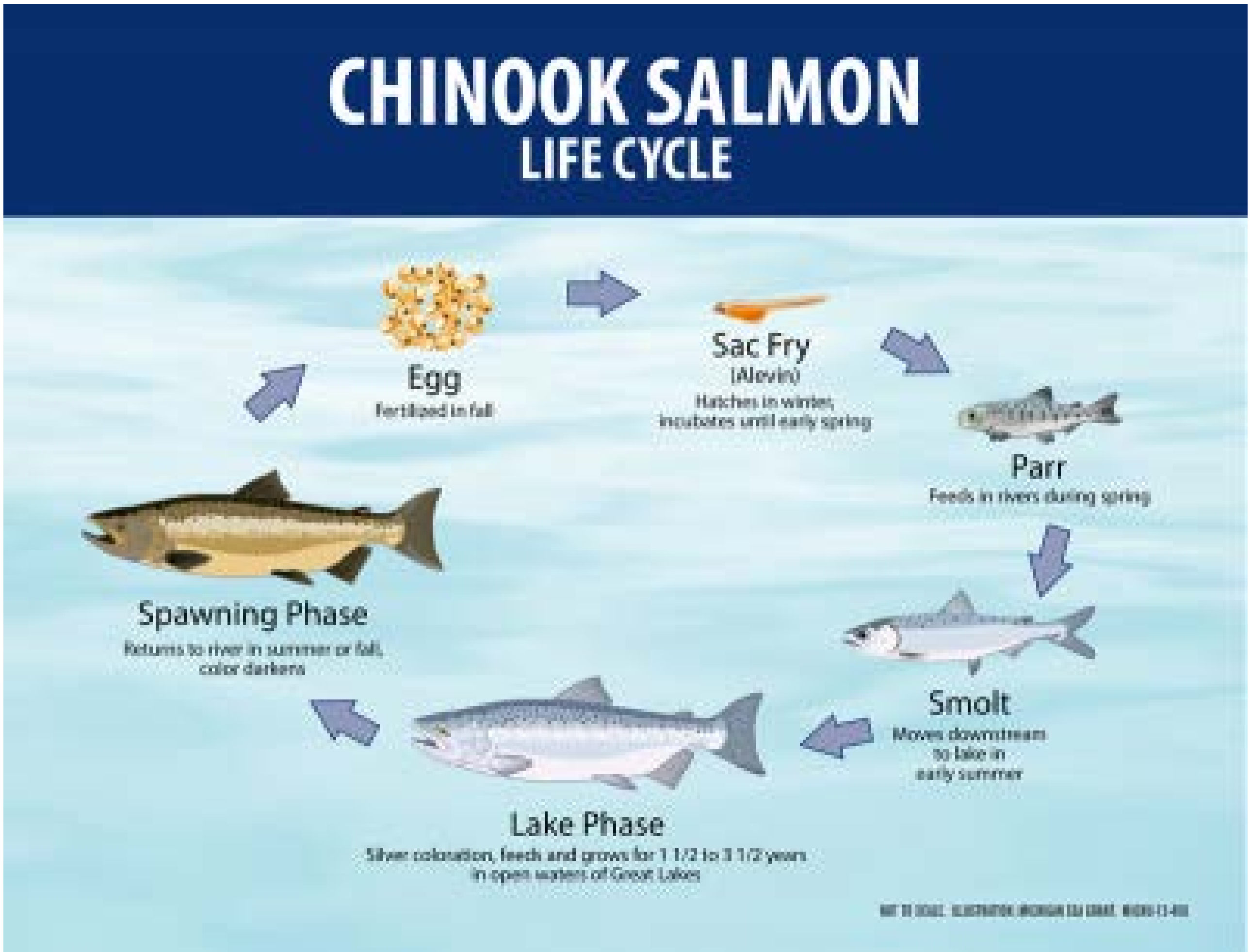

FIGURE 1. Life cycle of Chinook Salmon.

Overview of Chinook Salmon in Lake Superior

A Chinook Salmon program was established in Lake Superior based on the successful Chinook Salmon fishery created in Lake Michigan and strong support from sport anglers. Lake Superior fishery management agencies were interested in establishing a Pacific Salmon program because they wanted to diversify the sport fishery after the decline in Lake Trout, and attempt to control the greatly expanding non-indigenous Rainbow Smelt population that had become established in Lake Superior by the early 1950s. When Chinook Salmon eggs became readily available from Lake Michigan, the MIDNR began stocking Chinook Salmon in Lake Superior in 1967. The MNDNR followed their lead in 1974, the Wisconsin Department of Natural Resources (WIDNR) in 1977, and the Ontario Ministry of Natural Resources (OMNR) in 1988. All agencies predominately stocked fingerlings in the spring, and by the early 1980s a significant sport fishery for Chinook Salmon had developed (Peck et al. 1994; Bronte et al. 2003; Schreiner et al. 2010). Fishery management agencies also mistakenly assumed that if there was a desire to discontinue the Chinook Salmon program at some point in the future, they could simply eliminate stocking, and after a few years Chinook Salmon would no longer be present. However, by the early 1990s, Chinook Salmon had clearly become naturalized in Lake Superior, and populations were largely supported by natural reproduction (Peck et al. 1999).

Natural reproduction was first noted beginning in the mid-1980s, and since the early 1990s, the number of stocked Chinook Salmon in Lake Superior had declined; while the number of Chinook Salmon caught in the summer fishery remained relatively stable (Schreiner et al. 2016). A coordinated lake-wide study of the Chinook Salmon sport fishery from 1990-1994 found that over 75% of the Chinook Salmon harvested were naturally reproduced (Peck et al. 1999). In that study, stocked Chinook Salmon contributed 57% of the summer angler harvest in Minnesota, 32% in Wisconsin, 25% in Michigan, and 9% in Ontario. Chinook Salmon stocked in each jurisdiction contributed to the fisheries in all other jurisdictions, indicating that Chinook Salmon moved considerable distances and ranged widely from stocking sites during the summer angling season.

A similar, but more recent study to monitor the contribution of stocked Chinook Salmon was conducted by the MNDNR from 2000-2006. It showed that the contribution of Chinook Salmon stocked in the Minnesota waters of Lake Superior had declined to less than 5% of the Chinook Salmon harvested in the Minnesota summer sport fishery (Schreiner et al. 2006). In a similar finding, the OMNR documented that the contribution of stocked Chinook Salmon to the annual salmon fishing derbies in Thunder Bay, Ontario had also declined to only 0.6% on average from 2005–2012 (Eric Berglund, OMNR, Personal communication). These studies suggested that naturally reproduced Chinook Salmon made up a majority of the angler harvest, and in Lake Superior, returns of stocked fish were minimal and possibly too low to justify further stocking. Based on the contribution of wild fish, the need for continued stocking was questioned by each of the management agencies and many of the sport anglers. In response to the limited contribution of hatchery-reared fish, Chinook salmon stocking programs were discontinued in Minnesota in 2007, and Wisconsin in 2008, while both Ontario and Michigan reduced the number of Chinook Salmon stocked, and are discussing discontinuation of their Chinook Salmon stocking with constituents.

The remainder of this report focuses on the Minnesota Chinook Salmon program and will:1) summarize the actions undertaken to manage the Chinook Salmon fishery in Minnesota's portion of Lake Superior, 2) provide a description of the public input process and data used to support discontinuation of the stocking program in 2007, and 3) discuss the continued success of the Chinook Salmon fishery after discontinuation of the stocking program.

Management Actions

Stocking

Hatchery Program - Three strains of Chinook Salmon from the Pacific Northwest are routinely recognized and generally referred to as spring, summer and fall (Fulton 1968). The MNDNR originally decided that the spring strain would have the best chance of meeting the management objectives. The spring strain was stocked in 1974 and from 1976-1978. Eggs for the 1974 year class (YC) were obtained from the Rapid River Hatchery in Idaho and for the 1976-1978 year classes from the Cowlitz Hatchery in Washington (Close et al. 1984). In 1979, disease-free spring strain eggs were no longer available from the western hatcheries, so fall strain eggs were obtained from the Little Manistee River in Lake Michigan. The original source of the fall strain Chinook Salmon stocked into the Upper Great Lakes was Toutle River, Washington (Colvin and Close 1985). From 1979-1983, fall strain Chinook Salmon from the Little Manistee River in Lake Michigan were used by MNDNR until enough mature Chinook Salmon returned to the French River trap to provide eggs for a self-sustaining program that began in 1984.

All Chinook Salmon for the Minnesota program were reared at the French River Cold Water Hatchery (FRCWH). Most were reared to fingerling size before stocking, but in some years a small number of Chinook Salmon were stocked as fry for special projects. The discovery of Bacterial Kidney Disease (BKD) in Chinook Salmon from Lake Michigan alerted the FRCWH staff to investigate incidence of BKD in fish taken from the French River trap. Starting in 1990, paired spawning and a detection method for BKD, called ELISA, were used to examine all Chinook Salmon used for gamete collection taken from the French River trap. Only eggs that were BKD-free were used for production in the FRCWH (Schreiner 1995).

Enough eggs were collected at the French River trap to sustain the Chinook Salmon stocking program from 1984 through the late 1990s. However, when survival of hatchery-reared Chinook Salmon begin to decline, there were no longer enough mature Chinook Salmon returning to the French River trap to meet the established quota of 500,000 fingerlings (Schreiner 1995). From 1998-2002, eggs taken from Chinook Salmon captured at the Swan River Weir in Lake Huron were transferred to the FRCWH for rearing in an attempt to continue the stocking program and bolster the future spawning run. Providing Chinook Salmon gametes from outside the Lake Superior basin was an attempt to determine if the Minnesota strain of Chinook Salmon was inferior to other Great Lakes strains, as some anglers claimed, or if survival of any hatchery-reared Chinook Salmon strain was now limited in Lake Superior because Chinook Salmon had become naturalized, and other changes had also occurred in the Lake Superior fish community.

Criteria were established to determine if a Chinook Salmon stocking program should continue in Minnesota based on the results of stocking the Lake Huron strain. Survival of hatchery-reared Lake Huron strain Chinook Salmon was also very poor, and not enough mature fish returned to support a viable Chinook Salmon stocking program at the FRCWH. In 2006, the last Chinook Salmon were stocked from the FRCWH, because the feral broodstock collected at the French River trap could no longer support a viable hatchery program, and criteria to discontinue the stocking program were met (Schreiner et al. 2006).

Stocking Locations, Numbers, and Size - Four rivers were chosen as major stocking sites to establish a Chinook Salmon fishery in Minnesota (Figure 2). These included the French, Baptism, and Cascade rivers, which were initially stocked with fingerlings in 1974, and the Lester River, which was first stocked in 1980 (Table 1; Figure 3; Appendix 1). Five smaller streams were also stocked intermittently with Chinook Salmon for special projects or as experimental introductions, and the Lester, Baptism and Cascade were stocked with small amounts of fry in a few years (Appendix 2). The desired target size of hatchery-reared fingerlings was 100/pound, or an average size of about 3 inches during the early years of the stocking program. From 1996-1998, an experiment was conducted to determine if survival was positively correlated with fingerling size. This was possible because there were fewer Chinook Salmon being reared in the hatchery and extra rearing space was available. In 1996 and 1997, Chinook Salmon from larger fingerlings returned at a greater rate than those from the smaller fingerlings, but in 1998, return rates were similar between sizes (Figure 4). Following analysis of this experiment, attempts were made to increase survival by rearing fingerlings to a slightly larger size in years when extra rearing space in the hatchery was available (Appendix 1). In spite of this effort, survival of stocked Chinook Salmon continued to decline.

Cost of Stocked Fish - The life cycle of Chinook Salmon makes this species one of the least costly salmonids to produce in the hatchery. Because Chinook Salmon smolt and migrate to the lake as fingerlings, they are only reared in the hatchery for approximately 8 months. The first half of that period the Chinook Salmon are eggs or sac-fry, so they are only fed for about 4 months before they are stocked in June-July. Reported cost estimates only include production costs and do not include the cost of hatchery depreciation, disease testing, gamete collection, or stocking, so the cost estimates are conservative. Over the life of the Chinook Salmon program, the cost to produce an individual stocked fish increased due to inflation, changes in hatchery practices, total number of fish produced and attempts to increase survival by rearing fingerlings to a slightly larger size before stocking. Production costs per Chinook Salmon stocked have been estimated for three time periods over the life of the Chinook Salmon program. Production costs increased from $0.19/fish in 1976-1982 (Close et al. 1984) to $0.25/fish in 1988-1992 (Schreiner 1995) to $0.30/fish in 1999-2003 (Schreiner et al. 2006), an increase of approximately 15-20% over a 10 year period and 35-40% over a 20 year period.

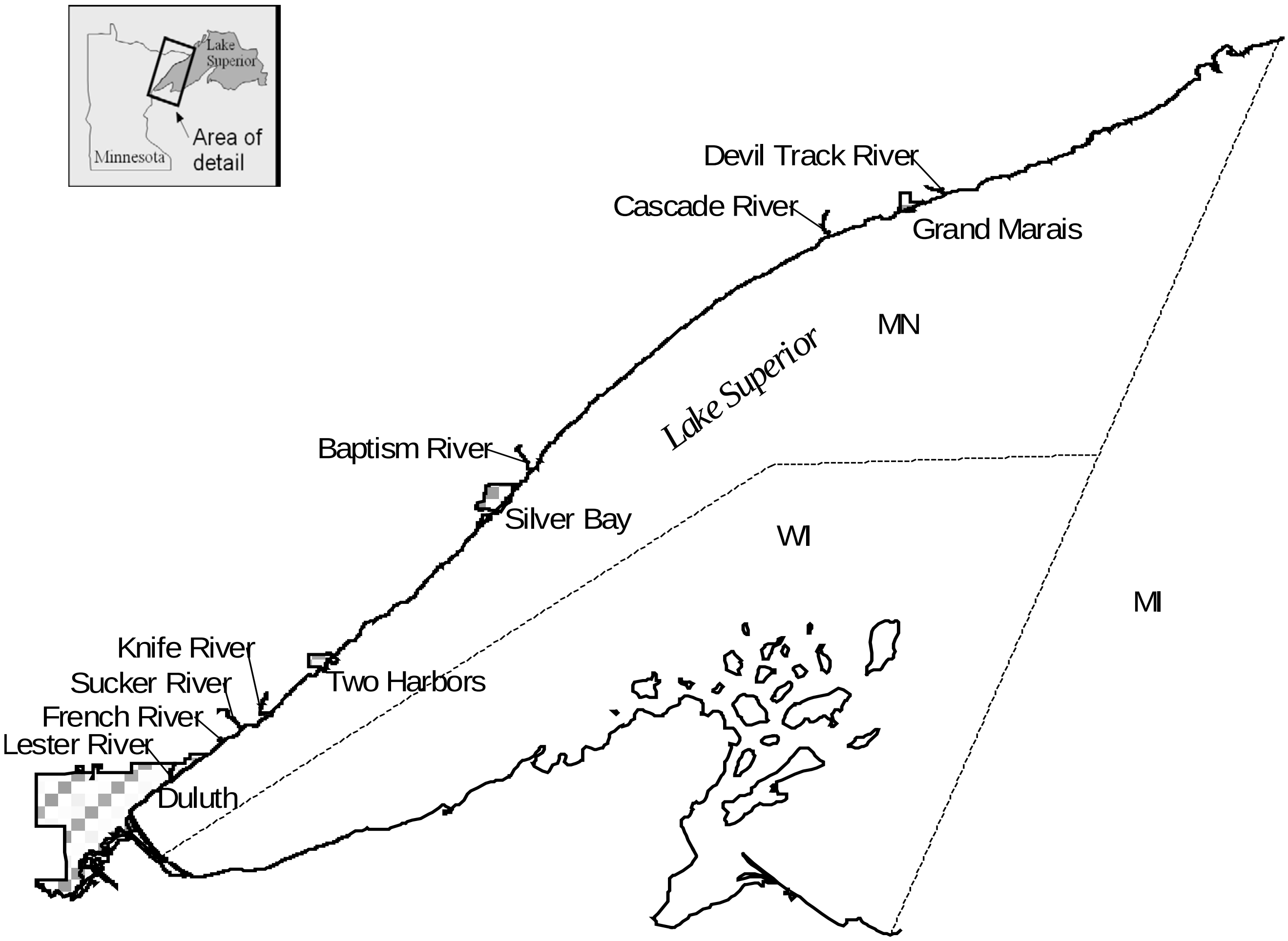

FIGURE 2. Map including four major rivers stocked with Chinook Salmon (Lester, French, Baptism, Cascade) and seven rivers sampled in the Lake Superior fall creel survey.

TABLE 1. Chinook Salmon fingerlings stocked in four major Minnesota tributaries to Lake Superior, 1974-2006.

Year Stocked	Number stocked				
	French River	Lester River	Baptism River	Cascade River	Total
1974	83,505	0	60,599	71,900	216,004
1975	0	0	0	0	0
1976	86,600	0	86,600	86,600	259,800
1977	40,573	0	0	11,000	51,573
1978	58,925	0	43,333	44,455	146,713
1979	72,246	0	73,410	48,357	194,013
1980	46,795	47,530	0	60,025	154,350
1981	86,844	57,240	154,759	113,560	412,403
1982	78,560	79,376	141,777	66,555	366,268
1983	100,102	75,668	95,160	104,710	375,640
1984	130,179	0[a]	100,079	101,866	332,124
1985	103,632	0[a]	107,193	112,256	323,081
1986	100,928	205,825	108,100	111,683	526,536
1987	105,797	98,809	100,300	103,626	408,532
1988	119,108	100,234	110,508	50,285	380,135
1989	103,255	203,263	111,776	100,025	518,319
1990	115,333	180,798	102,634	100,284	499,049
1991	101,945	152,140	101,927	103,048	459,060
1992	109,020	37,461	44,820	45,652	236,953
1993	105,159	146,723	100,004	101,034	452,920
1994	111,092	150,075	100,209	100,033	461,409
1995	100,103	88,138	53,308	57,009	298,558
1996	100,966	0	0	0	100,966
1997	36,235	0	0	0	36,235
1998	21,922	0	0	0	21,922
1999	100,431	96,172	91,531	84,699	372,833
2000	100,012	85,012	85,072	84,985	355,081
2001	103,522	88,075	88,025	88,006	367,628
2002	100,166	85,153	85,089	90,261	360,669
2003	55,859	0	0	0	55,859
2004	14,259	0	0	0	14,259
2005	43,128	0	0	0	43,128
2006	15,675	0	0	0	15,675

[a] No Chinook Salmon fingerlings stocked in Lester River due to research project.

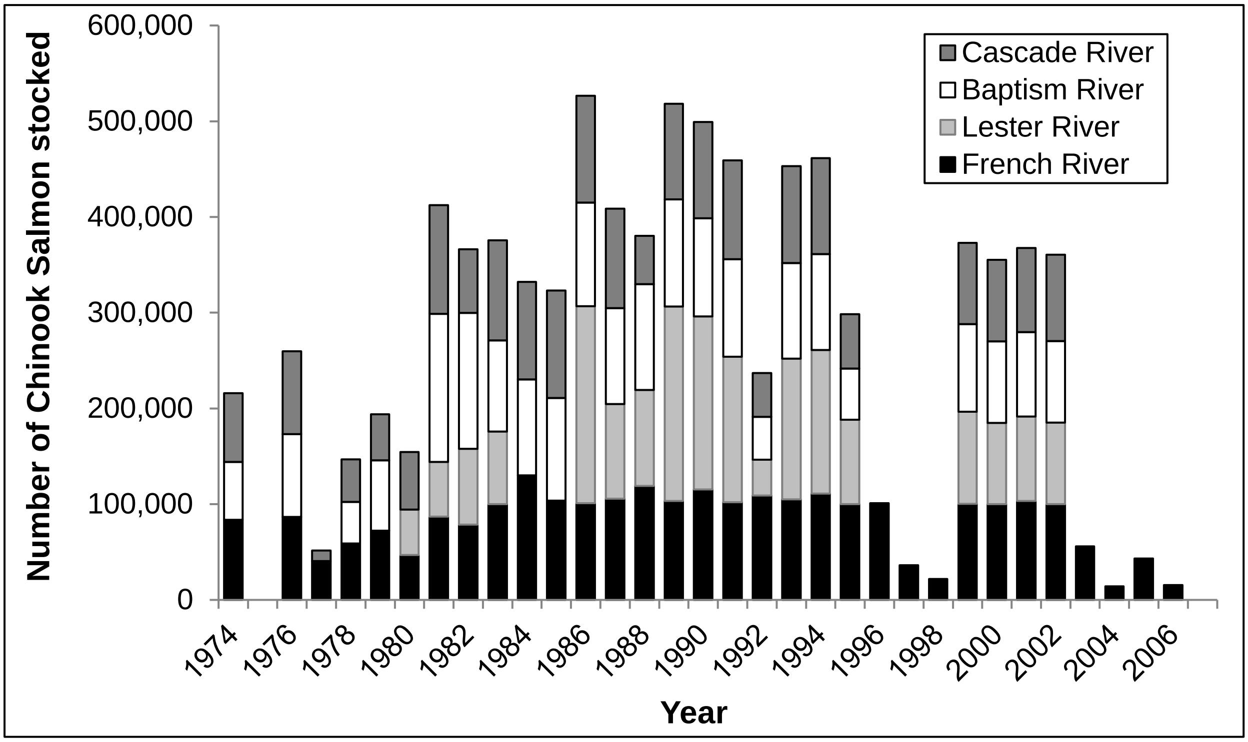

FIGURE 3. Chinook Salmon fingerlings stocked in four major Minnesota tributaries to Lake Superior, 1974-2006. Lake Huron strain Chinook Salmon were stocked from 1999-2002.

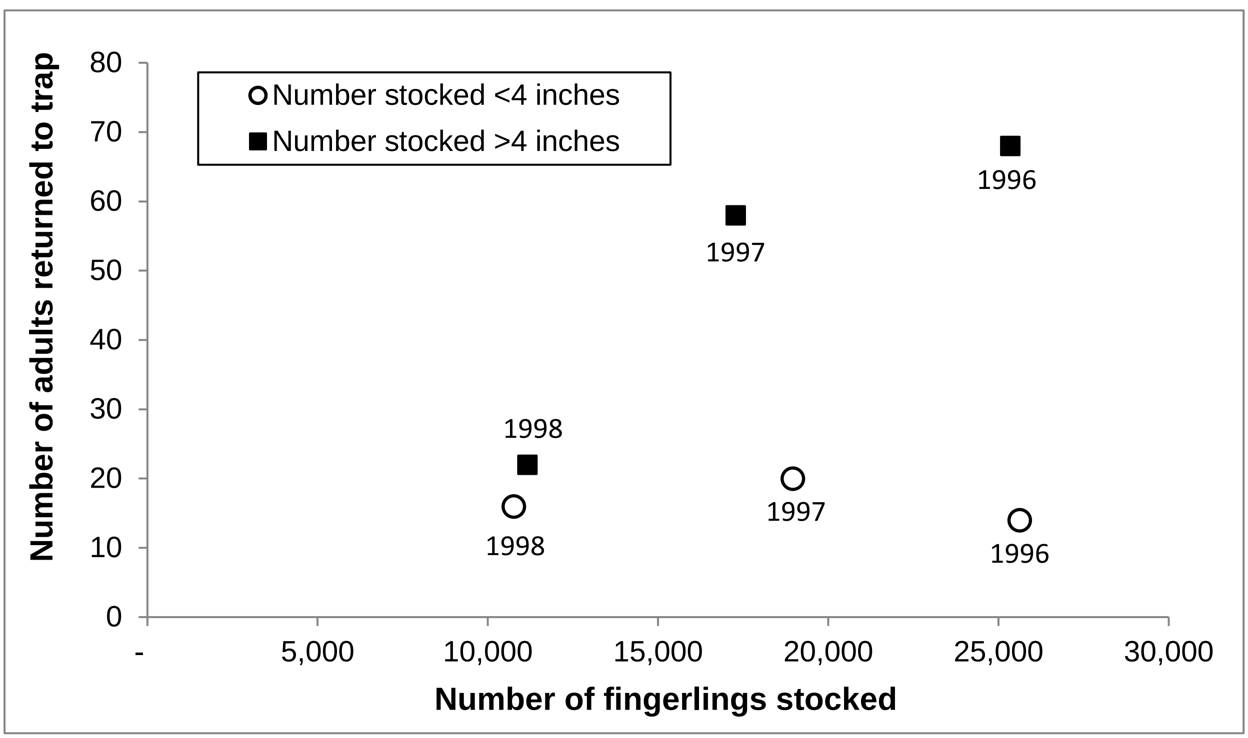

FIGURE 4. Return rates to the French River trap of Chinook Salmon stocked at different sizes, for the 1996-1998 year classes.

Regulations

When the Chinook Salmon program began in the mid-1970s, the possession limit for Salmon was set at 10 fish per angler in any combination of Coho, Chinook and Pink Salmon *Oncorhynchus gorbuscha* along with one Atlantic Salmon. There was no closed season, and a minimum size of 10 inches to protect recently stocked fish and wild smolts from harvest. The early regulations were very liberal because the fishery for Chinook and Coho Salmon was implemented to provide a put-grow-take fishery, while Pink Salmon were an accidental introduction that Lake Superior fish management agencies were not interested in protecting.

In 1998, Pacific Salmon regulations in Minnesota were changed to become more restrictive when it became evident that natural reproduction was supporting the majority of the Pacific Salmon fishery. To allow for adequate escapement of spawners, the possession limit for Salmon was decreased from 10 to 5, again in any combination with Chinook, Coho, Pink and one Atlantic Salmon. Although most anglers never harvested over five Chinook Salmon in the summer boat or fall stream fishery, there were times when many anglers harvested well over five Coho Salmon during the winter fishery, both from shore and through the ice. Because many anglers have difficulty distinguishing between Coho and Chinook Salmon, especially when Chinook Salmon are young, the regulation was applied to all Pacific Salmon. Although limited natural reproduction of Chinook and Coho Salmon occurs in Minnesota tributaries, protecting fish that spawn elsewhere is an appropriate management strategy because Minnesota anglers benefit greatly from Chinook Salmon that reproduce in other jurisdictions and contribute to the angler harvest in Minnesota. As of 2014 there were no plans to change angling regulations for Chinook Salmon in Minnesota.

Monitoring and Assessment

The status of Chinook Salmon in Minnesota's portion of Lake Superior were monitored using creel surveys, charter captain reports and returns to the French and Knife River traps. The traditional summer creel survey targeted the catch of Lake Trout and Pacific Salmon in the boat and shore fishery from Memorial weekend through September 30th (MNDNR Lake Superior Area files). Charter captain reports were also collected during the open water season. The fall creel surveys, conducted from October 1 to mid-November at seven sites (Figure 2), were established to monitor the shore and stream angler catch of Pacific Salmon, especially Chinook Salmon, during their fall spawning runs. The spring creel survey targeted angler harvest of Rainbow Trout (Steelhead and Kamloops) from shore and in streams during April and May, but recorded very few Chinook Salmon, generally less than five annually, and none in most years, so results from the spring creel survey will not be presented in this report. A winter creel survey was conducted at 3-5 sites along the lower shore in only three years: 1990, 1997 and 2001 (MNDNR Lake Superior Area files). Few Chinook Salmon were captured by anglers in the winter creel survey, but results were interesting and will be reported in the next section.

The French River trap served two roles in the Chinook Salmon program. One role was to monitor Chinook Salmon returns to a specific stocked stream, and the other was to provide gametes to sustain the Chinook Salmon hatchery program. The French River trap was also essential to collect biological information from individual fish, and assist in determining the cost:benefit of the Chinook program. The French River trap has been in operation since the mid-1970s and has een operated each spring through 2015 targeting Rainbow Trout. It was also operated each fall to monitor a variety of potamodromous salmonids through 2010, when fall monitoring was no longer required. Annual trap reports include detailed information on both the biology and behavior of many trout and salmon species that include Rainbow Trout, Brown Trout *Salmo trutta,* and Brook Trout *Salvelinus fontinalis*, along with Chinook, Coho, Pink and Atlantic Salmon (MNDNR Lake Superior and Duluth Area files). In 1994, a smolt trap was added to the adult trap on the French River (Dexter and Schliep 2007) making it an ideal experimental stream to test management alternatives on a variety of potamodromous species.

Results of the Program

Angler Harvest and Catch

As previously described, Chinook Salmon returns to the angler were monitored by four different creel surveys in Minnesota's portion of Lake Superior (spring, summer, fall and winter), because very few Chinook Salmon were caught in the spring creel no results from that survey will be reported on in this paper. The minimum harvest size for Chinook Salmon is 10 in, so anglers are required to release fish less than 10 in. Creel clerks reported that in some years a few anglers routinely practiced their fly fishing techniques on recently stocked Chinook Salmon yearlings. Therefore, in this report, all creel survey results are reported as either catch or harvest of legal sized fish.

Summer Creel Survey - Interviews in the summer creel survey were primarily with boat anglers, but some shore anglers were also interviewed at the busier shore fishing locations. Estimates of Chinook Salmon annual harvest in the summer creel survey ranged from 100-8,790, with a mean of 2,821 and a median of 2,302 from 1980-2014 (Table 2; Figure 5). It is noteworthy that some of the highest Chinook Salmon harvest and harvest rates occurred after 2006 when Minnesota-stocked fish made little or no contribution to the fishery. Chinook Salmon harvest rate from 1980-2014 in the summer creel ranged from a high of 0.053 fish per angler hour in 2012 to a low of less than 0.0001 fish per angler hour in 1980 (Table 2, Figure 5), with an overall average harvest rate of 0.016 fish per angler hour and a median of 0.011. The estimated fishing rate (number of hours to catch one fish) averaged 62.5 hours for Chinook Salmon from 1980-2014.

Charter Fishery - Mandatory catch records from the charter fishery are reported monthly by charter captains during the season. Prior to 1985, no charter license was required to fish Lake Superior in Minnesota, so charter reports were not filed. Chinook Salmon harvest in the charter fishery is included in the total harvest from the summer creel survey so summer creel and charter harvest numbers should not be added. Chinook Salmon harvest as reported by charter captains ranged from 276–1,969 fish with a mean of 899 and a median of 823 fish from 1985-2014 (Table 2; Figure 6). Chinook Salmon harvest rate in the charter fishery ranged from 0.009 - 0.046 fish per angler hour, with an overall average harvest rate of 0.025 fish per angler hour and a median of 0.022 fish per angler hour from 1985-2014 (Table 2, Figure 6). As expected, harvest and harvest rate in the charter fishery roughly followed the pattern observed in the summer creel survey.

Fall Creel Survey - The fall creel survey was intermittently conducted for 10 years between 1986-2005. Catch and catch rate were reported in the fall creel, except for 1986 and 1987, when harvest and harvest rate was reported. Catch was reported in most years instead of harvest because many anglers caught Chinook Salmon that they did not keep due to the deteriorated condition of the fish, especially late in the season. Also by law, anglers had to return any fish that were foul hooked. Catch and harvest varied greatly by year, but on average only about half the fish reported caught were kept by anglers. Estimates of Chinook Salmon catch in the fall creel surveys from 1986-2005 in years when the creel was conducted ranged from 52-1,629 with a mean of 549 and a median of 462 (Table 3; Figure 7). Chinook Salmon catch from individual streams surveyed during this period is presented in Appendix 3. Catch rate varied from 0.013 to 0.062 fish/angler hour with a mean of 0.035 and a median of 0.033 fish/angler hour. The estimated fishing rate (number of hours to catch one Chinook Salmon) averaged 28.5 hours in the fall creel survey from 1986-2005.

Winter Creel Survey - Only three formal winter creel surveys were conducted between 1974 and 2014 and these targeted Kamloops Rainbow Trout, Lake Trout and Coho Salmon. A few Chinook Salmon were also caught during the winter creel surveys with an estimated catch of 54 in 1990, 16 in 1997 and none in 2001. Although Chinook Salmon were not frequently caught in the winter fishery, the decreasing trend in catch followed a similar decline in the survival of stocked Chinook Salmon in Minnesota.

TABLE 2. Harvest and harvest rate for Chinook Salmon in the summer creel survey (1980-2014) and charter fishery (1985-2014). No Lake Superior charter license was required prior to 1985.

	Summer creel		Charter fishery	
Year	**Harvest**	**Harvest rate**	**Harvest**	**Harvest rate**
1980	100	0.000		
1981	773	0.003		
1982	1,191	0.004		
1983	3,374	0.007		
1984	1,044	0.004		
1985	827	0.004	297	0.016
1986	1,458	0.004	511	0.017
1987	1,757	0.008	416	0.018
1988	3,895	0.012	510	0.017
1989	1,748	0.006	746	0.017
1990	2,506	0.009	774	0.018
1991	1,158	0.005	1,105	0.029
1992	1,390	0.006	644	0.017
1993	2,306	0.011	431	0.016
1994	1,350	0.009	296	0.010
1995	6,728	0.043	1,213	0.041
1996	2,566	0.016	1,253	0.036
1997	3,667	0.027	1,145	0.037
1998	3,291	0.023	1,462	0.041
1999	2,302	0.016	1,211	0.029
2000	2,959	0.017	1,090	0.025
2001	3,855	0.022	1,079	0.027
2002	7,215	0.044	1,571	0.042
2003	3,390	0.022	855	0.022
2004	2,162	0.015	866	0.022
2005	2,145	0.013	682	0.019
2006	1,007	0.006	302	0.009
2007	3,378	0.017	790	0.024
2008	5,361	0.036	1,100	0.035
2009	1,410	0.010	276	0.010
2010	3,796	0.022	1,302	0.038
2011	1,971	0.011	658	0.018
2012	8,790	0.053	1,969	0.046
2013	6,312	0.035	1,821	0.041
2014	1,537	0.009	582	0.013

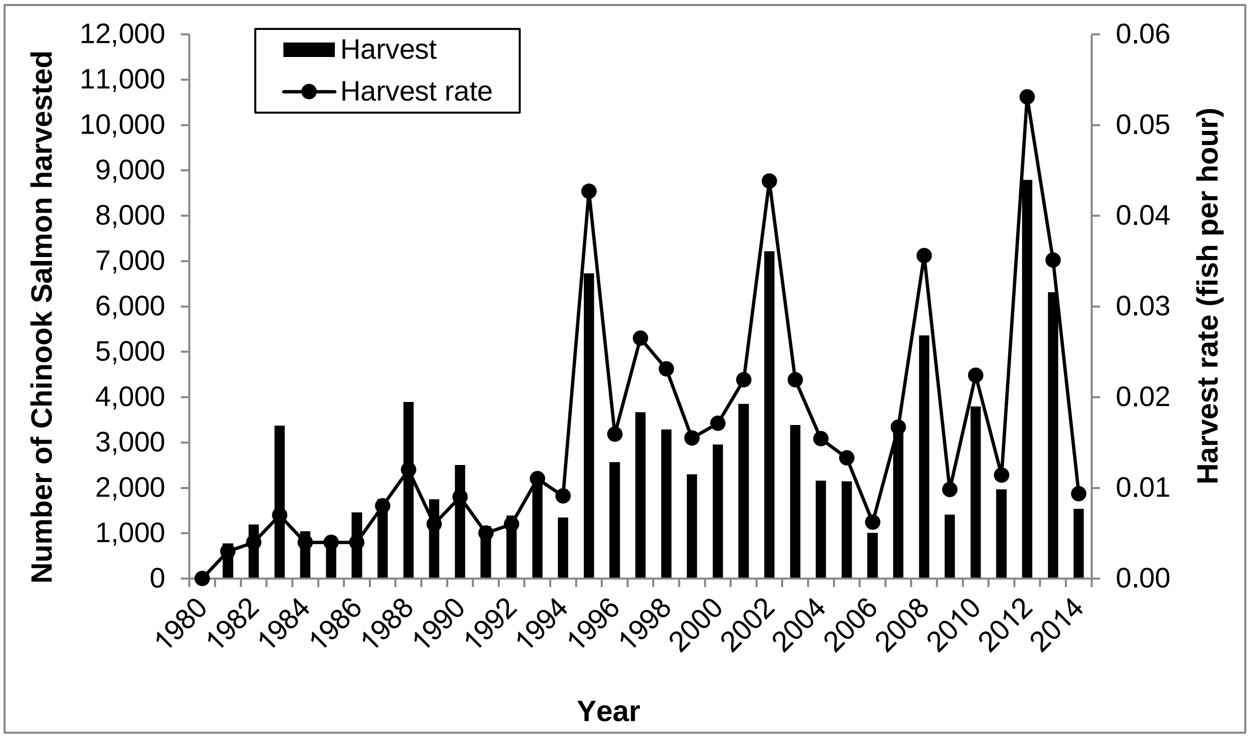

FIGURE 5. Estimated harvest and harvest rate of Chinook Salmon in summer creel surveys 1980-2014.

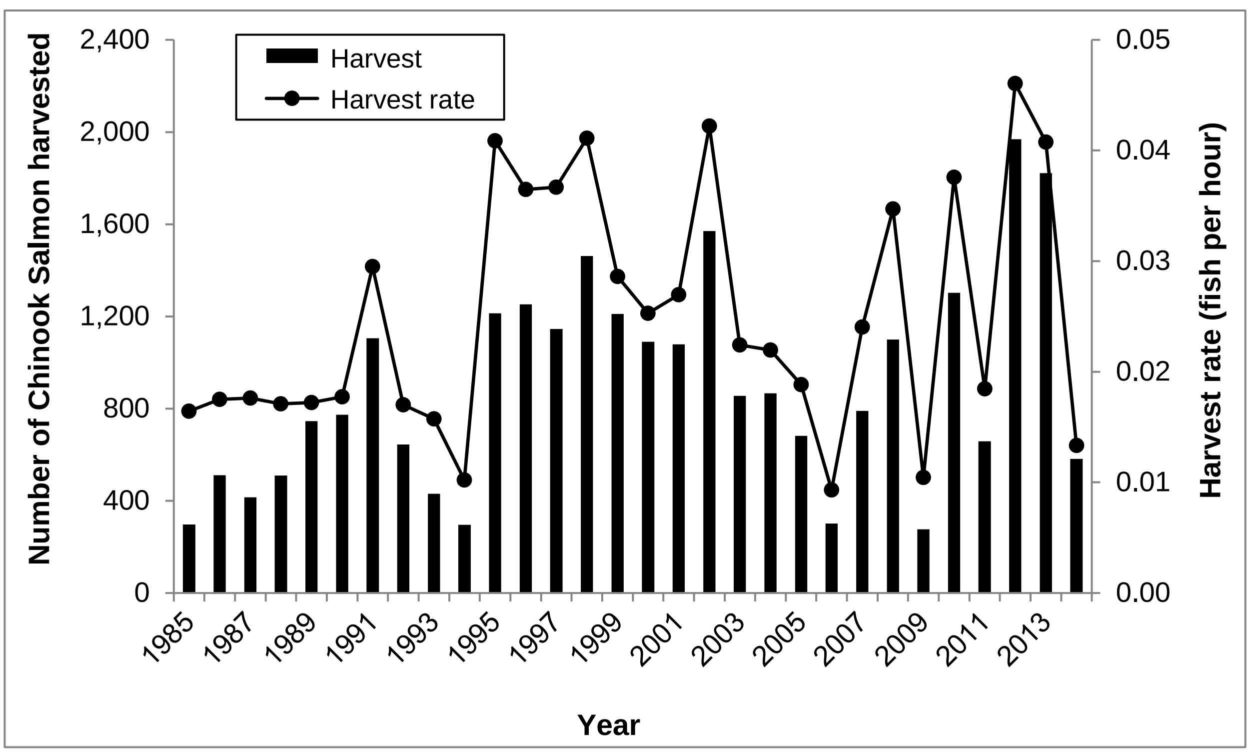

FIGURE 6. Estimated harvest and harvest rate of Chinook Salmon reported in the Minnesota Lake Superior charter fishery, 1985-2014.

TABLE 3. Estimates of catch and catch rates for Chinook Salmon caught in the fall creel survey 1989-2005. Harvest and harvest rate estimates are reported for 1986 and 1987. Fall creel surveys were conducted intermittently.

Year	Catch	Catch rate
1986	513	0.040
1987	426	0.034
1989	1,629	0.062
1991	962	0.051
1992	481	0.025
1993	474	0.031
1994	207	0.018
1998	450	0.047
2003	52	0.013
2005	292	0.031

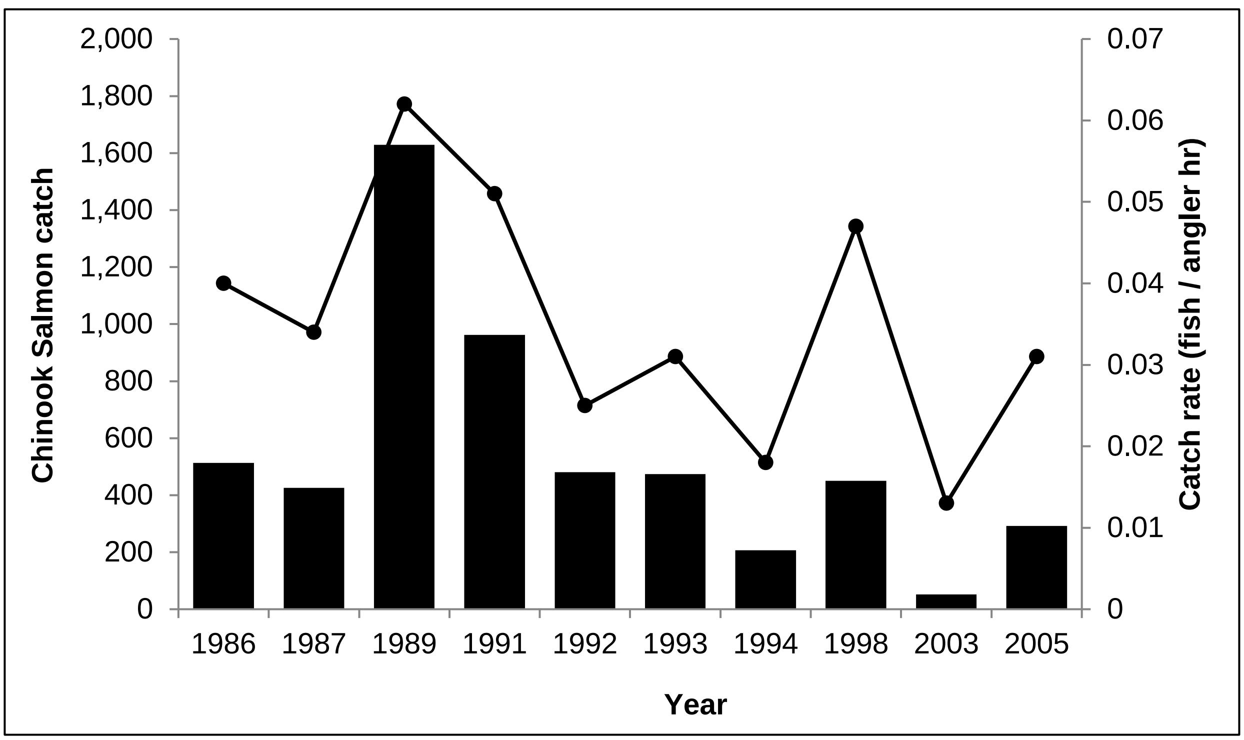

FIGURE 7. Estimates of catch and catch rate for Chinook Salmon caught in the fall creel survey 1989-2005. Harvest and harvest rate estimates are reported for 1986 and 1987. Fall creel surveys were only conducted intermittently.

Returns to the French and Knife River Traps

French River Trap - Chinook Salmon returns to the French River trap were monitored from 1976–2010 during the fall spawning run. The number of Chinook Salmon returning to the trap also included fish captured in the pool just below that trap, which was routinely seined. The number of Chinook Salmon that returned to the trap from 1976–2010 ranged from 2-1,605 fish with a mean of 352 fish and a median of 165 fish (Figure 8, Appendix 4).

In addition to monitoring the return of Chinook Salmon to the fall spawning run, the French River trap was also used as an egg take station for feral Chinook Salmon broodstock. During the Chinook Salmon program, gametes were taken at the trap from 1981-2005. The number of females spawned ranged from 9-380 (Figure 9) and the average number of eggs per female over this period was 3,849 (Appendix 5). Almost all Chinook Salmon eggs collected at the French River trap were reared at the FRCWH and stocked back into Lake Superior, except in a few years when excess eggs were provided to the WIDNR or to private hatcheries that requested them.

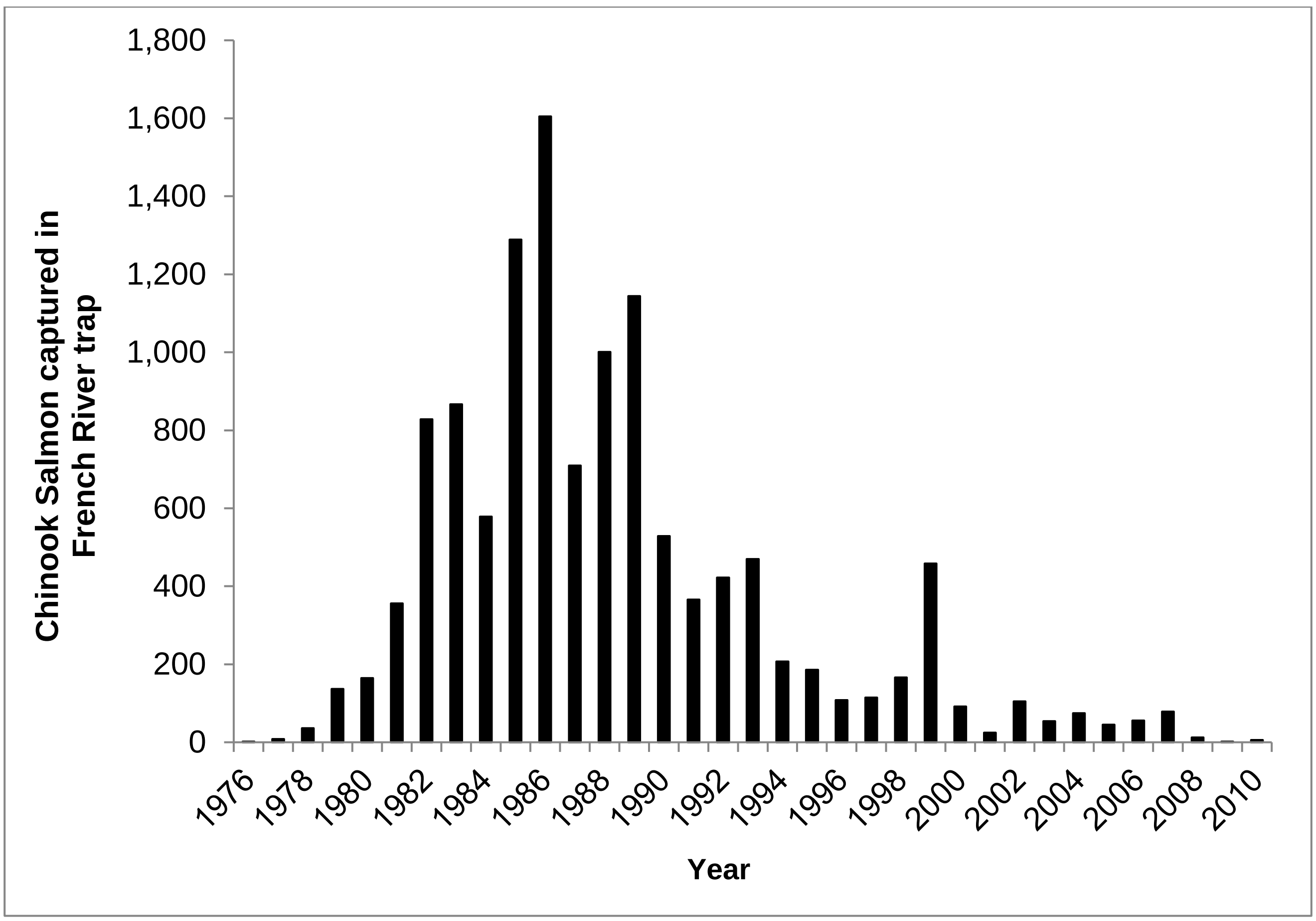

FIGURE 8. Number of Chinook Salmon captured in the French River trap by year.

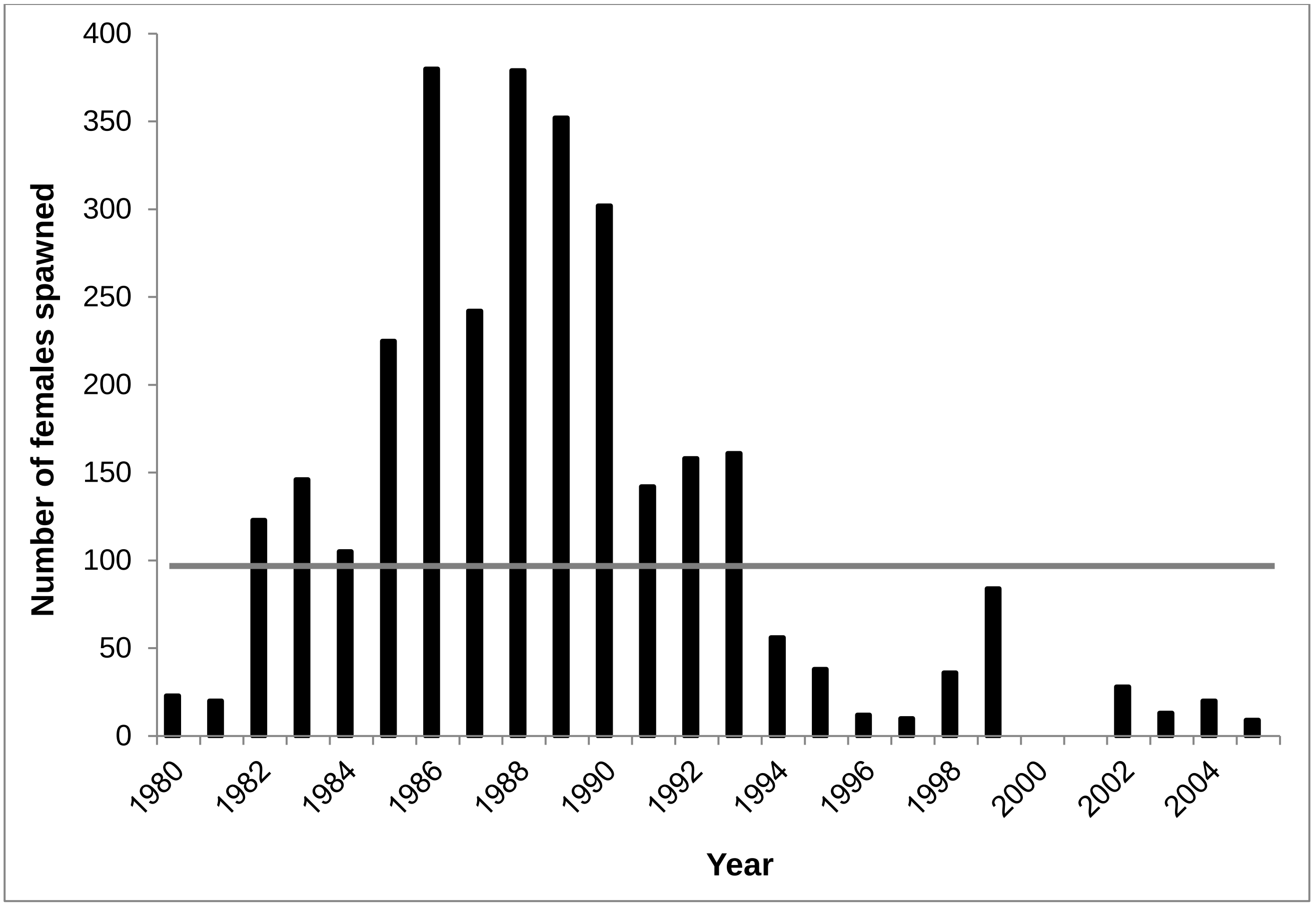

Figure 9. Numbers of female Chinook Salmon captured in the French River trap and spawned annually from 1980 to 2005. The horizontal line represents the number of spawning pairs (75 pairs) required to meet stocking program criteria.

Knife River Trap - The Knife River trap was constructed in 1995/1996 to monitor Steelhead runs in the Knife River. In Minnesota, most of the Rainbow Trout (Steelhead) run takes place during the spring spawning period; however, in some years with high flows, Steelhead may also run in the fall. In some years a few Chinook Salmon are captured during the fall run at the Knife River trap, counted and returned to the lake. To limit competition with Steelhead, they were never passed upstream above the Knife River trap, so little, if any, natural reproduction of Chinook Salmon occurred in the Knife River system. Chinook Salmon that entered the Knife River trap were either stocked or wild fish that strayed from other streams. The number of Chinook Salmon captured in the Knife River trap was minimal, ranging from 0-11 annually between 1996 and 2011, with an average of 3 and a median of 1 (Figure 10; Appendix 4). Because very few Chinook Salmon were captured in the Knife River trap, general trends or comparisons to Chinook Salmon returning to the French River trap are difficult to determine.

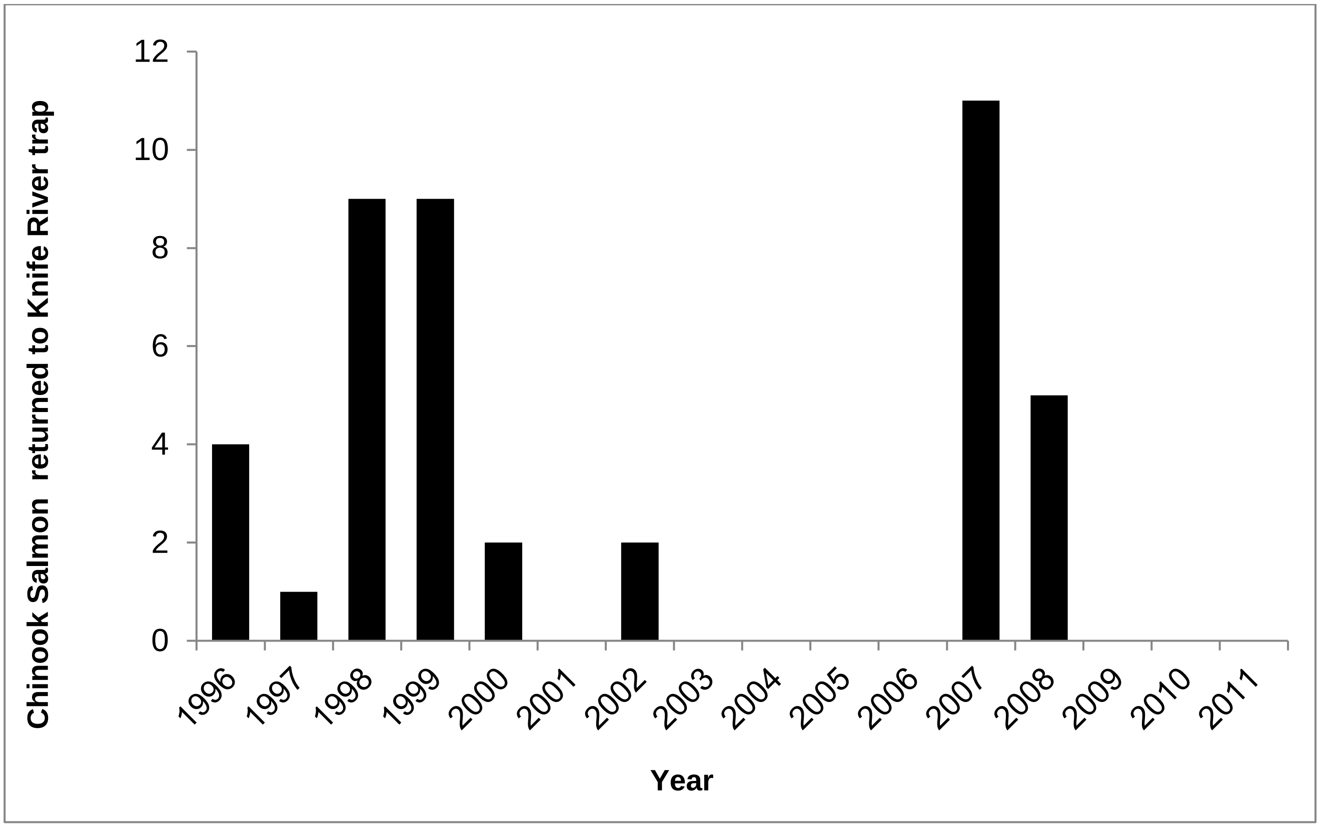

FIGURE 10. Number of Chinook Salmon captured in Knife River trap, 1996-2011.

Contribution of Hatchery-reared Chinook Salmon

Two major studies were conducted to determine the contribution of hatchery-reared Chinook Salmon to the Minnesota Lake Superior sport fishery and the French River trap. The first study was a lake-wide stocking evaluation where each agency that stocked Chinook Salmon (MIDNR, MNDNR, WIDNR and OMNR) marked each fish prior to stocking with an agency-specific fin clip from 1988-1990 (Peck et al. 1999). The objectives of this study were to evaluate the contribution of hatchery-reared Chinook Salmon to the sport fishery in Lake Superior, determine the extent of natural reproduction by Chinook Salmon, and monitor the movement of hatchery-reared fish among jurisdictions in Lake Superior. In Minnesota, returns from the 1988-1990 YC were monitored in the summer and fall creel surveys and at the French River trap from 1989-1995 (Jones and Schreiner 1997; Peck et al. 1999).

The second study was similar in design to the lake-wide study, but was conducted only by the MNDNR within Minnesota's portion of Lake Superior. This study was initiated because of a major decline in the return of Chinook Salmon to the French River trap during the mid-1990s (Schreiner 1995; Schreiner et al. 2006). The decline was so severe that the number of mature Chinook Salmon captured in the French River trap could no longer support a viable Chinook Salmon hatchery program. After much discussion, the decision was made in 1998 to extend the Chinook Salmon stocking program for four years, 1999-2002, using fertilized eggs collected from Lake Huron, in an attempt to re-establish a feral broodstock. This second study was designed to monitor the success of the "Lake Huron Experiment". All Chinook Salmon stocked by Minnesota from 1999-2002 were given a specific fin clip.

Returns were monitored from 2000-2006, again using the summer and fall creel surveys and the French River trap. The objectives were similar to the first study and focused on contribution of hatchery-reared Chinook Salmon to the Minnesota sport fishery, the extent of natural reproduction, and most importantly, returns to the French River trap, because re-establishing a viable feral broodstock was critical to the continuation of the Chinook Salmon stocking program (Schreiner et al. 2006).

Results from the two studies were reported as returns to the summer creel survey, fall creel survey and French River trap (Tables 4-7; Figures 11-13). Comparisons between studies were made where applicable and where similar data exist. To clarify this discussion, the first study that occurred in the early 1990s has been referred to as the “Lake-wide Study” (Jones and Schreiner 1997; Peck et al. 1999) and the second study that took place only in Minnesota in the early 2000s has been called the “Minnesota Study” (Schreiner et al. 2006). Two important measures calculated and compared between studies were *percent contribution* of stocked Chinook Salmon to the fishery (number of stocked fish captured/number of stocked and wild fish captured for the year class or year surveyed), and *percent return* of stocked Chinook Salmon (number of stocked fish captured/number of fish stocked for a given year class). Additional information on contribution and percent return of stocked Chinook Salmon to the French River trap in non-study years has also been included in this evaluation.

Summer Creel Survey - In the lake-wide study during 1989-1994, an average of 31% of the Chinook Salmon harvested in Minnesota were stocked by the MNDNR, 30% were stocked by other Lake Superior management agencies, and 39% were wild. The contribution of Minnesota stocked fish by year class varied from 25% for the 1990 YC to 38% for the 1989 YC (Jones and Schreiner 1997) (Table 4). In the Minnesota study, stocked fish contributed an average of 4.3% to the summer creel survey from 2000 to 2006. The contribution of stocked Chinook Salmon to the summer creel survey in the Minnesota study was not broken out by year class, but was determined for each year surveyed when the stocked fish would have been vulnerable to the fishery. Contribution of stocked fish by survey year varied from 2.6% in 2006 to 9% in 2001 (Table 4). Although contribution to the fishery was calculated differently between studies (year class vs survey year) it is clear that the contribution of stocked fish to the summer creel survey had declined approximately 7-fold over the ten year period between studies, with wild fish contributing over 95% to the summer harvest in the Minnesota study (Figure 11).

TABLE 4. Percent contribution of stocked Chinook Salmon in the summer creel survey by year class (1988-1990) and by year surveyed (2000-2006).

Year Class/Year surveyed	Percent contribution
1988	28.0%
1989	38.0%
1990	25.0%
Mean	**31.0%**
2000	4.9%
2001	9.0%
2002	3.1%
2003	4.1%
2004	3.3%
2005	2.9%
2006	2.6%
Mean	**4.3%**

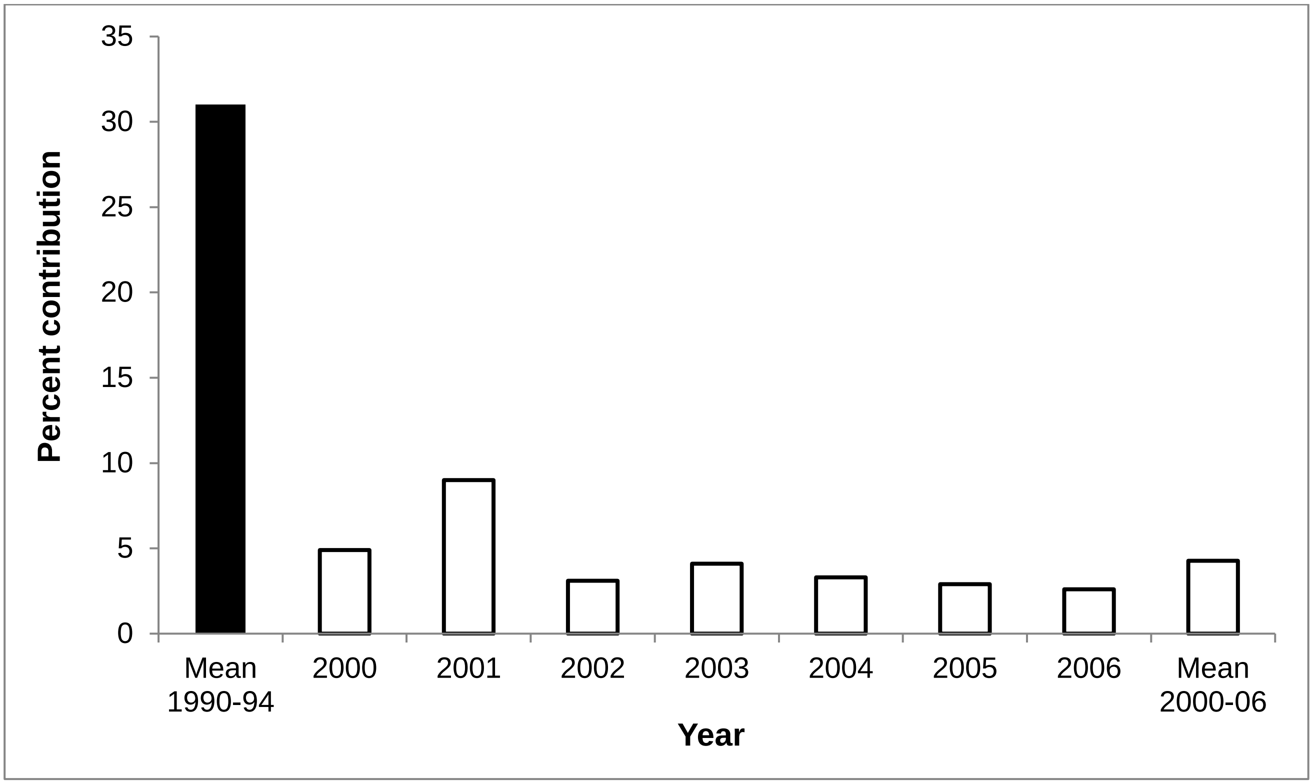

FIGURE 11. Percent contribution of stocked Chinook Salmon to the summer fishery in Minnesota waters of Lake Superior during the lake-wide study (solid bar) and the Minnesota study (open bars).

Percent return of stocked fish by year class to the summer creel survey was determined for each study and averaged 0.098% in the lake-wide study and 0.043% in the Minnesota study, over a 2-fold decline (Table 5). The declining trend in percent return from the lake-wide study compared to the Minnesota study is consistent with the decline in percent contribution, but the magnitude of the decline in percent return is not as great. Chinook Salmon harvest in the summer creel survey during the lake-wide study averaged 1,743 fish, while the average harvest during the Minnesota study was 3,258 (Table 2; Figure 5). A likely reason for the 7-fold decrease in percent contribution of stocked fish to the summer fishery is that wild fish abundance, along with average Chinook Salmon harvest, increased over the 10 year interim period, decreasing the impact of stocked fish. Considering these population shifts, it was apparent that the need for continued stocking to support the Chinook Salmon fishery was minimal.

TABLE 5. Return rate (%) of stocked Chinook Salmon to summer creel survey by year class.

Year class	Return rate
1988	0.094%
1989	0.129%
1990	0.069%
Mean	**0.098%**
1999	0.093%
2000	0.065%
2001	0.038%
2002	0.020%
Mean	**0.043%**

Fall Creel Survey - Chinook Salmon catch in the fall creel survey during the lake-wide study (1991-1994) averaged 531 fish, while the average catch in the fall creel from the Minnesota study (2003 and 2005) was 172 fish (Table 3: Figure 7). In the lake-wide study an average of 74% of the Chinook Salmon caught by anglers in the fall creel survey were Minnesota stocked fish, only 2% were stocked by other Lake Superior management agencies, and 24% were naturally reproduced from 1991-1994. Contribution of Minnesota stocked fish by year class varied from 61% for the 1988 YC to 81% for the 1989 and 1990 YC (Jones and Schreiner 1997) (Table 6). In the Minnesota study, monitoring the contribution of stocked fish to the fall fishery was not a major objective. Similar to the summer creel survey, percent contribution in the fall fishery was not broken out by year class, but was determined for two of the five years (2003 and 2005) that stocked fish would be expected to return and spawn (between 2002 and 2006). Based on these two surveys, the average contribution of stocked fish was 72.5% and ranged from 70% in 2005 to 75% in 2003 (Table 6). Although contribution of stocked fish to the fishery was calculated differently between studies (year class vs survey year) it is apparent that contribution of stocked fish to the fall creel survey remained essentially the same between studies. However, the overall catch of Chinook Salmon in the fall creel survey declined approximately 3-fold from an average of 531 fish during the lake-wide study to an average of 172 fish during the Minnesota study.

Percent return of stocked fish in the fall creel survey averaged 0.072% in the lake-wide study. In the Minnesota study percent return could only be estimated in the two years (2003 and 2005) when the fall creel was conducted. We assumed that the catch was made up of predominately age-3 and age-4 fish, which normally account for about 82% of the spawning run (Appendix 6), Percent return was calculated based on the total returns relative to the number stocked in those age classes. Using this method, the percent return to the fall creel in the Minnesota study averaged 0.033% (Table 6). The percent return from the fall creel survey during the Minnesota study decreased to less than half that of the lake-wide study (Table 6). Although the fall fishery was largely supported by stocking, the decrease in percent return over the 10 years between studies, the low harvest by anglers, and the poor quality of the fish harvested created a marginal fishery that was no longer supported by many anglers.

TABLE 6. Percent contribution and percent return of stocked Chinook Salmon in the Fall Creel Survey by year class (1988-1990) and year surveyed (2003 and 2005).

Year class	Year surveyed	Percent contribution	Percent return
1988		61.0%	0.076%
1989		81.0%	0.085%
1990		81.0%	0.054%
Mean		**74.3%**	**0.072%**
	2003	75.0%	0.011%
	2005	70.0%	0.056%
	Mean	**72.5%**	**0.033%**

French River Trap - In the lake-wide study, an average of 89% of the Chinook Salmon that returned to the French River Trap were stocked by the MNDNR, 2% were stocked by other Lake Superior management agencies, and 9% were naturally reproduced. Contribution of Minnesota stocked fish by year class varied from 84% for the 1988 YC to 92% for the 1989 and 1990 YC (Jones and Schreiner 1997) (Table 7; Figure 12). In the Minnesota study, the contribution of stocked fish to the French River trap averaged 72.9%. Because return to the French River trap was a major objective of the Minnesota study, percent contribution and percent return were calculated by year class. Contribution by year class in the Minnesota study varied from 96.8% for the 1999 YC to 18.6% for the 2002 YC (Table 7). Except for the extremely low contribution of stocked fish from the 2002 YC, contribution of stocked fish as measured by returns to the French River trap remained relatively stable between studies. However, the total number of fish returning to the trap declined dramatically (Figure 8).

Percent return of stocked fish to the French River trap was also determined for each study and averaged 0.32% in the lake-wide study and 0.06% in the Minnesota study, over a 5-fold decline during the 10 year period between studies (Table 7; Figure 12). This is a similar trend to that reported in the fall fishery, but demonstrates a much more dramatic decline in percent return of stocked fish. Because the French River trap returns are based on direct counts and the creel survey results were based on expanded estimates in only 2 out of 5 years for the Minnesota study, the information collected from the French River trap is likely more reliable in reflecting the changes in the stocking program.

TABLE 7 Percent contribution and percent return of stocked Chinook Salmon by year class to the French River trap.

Year class	Percent contribution	Percent return
1998	84.0%	0.30%
1989	92.0%	0.38%
1990	92.0%	0.28%
Mean	**89.3%**	**0.32%**
1999	96.8%	0.07%
2000	87.2%	0.07%
2001	89.0%	0.07%
2002	18.6%	0.01%
Mean	**72.9%**	**0.06%**

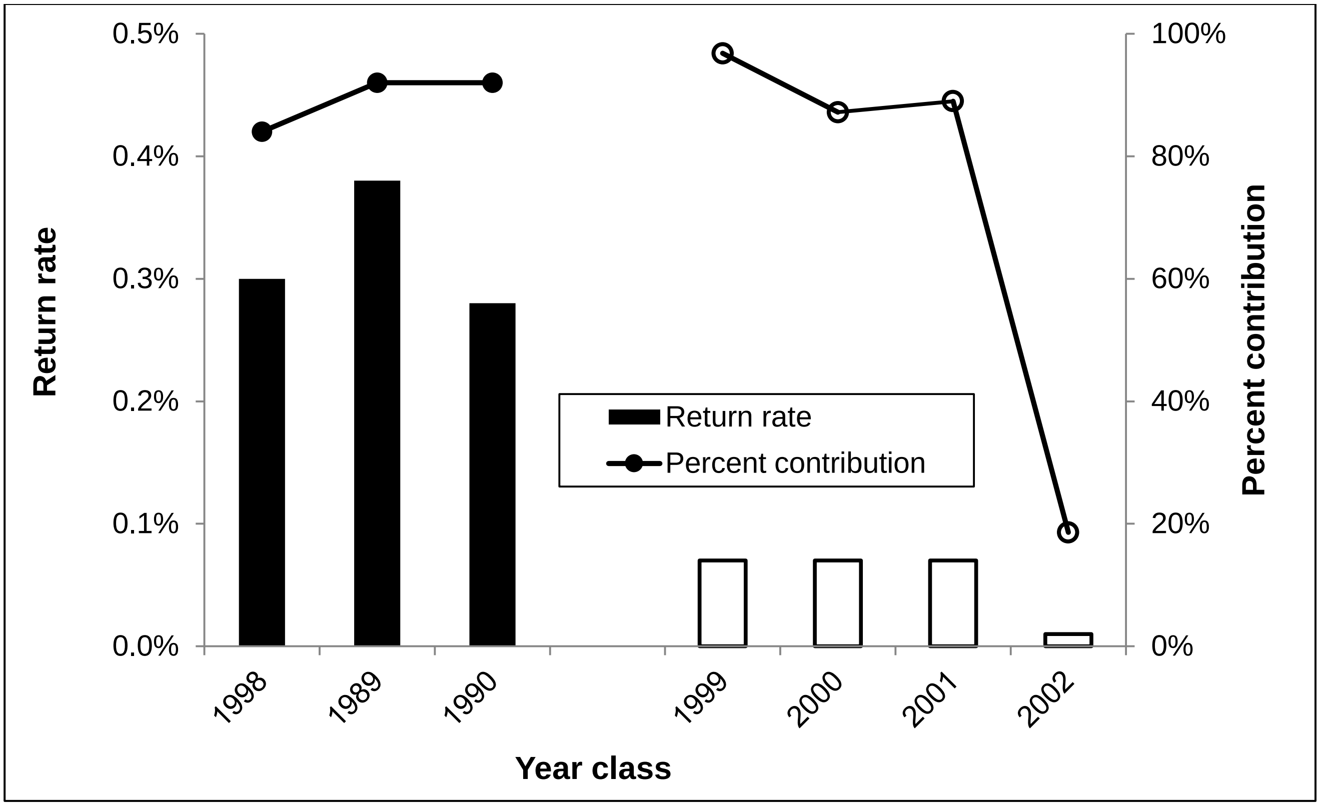

FIGURE 12. Return rates and percent contribution of stocked Chinook Salmon by year class to the French River trap, during the lake-wide study (filled bars and dots) and the Minnesota study (open bars and dots).

In addition to the "study" years, contribution and percent return of stocked Chinook Salmon by year class to the French River trap were also calculated for other years between 1981 and 2002 when stocked fish were marked with a fin clip. Percent return declined significantly from the early 1980s to the early 2000s, while percent contribution of stocked fish to the total run was relatively stable, except for 2002 (Figure 13). Similar to the two study periods, total returns to the French River trap decreased over time and was shown to be largely dependent on stocking.

The overall findings on percent contribution to the fishery and percent return of stocked Chinook Salmon appeared consistent between recapture methods. Both the fall creel returns and the French River trap returns had similar percent contributions and both evaluations focused on fish returning to spawn in stocked locations. The decline in percent return of stocked fish between studies strongly suggests that survival of stocked fish was declining over this 10 year period. Results from the summer creel survey indicated that the summer fishery was largely supported by wild fish. Given that the percent return of stocked fish to the French River had declined to such low levels that a hatchery program could no longer be sustained, and 95% of the summer fishery was supported by wild fish, the need for continued stocking was questioned.

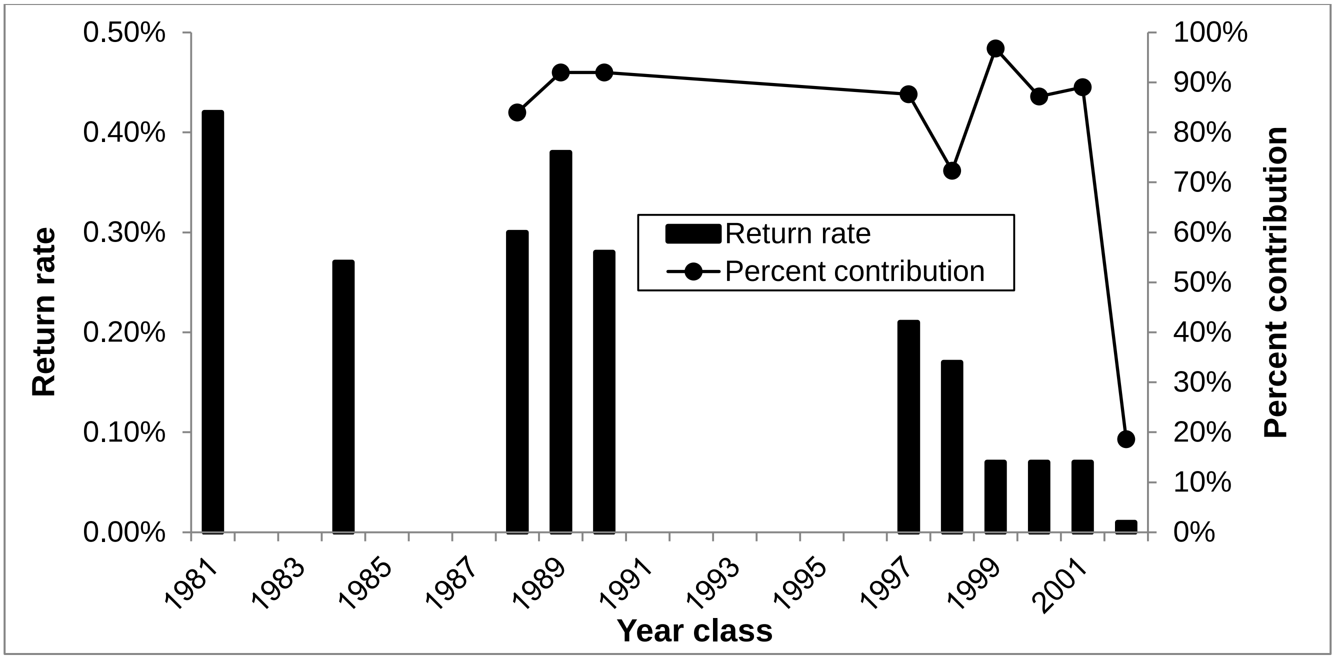

FIGURE 13. Return rate of stocked Chinook Salmon by year class to the French River trap, and percent contribution of stocked fish to the total trap returns in years when Chinook Salmon were marked.

Population Dynamics

Abundance - No studies to determine the absolute abundance of Chinook Salmon in Minnesota's portion of Lake Superior have been attempted. Use of Mark-recapture techniques could be attempted, but since the Minnesota portion of Lake Superior is not a closed system, and Chinook Salmon are known to migrate extensively, major assumptions of the technique would be violated. However, population size in a given year could be estimated based on the number of Chinook Salmon stocked, the ratio of stocked to wild fish recaptured at the French River trap, and estimates of mortality rates. Total annual mortality rates for Chinook Salmon between years were estimated as 0.995 for stocked age-0 fingerlings to age-1; 0.38 from age-1 to age-2; 0.30 from age-2 to age-3; 0.48 from age-3 to age-4; 0.8 from age-4 to age-5; and 0.99 from age-5 to age-6 in 2004 (Negus et al. 2008). Mortality rates were assumed to be the same for both stocked and wild fish. Annual estimates of Chinook Salmon abundance in various parts of the western arm (MN, WI, combined, etc.) are presented in Negus et al. (2008) and varied greatly depending on year, annual number stocked and contribution of stocked fish.

Growth - Average weight at age was determined by Negus et al. (2008) for Chinook Salmon returning to the French River trap during the fall spawning run over different time periods (Figure 14). Growth was compared over three time periods and indicated a significant decrease in weight at age, from the early 1990s to the mid-2000s, especially for age-4 and older Chinook Salmon. The decrease in growth coincides with the sharp decrease in percent return of stocked fish over the same time period. Chinook Salmon grow much slower in Lake Superior than in the lower Great Lakes, especially Lake Michigan (Claramunt et al. 2008). Similar to Lake Superior, growth rates of mature Chinook Salmon in Lake Huron also decreased dramatically after establishing naturalized (self-reproducing) populations, along with a major decline in alewives (Johnson and Gonder 2012). Average weight of Chinook Salmon harvested in the summer creel was variable, but generally declined from 1981 through 2013 (Figure 15). Although average weight of Chinook Salmon harvested in the creel and average weight of spawning adults that returned to the French River trap showed

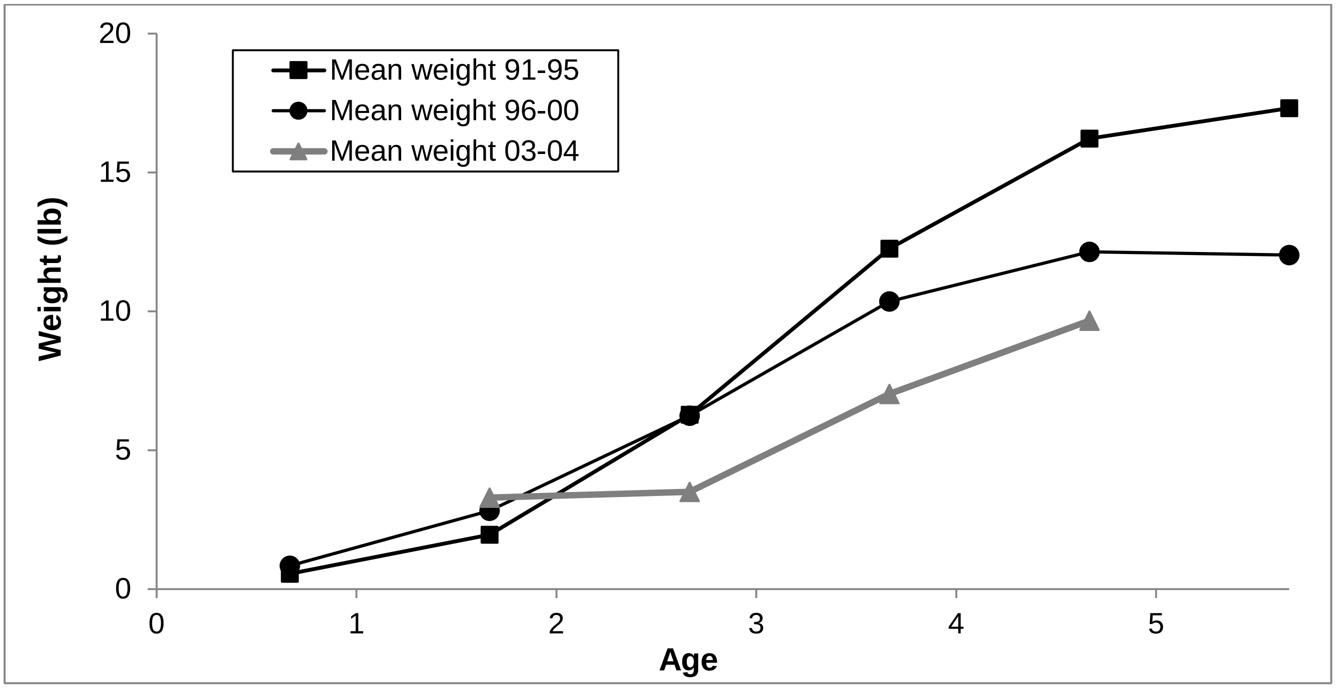

FIGURE 14. Mean weight at age for Chinook Salmon captured in the French River trap for three time periods between 1991 and 2004 (Negus et al. 2008).

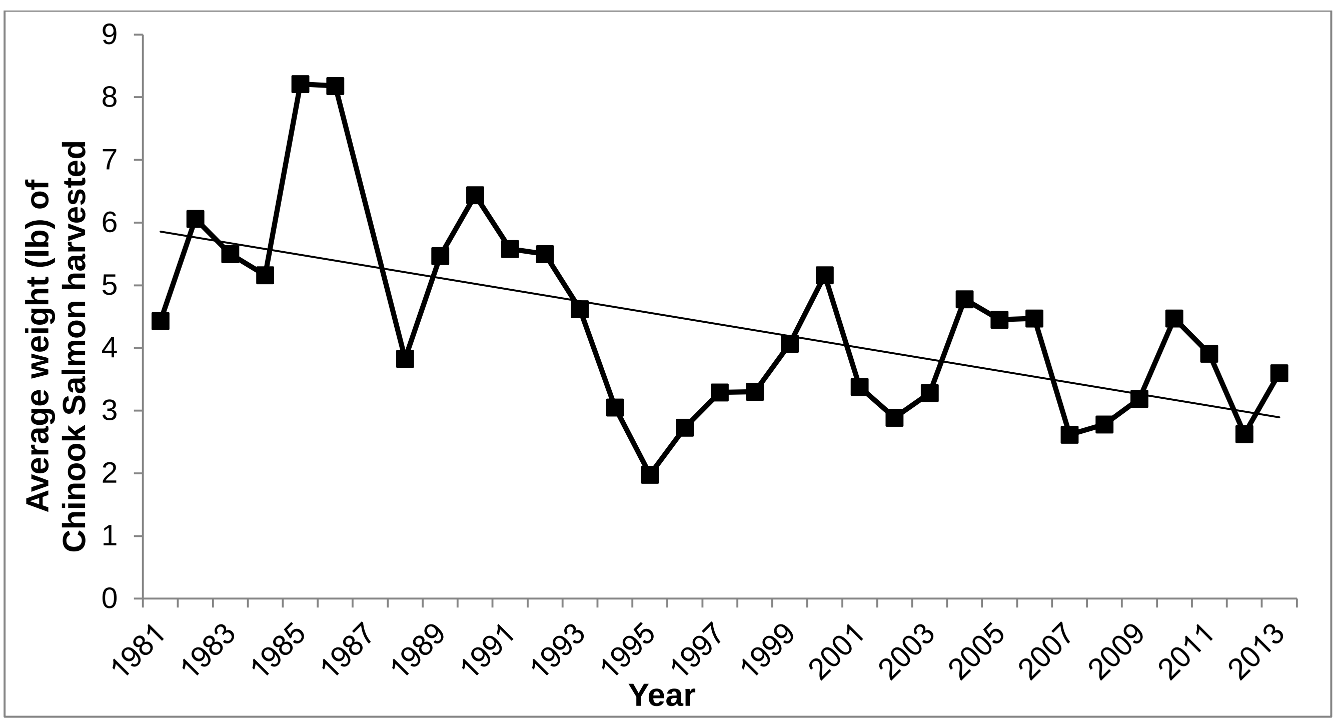

FIGURE 15. Average weight (pounds) of Chinook Salmon harvested in summer creel surveys, 1981-2013.

similar decreasing trends from the early 1990s to the mid- 2000s, the decrease in weight was more apparent for the older fish (> age-3) returning to the French River trap. The majority of the fish captured in the summer creel survey are younger than those captured at the French River trap and the larger mature fish may have more difficulty finding the required quantity of prey to sustain their growth trajectory throughout the year. In addition, large variations in natural year class strength can greatly influence the average weight of fish harvested in the summer sport fishery based on the size/age distribution for a given year, making the time series much more variable.

In addition to weight at age, length at age also declined for Chinook Salmon in Minnesota's portion of lake Superior (Figure 16), although not nearly as dramatically as weight, resulting in fish with decreased condition factor over time. The number of eggs per female also declined over time, especially from the early 1990s to the mid-2000s (Figure 17). This decline is not unusual since there is a strong relationship between female body size and number of eggs per female. The size of eggs over time remained relatively stable at between 4-5 eggs/ml (Figure 17) (Negus et al. 2007).

Age of maturity - Chinook Salmon returning to the French River trap ranged in age from 0-5 based on scale ages and fin clips. The most common age of Chinook Salmon in the spawning run from 1993-2007 was age-3 at 43%, followed closely by age-4 at 39% (Figure 18; Appendix 6). A few pre-mature males were captured in the trap (age-0 and age-1), but ripe males were not captured until age-2, and in most years not all age-2 males captured were sexually mature. Ripe females did not appear until age-3, and were most dominant at age-4. Age-5 male and female Chinook Salmon made up only about 5% of the total returns.

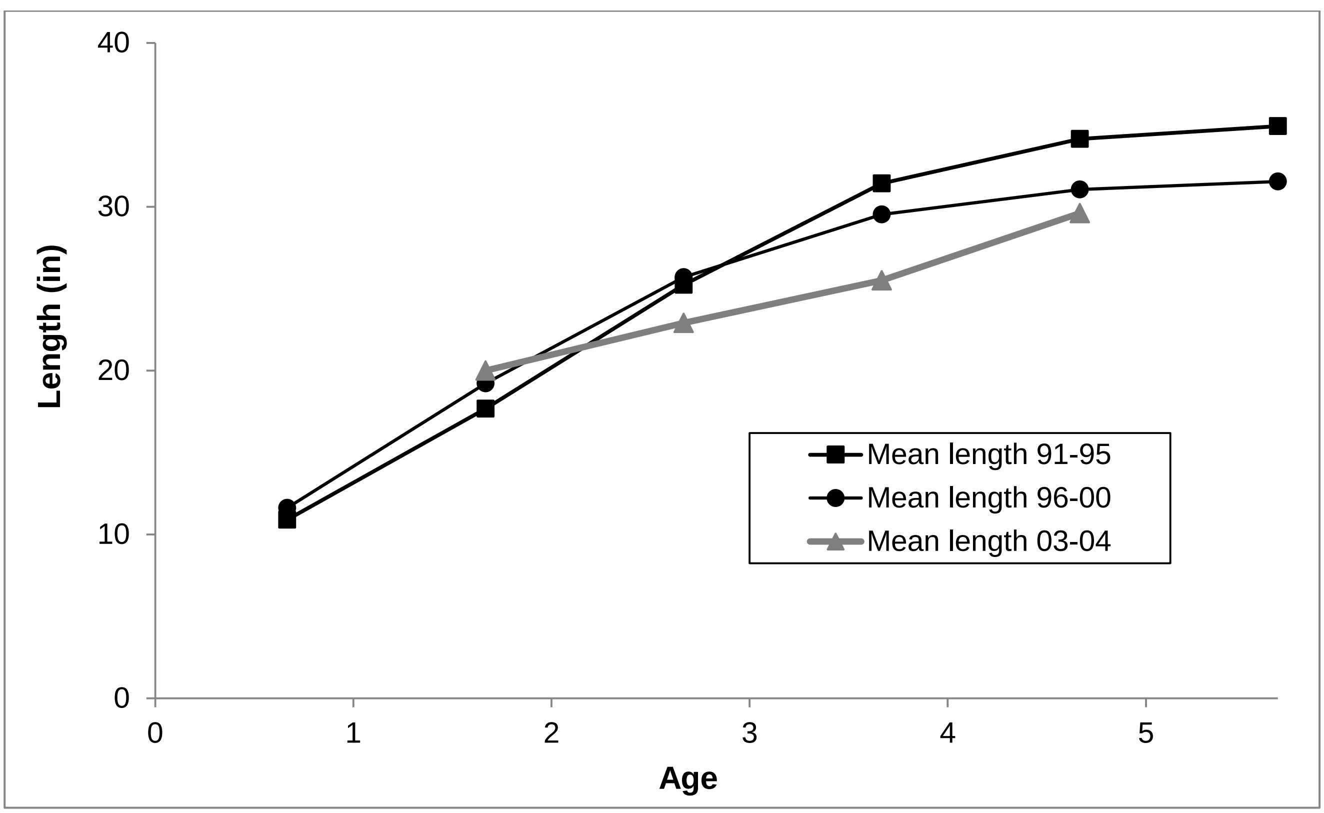

FIGURE 16. Mean length at age for Chinook Salmon captured in the French River trap for three time periods between 1991 and 2004.

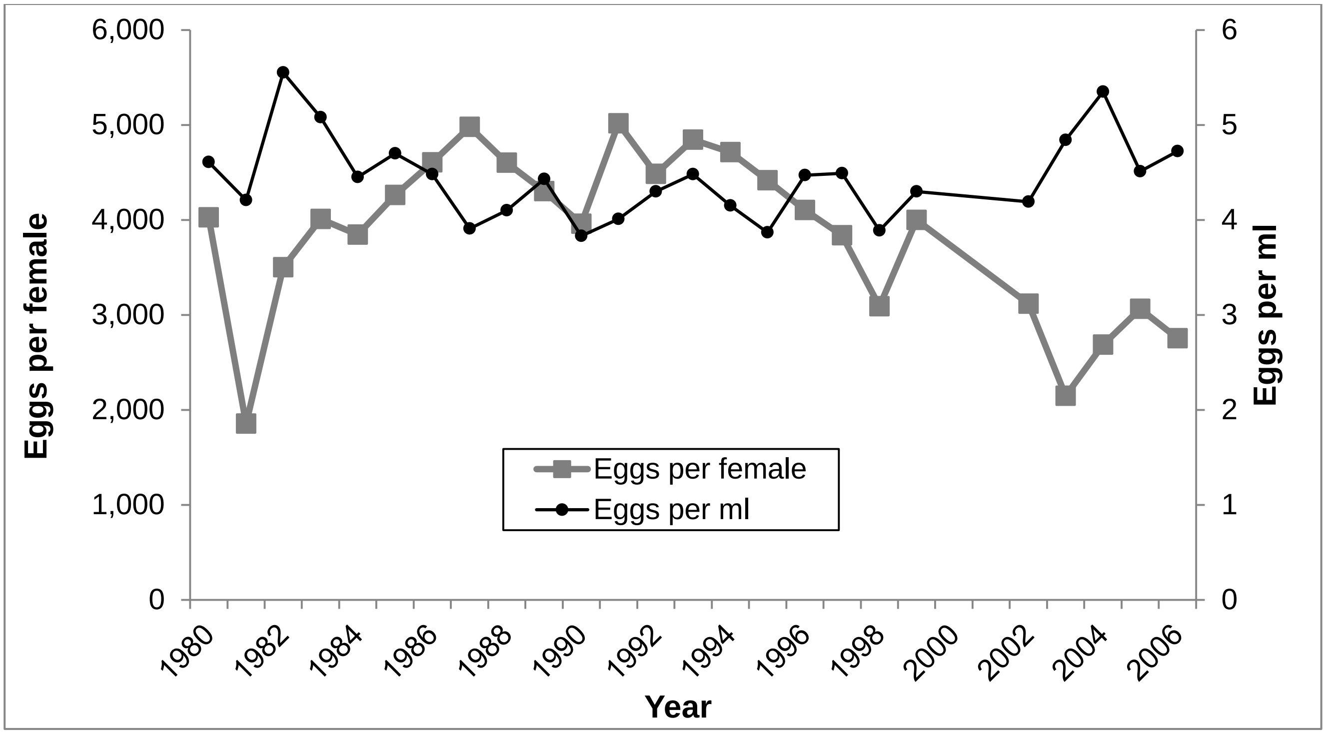

FIGURE 17. Mean number of eggs/female and eggs/ml for Chinook Salmon captured in the French River trap between 1980 and 2006.

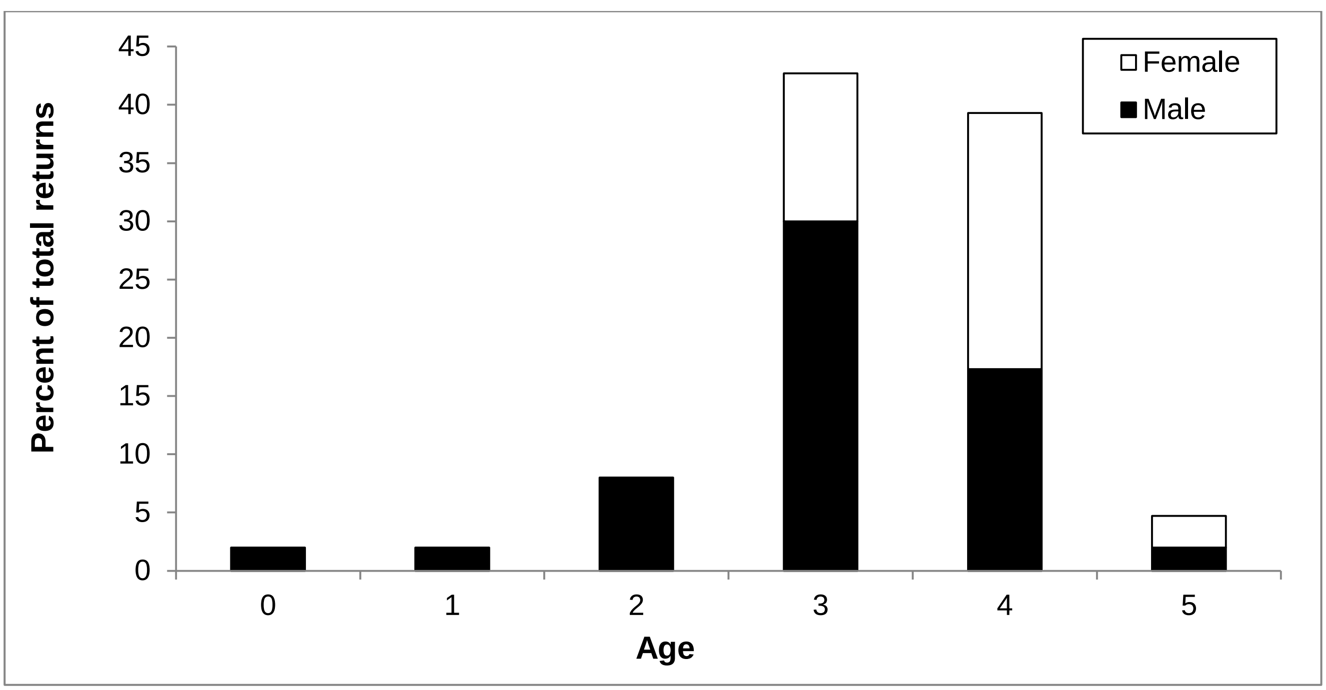

FIGURE 18. Average age frequency of male and female Chinook Salmon returning to the French River trap from 1993-2007.

Timing of return/spawning - In the fall, most spawning Chinook Salmon returned to the French River trap between early September and mid-November, with the majority of fish returning from mid-October through early November (MNDNR French River Trap Reports, Lake Superior and Duluth Area Files). Anglers reported that in general, Chinook Salmon returned to spawn later in the 2000s than during the early years of the program in the late-1970s and early 1980s. Unfortunately, many of the late returning Chinook Salmon were so deteriorated they were not harvested for consumption by anglers.

Diet - Chinook Salmon diet in Lake Superior has been reported in a number of studies (Conner et al. 1993; Ostazeski et al. 1999; Ray et al. 2007) and was summarized for the Western Arm of Lake Superior (MN and WI) based on percent weight of diet item in the stomach (Negus et al. 2007). Major changes in diet were noted between age-0 and age 1-5 fish and between the western tip of Lake Superior and the Minnesota north shore (Negus et al. 2007). In previous work, Negus (1995) created five diet categories for top Lake Superior predators in Minnesota. Using these categories, Chinook Salmon diet in the 1980s and early 1990s was composed of approximately 24% Coregonids, 20% Rainbow Smelt, 18% crustaceans (predominately Mysids), 2% insects, and 7% other fish species. Using the same diet categories, Chinook Salmon diet monitored in the late 1990s and early 2000s had changed to include approximately 76% Coregonids, 19% crustaceans (predominately Mysids), 3% Rainbow Smelt and 2% insects (Negus et al. 2007).

Factors Affecting Survival and Return Rates of Chinook Salmon

Smolting/Imprinting/Homing

Homing behavior of Chinook Salmon (anadromous and potamodromous) to natal streams is widely recognized. It has been determined that homing is largely dependent on olfactory cues learned by different juvenile life stages while they are exposed to water in their natal stream. This stage of olfactory learning is called imprinting and is critical for the successful completion of the adult homing migration (Dittman and Quinn 1996). Initially it was felt that most imprinting occurred during smoltification (parr-smolt transformation phase) when many physiological changes occur (Hoar 1976). More recently, investigators have developed a more complex hypothesis that describes salmonid homing, and is termed sequential imprinting (Brannon 1982; Dittman and Quinn 1996). This hypothesis suggests that salmon learn a series of olfactory waypoints, beginning at the nest site, as they migrate downstream, later retracing the path upon returning to spawn (Dittman et al. 2015). In addition to the smolting period (parr-smolt transformation), the embryonic period during hatching and emergence from the nest has also been show as an important stage for imprinting to occur (Tilson et al. 1994, Dittman et al. 2015).

In Minnesota, imprinting of Chinook Salmon during smoltification in the hatchery was examined to determine the best size and time for stocking (Negus 2000; 2003). The embryonic life stage was not examined in this study. Identifying when smoltification occurs is important so that fish can be stocked in target streams prior to smolting and imprinting. Negus (2003) used gill ATP-ase measurements to distinguish smolts from non-smolts, and the threshold ATP-ase level for smolting was compared to various juvenile criteria such as length, weight, coloration, condition factor, etc. To maximize imprinting to target streams, Chinook Salmon from the FRCWH needed to be stocked before imprinting occurred.

An ATPase level of 11 µmol Pi·(mg protein)$^{-1}$·hr^{-1} was determined to be the threshold for smolting in Chinook Salmon reared at the FRCWH. This level generally corresponded to a threshold fork length of 2.8 inches, a weight of 0.14 ounces and a body depth of 0.6 inches although as expected there was variability between year classes and individuals within a year class. Many of the Chinook Salmon stocked prior to this study in streams other than the French River were larger than the threshold size which likely increased their return (straying) to the French River, where the FRCWH is located. In addition to imprinting during smoltification some investigators have noted that secondary imprinting of hatchery-reared fish occurs at the time and site of stocking (Pascual et al. 1995). This secondary imprinting may explain why some of the post-smolt Chinook Salmon stocked in the Lester, Baptism and Cascade Rivers still displayed significant homing behavior to these rivers during the fall spawning run.

All hatchery supported anadromous and potamodromous salmon programs share a common dilemma; either release hatchery-reared fish into the wild at a younger age and smaller size that provides increased opportunity for imprinting and homing, or release salmon at an older age or larger size that may increase overall survival (Zabel and Achord 2004), but also increases straying. In Minnesota, stocking larger Chinook Salmon may have reduced imprinting and homing to target streams, but it also likely increased overall survival by avoiding potential predators (Figure 4). These competing concerns force managers to weigh the trade-offs when determining the best strategies to implement when managing hatchery-reared salmon programs. The conundrum between rearing fish to a larger size and the need to imprint on specific streams before smolting to facilitate homing has also been identified as an issue affecting the Rainbow Trout program (Negus et al. 2012) and the Atlantic Salmon program (Schreiner and Negus 2015) in Minnesota. Unfortunately, for many hatchery based salmonid programs, factors that affect imprinting and survival vary annually and cannot be easily addressed given the constraints of a hatchery based program.

Stream Factors

Lake Superior tributaries in Minnesota have limited habitat available for potamodromous salmonid spawning and nursery use. In many of these streams, natural barriers to upstream migration exist very close to the mouth (most less than one mile). These tributaries also experience extreme fluctuations in water levels and environmental conditions that are inhospitable for cold water fish. These tributaries have very little ground water input and rely on run-off to support flow (Ostazeski and Schreiner 2004). Juvenile Chinook Salmon may experience reduced flows in Minnesota's Lake Superior tributaries, and in some years stream temperatures can warm to intolerable levels during late spring and early summer, forcing some fish to emigrate prematurely. In some winters with little snow and extended cold temperatures (below -20^0 F), sections of streams routinely freeze to the bottom, further decreasing the limited nursery habitat available (Negus et al. 2012), and causing potential mortality to Chinook Salmon eggs and sac-fry in redds. Large annual variations in stream temperatures may influence time of smolting and emigration, potentially impacting survival of naturalized Chinook Salmon (Holtby et al.1989; Crozier and Zabel 2006; Steel and Beckman 2014). Spate flows in Minnesota tributaries are frequent during the spring and early summer when heavy precipitation coupled with snow-melt can physically destroy redds and negatively affect newly hatched fry (Close et al. 1989; Negus et al. 2012).

In the mid-late 1980s, Close et al (1989) examined interspecific competition between Rainbow Trout (Steelhead), Atlantic Salmon and Chinook Salmon for habitat use under low flow conditions in Minnesota's Lake Superior tributaries. The results indicated that because Chinook Salmon inhabit deeper portions of the stream, and emigrated from the streams at age-0 in late June or July, they had minimal interaction with Steelhead and Atlantic Salmon. The study did not address the competition between Chinook and Atlantic Salmon for spawning habitat, but other studies have found this to be a significant factor in other systems, sometimes limiting the spawning success of both species (Jones and Stanfield 1993; Crawford 2001; Scott et al. 2003; Scott et al. 2005). In Minnesota, spawning interactions are more likely to occur between Chinook Salmon and coaster Brook Trout, where Chinook Salmon may inadvertently destroy Brook Trout redds, especially given the limited spawning habitat in Minnesota streams, along with the much larger size and sometimes slightly later spawning period of Chinook Salmon (Fausch and White 1986; Huckins et al. 2008; Schreiner et al. 2008).

Lake Factors

A number of factors can affect survival of both naturally reproduced and hatchery-reared Chinook Salmon in Lake Superior. Cold water temperatures are a major factor that affects growth and survival of Chinook Salmon in Lake Superior. Most introduced salmonids in Lake Superior are on the thermal margin of their range for normal growth and survival. Preferred temperatures reported for adult Chinook Salmon ranged from 54-57^0 F (Scott and Crossman 1973) to 67^0 F (Coutant 1977), with an optimum temperature reported at 60^0 F (Wismer and Christie 1987). Chinook Salmon tracked with radio tags in Lake Ontario normally occupied temperatures from 44-56^0 F, and sought out the warmer temperatures when available (Haynes and Gerber 1989). Negus et al. (2007) reported that at no time in the western arm of Lake Superior did water temperatures reach even the lower level of the preferred or optimum range for Chinook Salmon, and in only two months did water temperatures exceed 50^0 F in 2000 and 2004. Studies on the minimum water temperatures for Chinook Salmon growth and survival are limited, but those conducted in the laboratory report little to no growth, and even some mortality, below sustained temperatures of 40 ^{0} F (Brett et al. 1982; Myers et al. 1998). In Lake Superior water temperatures did not exceed 43^0 F for 9 months, and did not exceed 37^0 F for 4 months, likely inhibiting any significant growth during these periods (Negus et al. 2007). The thermal physiology of Chinook Salmon and the location of the warmest water temperatures in lake Superior normally relegates their distribution to the inshore zone and pelagic portions of the nearshore and offshore zones (Schreiner et al. 2010).

Bioenergetics modeling suggests that Chinook Salmon consume more prey than any other Lake Superior species, when prey consumption is estimated on an individual basis (Negus 1995). Chinook Salmon also demonstrated the greatest food conversion efficiency of all predators modeled, and were the most sensitive to changes in forage abundance. A major reason Chinook Salmon weight at age has decreased over time is because of the sharp decrease of prey available in Lake Superior (Gorman 2010). Rainbow Smelt abundance is very low and Cisco stocks have still not rebounded to historic levels (Gorman 2010). Evidence suggests that the primary prey of Chinook Salmon in western Lake Superior is Coregonines (Ostazeski et al. 1999; Negus et al. 2007). Despite the high prey intake by individual Chinook Salmon, the cumulative impact on the Lake Superior forage base in Minnesota has been limited given the relatively low population abundance when compared to Lake Trout (Negus et al. 2008). However, when modeled on a more limited spatial scale (ex., depth < 240 feet) the cumulative predatory impact of Chinook Salmon becomes more significant. Given that Lake Superior may be at or near carrying capacity for predators (Kitchell et al. 2000; Schreiner et al. 2006; Negus et al. 2012) and that Chinook Salmon consume more forage per individual than any other Lake Superior species (Negus 1995, Negus et al. 2008) the decline of both growth and survival of stocked fish is not surprising.

Predation on newly stocked Chinook Salmon fingerlings and naturally produced smolts by Lake Trout and other top predators in Lake Superior may be a major cause of early mortality in young Chinook Salmon, especially in the absence of an abundant forage base. There is a strong relationship between increased Lake Trout abundance, decreased Rainbow Smelt abundance, and declines in survival of hatchery-reared Chinook Salmon. Most hatchery-reared salmonids in Lake Superior experienced decreased survival starting in the late 1980s (Hansen et al, 1994; Schreiner et al. 2010; Schreiner and Negus 2015). Hansen et al. (1995) reported that in Minnesota's portion of Lake Superior, decreased survival of newly stocked Lake

Trout was likely caused by predation from increased abundance of wild Lake Trout. Decreased survival of hatchery-reared Rainbow Trout (Negus et al. 2012) and Atlantic Salmon (Schreiner and Negus 2015) also occurred during this time period. Significant declines in survival of young Chinook Salmon were noted in Lake Huron in years when nearshore temperatures were colder than normal, allowing Lake Trout to forage nearshore in the vicinity of young Chinook Salmon. Higher survival of young Chinook Salmon was noted in years when nearshore water temperatures approached 65^{0} F, discouraging Lake Trout from moving closer to shore (Johnson et al. 2007). Johnson et al. (2007) also noted that in years with low Alewife abundance, predation on young Chinook Salmon increased, due to lack on an Alewife buffer.

Overall Chinook Salmon Program Costs

The overall cost of the Chinook Salmon program is difficult to calculate, but general estimates can be made based on both cost of fish produced in the hatchery and number of fish returned to the angler. Cost of fish produced is greatly influenced by the hatchery where the fish are reared, the mix of fish in the hatchery, the amount of time fish spend in the hatchery, and if the gametes come from a captive or feral broodstock. In Minnesota, all Chinook Salmon were reared at the FRCWH and most of the gametes used for the program were taken from feral broodstock returning to the French River trap, except when the program first began in the mid-1970s, and from 1999-2002 when eggs were obtained from Lake Huron. No captive Chinook Salmon broodstock was ever established for the Minnesota program. All Chinook Salmon were either stocked as fry or fingerlings, spent less than 9 months in the hatchery, and were never reared in raceways, so the cost/fish produced was relatively low when compared to other salmonid hatchery programs. The relatively large numbers of fish produced in the earlier years (350-500 thousand) also decreased the cost/fish significantly.

The average cost to produce a hatchery-reared Chinook Salmon in the early 1990s was approximately $0.25/fingerling (Schreiner 1995), and increased to $0.30/fingerling by the early 2000s (Schreiner et al. 2006). The total production program cost over that period ranged from approximately $125,000.00 – $150,000.00 annually. The production costs do not include depreciation of hatchery facilities, cost to procure gametes, disease testing and stocking fish into Lake Superior tributaries.

The cost of fish returned to the angler can be calculated by dividing the total cost of fish stocked by the number of fish returned to the angler. Although the cost to produce a Chinook Salmon was relatively low and stable over the years the program was conducted, the harvest of hatchery-reared Chinook Salmon by anglers was extremely variable and had a large impact on the cost of fish caught. This was especially evident in the later years of the program when over 95% of the Chinook Salmon harvested were wild fish (Figure 11). The average cost of Chinook Salmon caught from 1988-1994 in the Lake Superior fishery from all sources was approximately $63.00 per fish (Schreiner 1995). However, with the decreased survival of stocked fish, the cost of a hatchery-reared fish returned to the angler increased 6-fold to approximately $360.00/fish by the early 2000s.

When the same cost method was applied to fish stocked from 1999-2002 (gametes from Lake Huron), the cost per hatchery fish harvested averaged about $360.00 when both the summer boat and fall stream fishery were considered (Table 8). However, costs were variable and increased dramatically in some years when only the summer boat fishery was considered (Table 8).

TABLE 8. Cost to produce a hatchery-reared Chinook Salmon fingerlings, and cost of hatchery-reared Chinook Salmon returned to the angler for 1999-2002 year classes (Lake Huron strain).

Year class	Cost/fish stocked	Cost/fish caught in summer boat fishery	Cost/fish caught in summer boat and fall shore fisheries
1999	$0.25	$233.38	$147.67
2000	$0.32	$476.12	$241.07
2001	$0.29	$923.65	$672.50
2002	$0.32	$1,642.60	$381.31
Mean	**$0.30**	**$818.94**	**$360.64**

Discontinuation of Stocking

In the *1995 Fisheries Management Plan for the Minnesota Waters of Lake Superior* (LSMP), criteria were established to review the Chinook Salmon stocking program if adult spawners returning to the French River trap could not provide enough gametes to sustain the program at a minimum of 150,000 fingerlings per year (Schreiner 1995). Starting in 1994, the return of Chinook Salmon spawners to the French River trap was insufficient to meet the 150,000 fingerling target level. The 1995 LSMP also proposed catch objectives for the summer boat fishery and the fall stream fishery of 1,600 and 1,000 Chinook salmon respectively. The objective for the summer boat fishery has been met consistently, while catches in the fall fishery fell below 1,000 Chinook salmon beginning in 1991. Because criteria proposed for the Chinook Salmon program in the 1995 LSMP were not met, a series of public input meetings were held to determine the future of the program. After much discussion, the decision was made in 1998 to extend the Chinook Salmon stocking program for four years, 1999-2002, using fertilized eggs collected from Lake Huron in an attempt to reestablish a feral broodstock. If successful, the return of spawners to the French River trap would have to be large enough to support a Chinook Salmon hatchery program. Criteria were established to judge the success of the "Lake Huron Experiment" and to determine the future of the Chinook Salmon program if the criteria were not met. The criteria stated that the Chinook Salmon stocking program would be discontinued in 2006 or before if the annual return of mature Chinook Salmon to the French River trap fell below 75 BKD-free pairs for three consecutive years starting in 2003 (Appendix 7). Despite the four years of intensive stocking, returns to the French River trap remained very low. Returns of stocked Lake Huron strain Chinook salmon should have peaked from 2003-2006 based on the historical high returns of 3-5 year-old fish to the French River trap. Returns allowed the spawning of just 13, 20, 9 and 15 pairs from 2003-2006 respectively. Therefore, the recommendation to discontinue the Chinook Salmon stocking program was made and implemented during the 2006 LSMP (Schreiner et al. 2006).

Maintenance of summer and fall fisheries for Chinook Salmon is desirable from the perspective of providing diverse fishing opportunities to Lake Superior anglers. Natural reproduction occurring largely outside Minnesota with immigration to Minnesota has enabled harvest objectives to be met for the summer boat fishery, but not the fall stream fishery. Minnesota appears to lack sufficient spawning habitat to sustain significant runs of naturalized Chinook Salmon. Because the summer boat fishery is supported by over 95% wild fish and Chinook Salmon stocked in Minnesota constituted an average of less than 5% of the harvest from 2000-2006, discontinued stocking has not significantly impacted this fishery. The fall fishery was affected by discontinuing the stocking program because a majority (73.4%) of Chinook Salmon harvested in the fall creel were of Minnesota hatchery origin. Returns to the fall creel and the French River trap declined to very low levels despite high levels of stocking and favorable stream flows, indicating that the fish community dynamics in Lake Superior changed such that significant fall runs and a feral brood stock could no longer be supported through a reasonable stocking effort.

With the restoration of Lake Trout, establishment of naturalized Chinook Salmon populations, and concerns over the forage base, stocking Chinook Salmon was no longer necessary or prudent. Various studies have found that stocking to supplement wild or naturalized populations is usually inefficient, can introduce disease, and may pose genetic risks to the sustainability of the wild populations (Krueger et al. 1994; Miller and Kapuscinski 2003; Negus et al. 2012). The cost-effectiveness of stocking Chinook Salmon in Lake Superior is being examined by agencies still implementing those programs (Schreiner et al. 2010; Schreiner et al. 2016). Based on the continued low contribution of hatchery-reared Chinook Salmon to the fishery and the low return rate to the French River trap in addition to meeting the criteria established for program discontinuation, the stocking of Chinook Salmon in Minnesota was eliminated in 2007.

Present/Future Status

Abundance of Chinook Salmon in Minnesota's portion of Lake Superior varies annually, but continues to provide a diverse and productive fishery. The fishery is now entirely dependent on natural reproduction, since stocking was discontinued in 2007, yet angler harvest of Chinook Salmon in the summer fishery has remained high. In fact, in recent years Minnesota anglers have experienced some of the highest harvest and harvest rates for Chinook Salmon in the summer and charter fishery on record (Figures 5 and 6). Natural year class strength of Chinook Salmon now drives the overall abundance in Lake Superior, with most of the fish harvested in Minnesota being produced in the larger rivers of other jurisdictions (Nipigon, Michipicoten, Brule, etc.). As with many other fisheries, natural year class strength can vary annually and there are years of low production along with years of very high production, especially with a species that is relatively short lived like Chinook Salmon (vulnerable to angling for approximately three years).

Chinook Salmon are now present and self-sustaining throughout the Lake Superior basin. There is no indication that continued stocking of hatchery-reared Chinook Salmon is necessary to provide a diverse fishery, and continued stocking may actually be detrimental to the fishery through the potential threat of disease introduction and negative genetic impacts to the naturalized populations (Schreiner et al. 2010). There are major concerns, and examples of transferring disease from hatchery-reared salmonids to wild populations (Pacific Northwest Fish Health Protection Committee 1989; Noakes et al. 2000). In the Great Lakes, BKD and whirling disease have already caused mortality in wild stocks, and there is continued concern surrounding Viral Hemorrhagic Septicemia (VHS), a virus that Chinook Salmon are vulnerable to (Phillips et al. 2014). To reduce the threat of disease, stocking of Chinook Salmon should be critically reviewed by the agencies that continue to stock, especially given the minimal contribution of hatchery-reared fish to the angler. If Chinook Salmon are stocked, strict adherence to Great Lakes fish health protocols must be followed (Hnath 1993; Horner and Eshenroder 1993; Philips et al. 2014). Unless extreme changes in the Lake Superior fish community occur, or a disease specific to Chinook Salmon is introduced, they will likely remain an important part of the Lake Superior fish community.

As described earlier, Chinook Salmon in Lake Superior are on the margin of their thermal range in most months, having to endure cold water temperatures for extended periods. They often grow and survive much better in years when water temperatures are warmer. If climate change continues to increase Lake Superior water temperatures, and extend the open water period, these changes may enhance the environmental conditions for Chinook Salmon in Lake Superior (Magnuson et al.1997; Schreiner et al. 2006; Cline et al. 2013). On the other hand, if water temperatures in spawning and nursery streams increase, streams become barred off in the fall due to low lake levels, or catastrophic events increase (e.g. floods and droughts) natural reproduction may be inhibited and Chinook Salmon populations may decline.

Similar to Coho Salmon, the naturalization of Chinook Salmon should be viewed as a success by anglers interested in a diverse Lake Superior sport fishery. Present environmental conditions in Lake Superior, especially relatively cold water temperatures throughout much of the year, and a reduced level of prey abundance, may continue to limit the total production of Chinook Salmon to 10-20% of the overall sport fish harvest. Growth and maximum size of Chinook Salmon has declined from the late 1970s and 1980s when Rainbow Smelt were much more abundant. With the Lake Superior fish community now considered at carrying capacity for top predators, increases in growth and maximum size of Chinook Salmon are unlikely unless prey availability increases or Lake Trout abundance decreases. A changing climate, and population dynamics of the prey fish community will have a large influence on the future of the Chinook Salmon stocks in Lake Superior.

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Appendices

Appendix 1. Chinook Salmon fingerlings stocked into four major streams. Rate = number/pound.

	French River		Lester River		Baptism River		Cascade River		Total	Average
Year Stocked	**Number stocked**	**Rate**	**Number stocked**	**Rate**	**Number stocked**	**Rate**	**Number stocked**	**Rate**	**Number stocked**	**Rate**
1974	83,505		0		60,599	77	71,900		216,004	77
1975	0		0		0		0		0	
1976	86,600		0		86,600	60	86,600		259,800	60
1977	40,573	16	0		0		11,000		51,573	16
1978	58,925		0		43,333	36	44,455		146,713	36
1979	72,246	178	0		73,410	150	48,357		194,013	164
1980	46,795	245	47,530	245	0		60,025	245	154,350	245
1981	86,844	190	57,240	277	154,759	245	113,560		412,403	237
1982	78,560	155	79,376	164	141,777	177	66,555		366,268	165
1983	100,102	117	75,668	165	95,160	122	104,710		375,640	135
1984	130,179	105	0[a]		100,079	270	101,866		332,124	188
1985	103,632	111	0[a]		107,193	120	112,256		323,081	115
1986	100,928	119	205,825	79	108,100	115	111,683	121	526,536	109
1987	105,797	95	98,809	104	100,300	118	103,626	114	408,532	108
1988	119,108	85	100,234	94	110,508	95	50,285	89	380,135	91
1989	103,255	76	203,263	100	111,776	112	100,025	81	518,319	92
1990	115,333	72	180,798	82	102,634	80	100,284	89	499,049	81
1991	101,945	87	152,140	97	101,927	94	103,048	109	459,060	97
1992	109,020	93	37,461	73	44,820	76	45,652	84	236,953	81
1993	105,159	108	146,723	115	100,004	132	101,034	110	452,920	116
1994	111,092	77	150,075	84	100,209	96	100,033	100	461,409	89
1995	100,103	56	88,138	63	53,308	40	57,009	226	298,558	96
1996	100,966	50	0		0		0		100,966	50
1997	36,235	60	0		0		0		36,235	60
1998	21,922	78	0		0		0		21,922	78
1999	100,431	97	96,172	96	91,531	108	84,699	95	372,833	99
2000	100,012	77	85,012	78	85,072	96	84,985	89	355,081	85
2001	103,522	84	88,075	106	88,025	101	88,006	101	367,628	98
2002	100,166	78	85,153	89	85,089	105	90,261	100	360,669	93
2003	55,859	46	0		0		0		55,859	46
2004	14,259	26	0		0		0		14,259	26
2005	43,128	80	0		0		0		43,128	80
2006	15,675	47	0		0		0		15,675	47

[a] No Chinook Salmon fingerlings stocked in Lester River due to research project.

Appendix 2. Chinook Salmon stocked in small streams, using various life stages. Fgl = fingerlings.

River	Year Stocked	Life stage	Number stocked
Chester	1991	Fgl	50,013
	1993	Fgl	49,939
	1994	Fgl	50,546
Two Island	1982	Fry	147,416
	1984	Fry	9,060
	1985	Fry	20,584
	1986	Fry	9,000
	1987	Fry	20,115
Temperance	1980	Fgl	24,304
	1981	Fry	78,486
	1982	Fry	106,218
	1982	Fgl	58,829
	1983	Fry	379,143
Fall	1980	Fgl	20,580
	1981	Fgl	30,725
	1982	Fgl	19,890
	1983	Fgl	29,920
	1988	Fgl	10,000
Lester	1984	Fry	5,200
	1985	Fry	5,227
	1986	Fry	18,052
	1987	Fry	5,037
Cascade	1986	Fry	23,984
	1987	Fry	12,338
Baptism	1987	Fry	13,740
Brule	1982	Fry	154,935

Appendix 3. Historical catches of Chinook salmon in the Fall Anadromous Creel Survey by station, 1986-2005. Totals in 1986 and 1987 are harvest only.

Station	1986	1987	1989	1991	1992	1993	1994	1998	2003	2005
Lester River	373	205	587	508	285	332	100	170	4	89
French River	0	0	364	90	97	44	0	10	0	0
Sucker River		0	0	0	0	0	49	7	0	0
Knife River	0	49	10	255	0	0	9	26	0	26
Baptism River	112	137	563	73	70	25	11	125	6	10
Cascade River	28	35	105	36	29	73	38	92	42	167
Fall creel totals	**513**	**426**	**1,629**	**962**	**481**	**474**	**207**	**450**	**52**	**292**

Appendix 4. Number of Chinook Salmon that returned to the French River trap (1976-2010) and Knife River trap (1996-2011) during the fall spawning run.

Year	French River trap	Knife River trap
1976	2	
1977	8	
1978	36	
1979	137	
1980	165	
1981	356	
1982	828	
1983	867	
1984	579	
1985	1,289	
1986	1,605	
1987	710	
1988	1,001	
1989	1,144	
1990	529	
1991	366	
1992	422	
1993	470	
1994	207	
1995	186	
1996	108	4
1997	115	1
1998	166	9
1999	458	9
2000	92	2
2001	25	0
2002	105	2
2003	54	0
2004	75	0
2005	45	0
2006	56	0
2007	79	11
2008	12	5
2009	2	0
2010	6	0
2011	Not operated	0
2012	Not operated	Flood

Appendix 5. Number of spawning females captured in the French River trap, and eggs per female, 1980-2005.

Year	Females spawned	Total eggs	Eggs per female
1980	23	92,575	4,025
1981	20	37,100	1,855
1982	123	430,500	3,500
1983	146	585,460	4,010
1984	105	403,725	3,845
1985	225	958,725	4,261
1986	380	1,750,280	4,606
1987	242	1,204,676	4,978
1988	379	1,743,779	4,601
1989	352	1,515,008	4,304
1990	302	1,195,316	3,958
1991	142	712,414	5,017
1992	158	708,472	4,484
1993	161	780,206	4,846
1994	56	263,928	4,713
1995	38	167,846	4,417
1996	12	49,248	4,104
1997	10	38,370	3,837
1998	36	111,312	3,092
1999	84	336,000	4,000
2000	0		
2001	0		
2002	28	87,304	3,118
2003	13	27,911	2,147
2004	20	53,720	2,686
2005	9	27,576	3,064
Mean	**123**	**532,910**	**3,849**

Appendix 6. Average return to French River trap of Chinook Salmon by sex and age from 1993-2007.

Age	Male	Female	Total
0	2	0	2
1	2	0	2
2	8	0	8
3	30	12.7	42.7
4	17.3	22	39.3
5	2	2.7	4.7

Appendix 7. Criteria used to discontinue stocking and determine future of the Chinook Salmon program.

MNDNR CHINOOK SALMON PROGRAM
JULY 1998

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

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

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

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

Evaluation - Evaluate from 2000 - 2006.

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

Criteria:

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

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

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