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**FISHERIES DIVISION**

**RESEARCH REPORT**

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# Contribution of Hatchery Fish to Chinook Salmon Populations and Sport Harvest in Michigan Waters of Lake Superior, 1990-94

**James W. Peck**

*Michigan Department of Natural Resources*
*Marquette Fisheries Station*
*484 Cherry Creek Road*
*Marquette, Michigan 49855*

*Abstract.*–The composition of chinook salmon *Oncorhynchus tshawytscha* populations in Lake Superior was assessed in 1990-94 by all agencies stocking chinook salmon to determine relative contribution of hatchery and naturally-produced fish. These data were gathered to assess chinook salmon stocking programs and provide the basis for evaluating effects of chinook salmon on the Lake Superior fish community. About 1-3 thousand chinook were caught annually in Michigan's Lake Superior sport fishery during 1990-94. Chinook ranked third behind lake trout and coho salmon *Oncorhynchus kisutch*, and represented 6% of total salmonines caught. Most chinook were ages 2 and 3 in lake catches and ages 3 and 4 in stream catches. Michigan hatchery chinook contributed 7% to the Michigan lake catch during 1990-94, with Minnesota, Wisconsin, and Ontario fish contributing 10%, 5%, and 2%. The highest contribution of hatchery fish was in Keweenaw-Huron Bays (31%), with 8% Michigan fish. The lowest was at Black River-Ontonagon (9%), but all were Michigan fish. The 1989 year-class provided the best return to the lake sport fishery as a percentage of number stocked (0.10%), with an average return of 0.07% for all year-classes. Number of coded-wire tags recovered per 100,000 tagged fingerlings stocked were higher from sport fisheries on stocked tributaries than from lake fisheries, with highest returns from Black and Dead rivers. Chinook salmon spawned in at least 10 Michigan tributaries during 1990-94 (four stocked and six non-stocked). Hatchery chinook made up 80% of spawning runs in two stocked streams and most (70%) were Michigan fish; whereas in a non-stocked stream, naturally-produced chinook contributed 70% and most hatchery fish were from Wisconsin (17-22%). Michigan hatchery chinook moved east and west from all stocking sites and strayed throughout Lake Superior, with one moving about 600 miles to southern Lake Michigan. Length-at-age of chinook captured during February-June ranged from 12 inches at age 1 to 33 inches at age 5, with growth increments of 10 inches between ages 1 and 2, 5 inches between ages 2 and 3 and 3 and 4, and about 3 inches between ages 4 and 5. A chinook salmon weight-length relationship calculated from 1992 data was $\log_e$ [weight (lb)] = -8.52 + 3.14 $\log_e$ [total length (in)], and was similar to relationships calculated from 1993 and 1994 data. Total annual mortality rates for age-3 chinook and older averaged over 70%. Sea lamprey wounding on chinook was less than 5 wounds per hundred fish, and incidence of bacterial kidney disease was 2.3%. Fish made up 99% by weight of chinook food items and most (53%) were coregonines. Michigan should cooperate with other agencies to at least maintain current lake-wide stocking levels. Michigan should explore strategies for increasing imprint and survival of chinook it stocks to develop fisheries in tributaries. The number of chinook stocked in Lake Superior probably could be increased without harming lake trout populations, but it is not certain if this would result in more fish for the fishery.

## Introduction

Stocking hatchery-reared chinook salmon *Oncorhynchus tshawytscha* was a major part of the revitalization of the Great Lakes sport fishery in the late 1960s. Chinook salmon played a major role in the increase in angler-days in all of Michigan's Great Lakes waters from insignificance in 1965 to over 3 million in 1971 and dominated the salmonine sport catch in much of Lake Michigan and Lake Huron by the mid-1980s (Rybicki 1973; Rakoczy and Rogers 1987; Hansen 1990). Chinook salmon also have become an important sport fish in Lake Superior. Chinook have generally ranked third numerically behind lake trout *Salvelinus namaycush* and coho salmon *Oncorhynchus kisutch* in Michigan waters (Peck 1992; Peck et al. 1994). Chinook salmon grow to large size in Lake Superior during their 3- to 5-year life span, reaching weights between 20 and 30 lb and averaging 5-8 lb in the sport catch (Close et al. 1984; Peck 1992).

Chinook salmon were first stocked in Lake Superior in late 1800s, when 60,000 were stocked in Carp River at Marquette, Michigan in 1874 and 4,000 were stocked in St. Louis River at Duluth, Minnesota in 1875 (Parsons 1973). These fish were part of over 11 million chinook salmon stocked in the Great Lakes during 1873-1933. Apparently few of these fish survived to be adults, and there was no evidence of natural reproduction in any of the Great Lakes. Most of these chinook were Sacramento River (California) strain stocked as fry in December and January and in a wide range of environments (Parsons 1973). No further chinook salmon stocking was done in the Great Lakes until 1967-68 when Michigan stocked Columbia River (Oregon) strain fingerlings in tributaries to lakes Michigan, Huron, and Superior. Michigan's objectives for re-introducing coho and chinook salmon in the mid-1960s were to reduce the abundance of alewife *Alosa pseudoharengus* in Lake Michigan and Lake Huron through predation, provide fish for a new and diversified sport fishery and revitalization of the commercial fishery, and establish naturalized populations (Tody and Tanner 1966). Although alewife were scarce in Lake Superior, Michigan stocked coho and chinook there to enhance fisheries and establish natural populations. Chinook salmon have been stocked annually at one or more sites in Lake Superior waters in Michigan since 1967. Other agencies that have also stocked chinook annually are Minnesota since 1974, Wisconsin since 1977, and Ontario since 1988 (Peck et al. 1994). The number of chinook stocked increased from 34,000 by Michigan in 1967, reached 1.8 million by all agencies in 1990, then decreased to about 1.4 million by 1994. Fingerlings were routinely stocked by all agencies, usually in May, at about 4-5 months old.

This study was undertaken to evaluate the relative contribution of hatchery and naturally-produced chinook salmon to chinook populations in Lake Superior. Michigan and other agencies stocking chinook in Lake Superior were interested in an assessment of whether hatchery chinook were providing a return to fisheries. Data on relative contribution hatchery and naturally-produced were also needed to determine chinook salmon stock size and assess potential impact of chinook salmon on the Lake Superior fish community, especially lake trout. Lake trout growth decreased during the 1980s and competition with chinook salmon and other non-native salmonines for decreased abundance of the major forage fish, rainbow smelt *Osmerus mordax*, was considered to be a factor (Hansen et al. 1994a; 1994b). Rainbow smelt abundance decreased 90% between 1978 and 1981, recovered somewhat in the mid-1980s, but decreased again to only 25% of its 1978 biomass by 1992 (Selgeby et al. 1994). Rainbow smelt made up similar proportions in lake trout and chinook salmon diets but were less important in diets of other non-native salmonines (Conner et al. 1993), so chinook were suspected to be the major competitor with lake trout. The Lake Superior fish community objective for non-native salmonine predators was a predator-prey balance that maintained normal growth of lake trout (Busiahn 1990), and a lake trout rehabilitation plan for Lake Superior (The Lake Superior Technical Committee, unpublished) called for reduced stocking of chinook salmon if lake trout growth decreased. Some Lake Superior biologists believed that chinook salmon populations were largely hatchery fish and could be controlled by stocking levels (Busiahn 1990), whereas others questioned this because other introduced *Oncorhynchus* species in Lake Superior had developed naturally-reproducing populations (Wagner and Stauffer 1978; 1982; Peck 1992). The Lake Superior Committee of the Great Lakes Fishery Commission directed the Lake Superior Technical Committee to determine the representation of hatchery and wild fish in the Lake Superior chinook population. The technical committee concluded that to determine the contribution of hatchery chinook would require marking all chinook stocked in Lake Superior for at least 3 years and assessing their relative abundance in the chinook sport catch. Additional data would be obtained from assessments of spawning runs in Lake Superior tributaries, assessment netting for other species, and voluntary reports by anglers. Technical committee members agreed to pool data in a common report, as well as prepare individual reports describing results in their waters. Objectives of this study were (1) to determine relative contribution of wild chinook salmon and hatchery chinook salmon stocked by Michigan and other agencies to Michigan's Lake Superior sport fishery, (2) to determine movements of hatchery chinook salmon from Michigan stocking sites and subsequent return to the sport fishery, and (3) determine age composition, growth, mortality, and food habits of chinook salmon in Michigan waters.

## Methods

All chinook salmon stocked in 1988, 1989, and 1990 in Lake Superior were marked with a fin clip specific to each agency. Assignment of fin clips was coordinated by the Great Lakes Fishery Commission. Clips assigned were right-ventral (RV) to Michigan, left-pectoral (LP) to Minnesota, left-ventral (LV) to Wisconsin, and right-pectoral (RP) to Ontario. Michigan chinook were tagged with coded-wire tags (CWTs) to evaluate return to specific stocking sites, straying from Lake Superior to other Great Lakes, and provide known-age fish to validate aging techniques. Convention dictated that the adipose (Ad) fin clip be used on fish that are tagged with CWTs, so Michigan used this clip instead of RV. Coded-wire tags are marked with a binary code that can be used to identify numerous variables (Jefferts et al. 1963), which in this study included stocking site, stocking date, and hatchery where reared. Michigan evaluated fin-clip quality and loss of CWTs prior to stocking.

Since introduction of Green River (Washington) strain in Lake Superior in 1967, chinook stocked in Michigan waters of Lake Superior have been progeny of chinook from Lake Michigan. Chinook salmon stocked for this study during 1988-90 originated from eggs collected from spawning runs in Little Manistee River, a Lake Michigan tributary. Most were hatched, reared, and stocked by Thompson State Fish Hatchery located near Manistique, Michigan, but about 20,000 chinook at each of three sites in 1988 and about 10,000 chinook at each of two sites in 1989 were hatched, reared, and stocked by Wolf Lake State Fish Hatchery located near Kalamazoo, Michigan. These Wolf Lake chinook had been heat-shocked to induce triploidy and carried specifically-coded CWTs. Chinook at Thompson hatched in early January, were fin clipped and tagged in April, and were stocked in early to mid May. Chinook at Wolf Lake hatched in late December but were stocked in mid to late April so age at stocking by both hatcheries was 4 months. Number of fingerlings per kg was estimated by hatchery personnel from random scap-net samples that were weighed and counted. Number per kg was used to apportion the designated number for each stocking site and to estimate mean weight of individual fish. Mean weight was generally 3-5 g, except those from Wolf Lake in 1988 averaged about 8 g.

Fin clipping and tagging at Thompson State Fish Hatchery was done during a 3-week period in April each year by temporary workers supervised by Marquette and Charlevoix Fisheries Station personnel. Evaluation of fin-clip quality was done during the 3-week period, and evaluation of CWT retention was done immediately before stocking, 2-3 weeks after tagging. A good adipose clip was one that passed through the stem completely and removed the entire lobe; whereas, excision higher on the fin, either vertically or horizontally through the lobe, might not be recognized as a clip (Jones 1979). Presence or absence of a CWT was determined by checking a random sample of fish with a Northwest Marine Technology Field Detector.

The contribution of Michigan hatchery chinook to populations in Lake Superior was determined primarily from their representation in sport catches during 1990-94. Michigan, Minnesota, and Wisconsin all had creel surveys at major Lake Superior sites during most of the fishing season. Ontario did not have a creel survey to determine total catch but did determine percentage of hatchery chinook in their sport catch by checking fish during 2- to 4-d fishing derbies at two to four sites per year. Chinook generally enter the sport fishery at age 1, so fingerlings stocked in 1988 would contribute to the fishery in 1989. However, Michigan did not have a creel survey in 1989 and percentage of age-1 chinook in the catch was low in other jurisdictions, so assessment began with the 1990 fishing season. Creel surveys in Michigan, Minnesota, and Wisconsin or derby monitoring in Ontario were on-site where clerks interviewed anglers to gather data on fishing effort (angler-hours) and/or fish caught (number, fin clip, length, weight, sex, age, and sea lamprey wounds).

In Michigan, clerks supervised by Department of Natural Resources District 1 Fisheries surveyed the sport fishery at Black River Harbor, Ontonagon, Keweenaw Bay, and Huron Bay; and clerks supervised by Marquette Fisheries Station surveyed the sport fishery at Marquette, Dead River, AuTrain, and Munising (Figure 1). Creel surveys were done various months during February-October, depending on sites, budgets, and ice conditions. Counts and angler interviews recorded by creel clerks were sent to Charlevoix Great Lakes Station, Charlevoix, Michigan where estimates were made of angler-hours, catch per angler-hour (CPE), and total catch.

Number of Michigan's Lake Superior tributaries having chinook salmon spawning runs was determined from angler reports, and observations and electro-fishing surveys by Department of Natural Resources personnel. Percentage of hatchery and wild chinook salmon in spawning runs in certain Lake Superior tributaries during September-October 1990-94 was determined from sport catches sampled by creel survey (Dead River) or from electro-fishing survey catches (Carp River, AuTrain River, Silver River). Wisconsin monitored Brule River chinook salmon spawning runs by observing fish as they passed a viewing window in a weir. Minnesota determined composition of chinook runs in French River based on catch in a weir trap, and in several other tributaries based on sport catch sampled by creel survey. Ontario assessed chinook salmon spawning runs in Kaministiquia River with a creel survey.

Movements of hatchery chinook salmon stocked by Michigan and other agencies was determined by reported recovery of Michigan fish in other jurisdictions and recovery of fish stocked by Wisconsin, Minnesota, and Ontario in Michigan. Movements of hatchery chinook salmon stocked at specific Michigan sites was determined from recoveries of CWTs in all jurisdictions of Lake Superior and in other Great Lakes. Heads or snouts of Ad-clipped chinook salmon were solicited from anglers via direct contact with anglers by creel clerks, or through articles in newspapers, and posters placed at fishing sites. Heads were also recovered from fish collected with electrofishing gear by Marquette Fisheries Station personnel. Other agencies working on Lake Superior and tributaries were also asked to save heads or snouts from Ad-clipped chinook. The heads were checked for presence of a CWT at the Marquette Fisheries Station using a Northwest Marine Technology Field Detector, then sent to the Charlevoix Fisheries Station at Charlevoix, Michigan for tag removal and reading. Binary codes on CWTs were specific to stocking sites in Michigan waters so movement from and homing to each site could be assessed. Chinook salmon stocked in Lake Michigan and Lake Huron had also received CWTs so agencies on these lakes were also collecting chinook heads to recover tags.

Age of chinook salmon sampled in the sport catch at Black River Harbor, Ontonagon, Keweenaw Bay, and Huron Bay was determined from scales and CWTs by District 1 Fisheries and Marquette Fisheries Station personnel. Age of chinook in the sport catch and spawning runs sampled at Marquette, AuTrain, Munising, Dead River, Carp River, and AuTrain River was determined from scales and CWTs in 1990-91 and a combination of scales, otoliths, and CWTs in 1992-94 by Marquette Fisheries Station personnel. Annuli were usually recognizable on scales of immature fish, but not on mature fish collected during August-December. Latter stages of gonad development resulted in absorption of scale material, often to the extent that the annulus formed that year was absorbed. Chinook otoliths soaked in hot xylene were found to be a better structure than scales for aging mature fish when the two structures from known-age fish were compared. Known-age fish were hatchery chinook with CWTs because the binary code on the tag specifically identified year stocked. Growth of chinook salmon was based on total length (in) or weight (lb) at age of capture.

Total annual mortality was estimated from number caught in each age group on the descending limb of the catch curve during 1990-94 using the method described by Robson and Chapman (1961), and by comparison of year-class catch per angler-hour during successive years of vulnerability (Ricker 1975, p. 39). Sea lamprey predation was assessed by recording number of sea lamprey wounds (King and Edsall 1979) on chinook sampled in creel surveys and electrofishing surveys. Incidence of bacterial kidney disease (BKD) in chinook salmon in Lake Superior was assessed in 1991 and 1992. Assessments were based largely on observed clinical signs in 1991, and mainly on results of the Field ELIZA Test on kidney and ovarian fluid samples in 1992. Creel clerks recorded presence or absence of BKD clinical signs for chinook captured in the sport fishery at Marquette, AuTrain, Munising, and Dead River and collected kidney and ovarian fluid samples from chinook at these sites in 1992. Marquette Fisheries Station personnel collected kidney and ovarian fluid samples from chinook in Carp, AuTrain, and Silver rivers in 1992. Samples were sent to the fish pathology laboratory at Wolf Lake State Fish Hatchery for Field ELIZA Test analysis.

Chinook stomachs were collected by creel-survey clerks during March-August 1992-93 from chinook captured in the Lake Superior sport fishery between Marquette and Munising. Stomachs were preserved in 10% formalin and later examined by Marquette Fisheries Station personnel to determine diet composition. Food items were identified to the lowest recognizable taxon, counted, and weighed. Diet data were characterized as percent frequency of occurrence and percentage of total food by weight.

## Results

*Number stocked, marked, and tagged*

Number of chinook salmon fingerlings stocked annually during 1988-90 ranged from 335,000 to 365,000, with about 100,000 stocked in each of the Dead and Carp rivers at Marquette, and the remainder stocked in Ontonagon River at Ontonagon and at the mouth of Black River near Ironwood (Figure 1, Table 1). Percentage of good clips on chinook salmon stocked at the four sites during 1990-94 ranged from 90% at Black River Harbor to 95% at Ontonagon, with an overall average of 93% (Table 2). Percentages within sites were more variable with a low of 74% at Black River Harbor in 1989 to a high of 99% at Black River Harbor and Ontonagon in 1990. Estimated number of chinook stocked with a good fin clip ranged from about 176,000 in Ontonagon River to 287,000 in Dead River. Tag retention ranged between 83% and 97% among and within all sites and averaged 92% overall. Estimated number stocked with a good fin clip and carrying a CWT ranged from 167,000 at Black River Harbor to 262,000 at Dead River.

*Sport Fishery and Contribution of Hatchery Fish*

The estimated chinook salmon sport catch in Michigan waters of Lake Superior was a little over 1,000 in 1990 when only a summer creel survey was done, and ranged between 1,779 and 3,746 during 1991-94 when both summer and winter creels were surveyed (Table 3). The chinook salmon catch was most consistent at Marquette but highest in Keweenaw Bay in three of the five years (1992-94). Chinook catch per angler-hour (CPE) was fairly constant at Marquette, but fluctuated without trend at other survey sites. Under the minimum size limit of 10 inches, chinook enter the sport catch at age 1 in the late winter-early spring ice fishery, but most fish were older and taken in the open-water troll fishery during May-June (Rakoczy and Svoboda 1995). Ages 1 through 6 were represented in the lake sport catch with ages 2 and 3 generally contributing most fish caught in 1990-94 (Table 4). Age composition during 1990-94 indicated that 1989 and 1991 year classes were stronger than 1988 and 1990. The 1989 year class dominated at age 2 in 1991 and age 3 in 1992, and was well represented at age 4 in 1993. The 1991 year class dominated in 1993 and 1994. Sport catch of spawning-run chinook in a stocked tributary (Dead River) decreased from over 1,100 in 1990 to around 100 in 1994 (Table 5). Effort and CPE also decreased in Dead river during 1990-94.

Contribution of hatchery chinook to the chinook catch in Michigan's Lake Superior sport fishery ranged from 13% to 33% and averaged 24% during 1990-94, but most hatchery fish were stocked by other agencies (Table 6). Michigan hatchery chinook salmon contributed 7% of the Michigan sport catch during 1990-94, ranging from 5% in 1991 and 1993 to 10% in 1990, 1992, and 1994. Minnesota fish made up 10% of the catch, ranging from 2% in 1990 to 13% in 1992 and 1994. Wisconsin fish accounted for 5% (range = 1-7%) and Ontario 2% (range = 0-4%) of the Michigan sport catch. Adjusting for missed or unrecognizable adipose clips would raise the contribution of Michigan hatchery fish to the Michigan sport catch from 7% to 8%.

Contribution of hatchery and wild chinook to sport fisheries varied among the four Michigan areas of Lake Superior creel-surveyed in 1990-94, with the highest contribution of hatchery fish in Keweenaw-Huron Bays and lowest at Black River-Ontonagon (Table 6). At Black River-Ontonagon, all hatchery fish were Michigan fish and this was the highest representation among areas. Keweenaw-Huron Bays had the next highest percentage of Michigan fish and the highest percentage of Minnesota fish. The highest percentages of Wisconsin and Ontario hatchery chinook were reported from Marquette.

Return of Michigan hatchery chinook salmon to Michigan's Lake Superior sport fishery (percentage of recognizably-marked chinook caught by anglers) during 1990-94 was highest for the 1989 year class, lowest for the 1988 year class, and averaged 0.07% for all year classes (Table 7). Returns to the Dead River sport fishery were generally higher than to the lake fishery, and decreased from 0.37% for the 1988 year class to 0.09% for the 1990 year class and averaged 0.22% overall.

Returns of CWTs (number with tags caught in the sport fishery per 100,000 stocked with good clips and retained tags) ranged from 5 to 54 during 1990-94 (Table 8). Returns were higher in two of the four stocked tributaries than in any lake fishery. Among tributary fisheries, returns were highest in Black and Dead rivers. Returns from the Lake Superior sport fishery were highest for chinook stocked in Ontonagon and Carp rivers.

### *Contribution to Spawning Runs*

I found evidence of chinook natural reproduction in 10 of 32 Michigan tributaries surveyed during 1990-94 (Table 9). In addition to the four stocked tributaries (Black River, Ontonagon River, Dead River, Carp River), adult chinook and/or chinook redds were found in six other streams (Big Iron, Falls, Silver, Laughing Whitefish, AuTrain, and Sucker rivers). Most adult chinook salmon were hatchery fish in stocked streams and naturally-produced fish in non-stocked streams. Michigan hatchery chinook made up about 70% of spawning runs in the stocked Dead and Carp rivers, with Wisconsin and Minnesota contributing about 10%. In the non-stocked AuTrain River, naturally-produced chinook made up about 70% of spawning runs, with hatchery fish being mainly from Wisconsin (17-22%). Chinook ages 3 and 4 made up 91-98% of spawning fish in the stocked Dead and Carp rivers in 1992-94 and 80% in the non-stocked AuTrain River in 1992-93 (Table 10).

*Movements of Hatchery Chinook Salmon*

Michigan chinook salmon moved throughout Lake Superior and strayed extensively during the spawning period. Michigan chinook contributed 6%, 5%, and 1% to lake sport catches in Minnesota, Wisconsin, and Ontario, respectively, and made up 1-2% of spawning runs in some Minnesota, Wisconsin, and Ontario tributaries (Lake Superior Technical Committee, unpublished data). Recovery of CWTs from Michigan-stocked chinook indicated that movement was both east and west in Lake Superior from all Michigan stocking sites, and some fish moved out of Lake Superior. Michigan hatchery chinook from Ontonagon and Dead River sites were recovered in spawning runs in Lake Michigan tributaries, the Grand and Little Manistee rivers. For one of these fish, the distance between stocking site and recapture site was about 600 miles. Movement into Lake Superior also occurred; a chinook stocked in St. Marys River at Sault Ste. Marie, Michigan was captured in Dead River in 1993.

*Growth*

Chinook salmon captured in February-June at Marquette, AuTrain, and Munising (MI-5 and MI-6) ranged in length from about 12 inches at age 1 to 33 inches at age 5 during 1992-94. Age-6 chinook were smaller than age-5 fish, and scale-growth patterns indicated they formed their first annulus in the stream and entered the lake as yearlings. Chinook growth in length was about 10 inches between age 1 and age 2, and about 5 inches between ages 2 and 3 and between ages 3 and 4 (Table 11). Limited data indicated a 2-4 inch increase between age 4 and age 5. Average weight of chinook collected during February-June ranged from 0.5 lb to 0.7 lb at age 1, 1.8 lb to 2.9 lb at age 2, 4.8 lb to 6.1 lb at age 3, 8.1 lb to 11.1 lb at age 4, and 12.6 lb to 13.3 at age 5. Chinook weight-length relationships during 1992-94 were similar for all three years (Table 12).

Chinook collected during July-October were larger at a given age than those collected earlier because most growth occurred during this period. However, mean length and weight of chinook in July-October samples were more variable among years than in February-June samples because fewer fish were sampled, and size was more related to when samples were collected within this period of faster growth than during February-June when growth was slow.

*Mortality*

Total annual mortality rates (fractional), calculated from catch-at-age for age-3 and older chinook salmon in Michigan's Lake Superior sport fishery in 1990-94 (Table 4), were 0.82 in 1990, 0.65 in 1991, 0.91 in 1992, 0.68 in 1993, 0.77 in 1994, and 0.75 for all years combined. Cohort mortality rates between successive years of vulnerability averaged 0.06 between ages 2 and 3, 0.67 between ages 3 and 4, 0.87 between ages 4 and 5, and 0.73 between ages 5 and 6. Sea lamprey wounding on chinook salmon ages 2-5 was less than 5 wounds per 100 fish during 1990-94. Of 176 chinook salmon tested for BKD incidence in 1992 (56 from lake sport catch and 120 from spawning runs in tributaries), four fish tested positive, an incidence of 2.3%. The four fish included a hatchery fish from the Dead River, two non-clipped (presumed naturally-produced) fish from AuTrain River, and one of unknown origin from the lake sport fishery.

*Diet*

Marquette Fisheries Station personnel examined contents of 178 chinook salmon stomachs collected in the April-October creel survey at Marquette, AuTrain, and Munising during 1992-93. Most stomachs were collected during May-July each year. Of the 178 stomachs examined, 47 (26%) contained food and 131 (74%) were empty. In stomachs with food, fish occurred in 87% and made up 99% of the diet by weight. Of the 99% by weight of fish, 53% were coregonines (20% lake herring *Coregonus artedii*, 18% lake whitefish *Coregonus clupeaformis*, 15% unidentified), 36% rainbow smelt, 8% yellow perch *Perca* *flavescens*, and 2% ninespine stickleback *Pungitius pungitius*. Invertebrates were found in about 18% of the stomachs containing food, and included insects (Ephemoptera, Lepidoptera, Hymenoptera) and crustacea (*Mysis, Bythotrephes, Diporeia*).

## Discussion

Chinook salmon do not make up a large component of Michigan's Lake Superior sport fishery, but attract interest among some anglers probably because of their large size and fighting ability. They fulfill one of the original goals of providing diversity to the fishery. Chinook catches during 1990-94 averaged 6% of the total number of salmonines harvested, ranking third behind lake trout (60%) and coho salmon (30%) (Rakoczy 1992; Rakoczy and Svoboda 1995). Chinook salmon likewise ranked third behind coho salmon and lake trout in the sport fishery at Marquette, Michigan during the 1980s, and 5% of anglers surveyed then indicated they were fishing specifically for chinook salmon (Peck 1992). Chinook catch in tributaries likely exceeds that in the lake fishery, but few tributaries are surveyed. Catch in just the Dead River was comparable to the total lake catch in 1990, and CWT returns indicate that catch in Black River may be even higher. Catch of chinook in Dead River exceeded the lake catch at Marquette during 1984-87 (Peck 1992). However, lack of fish appears to have caused a precipitous decline in the Dead River chinook fishery. Catch decreased more than 90% during 1990-94. Decrease in catch is likely due in part to a 50% reduction in number stocked after 1987, but may also be due to a decrease in survival of stocked chinook. Michigan's chinook sport fishery in Lake Superior at Marquette also has changed over the years. Creel survey data indicated between 1984-87 and 1990-94 chinook catch decreased and shifted from mostly mature fish in August-September to mostly immature fish in April-June (Peck 1992; Rakoczy and Svoboda 1995). The apparent decrease in number of chinook returning to Dead River may also be responsible for the lower lake catch of mature fish during August-September at Marquette.

As has been found for most other non-native salmonines in Michigan waters of Lake Superior, most chinook salmon sampled during 1990-94 were naturally produced. Introduced rainbow trout *Oncorhynchus mykiss*, brown trout *salmo trutta*, pink salmon *Oncorhynchus gorbuscha*, and coho salmon reproduce in Lake Superior tributaries and lake populations are all or mostly naturally-produced (Wagner and Stauffer 1978; Wagner and Stauffer 1982; Peck 1992; Seelbach and Miller 1993). In Minnesota, Wisconsin, and Ontario, naturally-produced chinook made up 44%, 68%, and 91% of 1988-90 year-class fish, respectively (Lake Superior Technical Committee, unpublished data). That percentages of hatchery fish were higher in Minnesota and Wisconsin than in Michigan could be due to more intensive stocking and less natural reproduction. Minnesota stocked around 500,000 chinook per year and Wisconsin stocked around 400,000 per year, and both jurisdictions together comprise much less area than Michigan (Peck et al. 1994). Chinook were also stocked in western Michigan and Ontario so over 70% of the chinook fingerlings stocked in Lake Superior during 1988-90 were stocked in or near Minnesota and Wisconsin waters. Minnesota and Wisconsin also reported fewer streams with evidence of chinook natural reproduction than Michigan and Ontario (Lake Superior Technical Committee, unpublished data) so it is likely that there were fewer naturally-produced fish in these waters. Hesse (1994) reported a much higher percentage of hatchery chinook in Michigan's Lake Michigan waters (33-78%), but stocking there was 15-16 times the number stocked in Michigan waters of Lake Superior, so actual number of naturally-produced chinook is likely greater in Lake Michigan than in Lake Superior. Whether chinook salmon have become naturalized in Lake Superior has not been determined, and it is unknown how much of natural reproduction is by hatchery and how much is by natural parents.

Hatchery chinook are a shared resource in Lake Superior, and proximity to a stocking location did not appear to benefit lake fisheries in Michigan. Most hatchery chinook caught in Michigan were stocked in Minnesota, Wisconsin, and Ontario, and Michigan hatchery chinook contributed 1-6% to these other jurisdictions (Lake Superior Technical Committee, unpublished data). Minnesota was the only jurisdiction where local hatchery fish contributed more to the lake fishery than hatchery fish stocked elsewhere. This might be because Minnesota hatchery fish were reared in water from a Lake Superior tributary, French River (Peck et al. 1994), providing a better imprint which retained or returned more fish to Minnesota waters and the local fishery. That Minnesota chinook were more abundant in Michigan's sport fishery than Michigan chinook was due in part to the greater number stocked by Minnesota. Adjusting for number stocked, percentage return of Minnesota fish to Michigan's sport fishery was 0.06%, which was slightly less than return of Michigan fish. The better overall contribution of Minnesota chinook may have been due to higher survival, but that has not been determined.

Chinook salmon growth in 1990-94 was as good as in 1984-87, and mortality of adult fish may be less. Mean length-at-age of chinook captured in the sport fishery during January-June 1984-87 (Peck 1992) was similar to that observed in this study. The presence of age-5 chinook in 1990-94 samples and absence of this age in 1984-87 samples may indicate better survival during the 1990s. Estimated total mortality rates of age-3 and older chinook may have been influenced by small sample size and fluctuations in year-class strength of recruits to these age groups. Chi-square values associated with the Robson-Chapman method in 1990, 1992,1993, and for all years combined exceeded 3.84 which indicated that there was greater than a 5% chance that factors other than sampling were affecting age composition (Robson and Chapman 1961). Variations in year-class strength were evident in age composition and violated the uniform recruitment assumption of the Robson-Chapman method. Although the Robson-Chapman rates are suspect, they were similar to rates calculated using the cohort method, and similar to rates calculated in other studies. Total mortality rates of 70%, 95%, and 98% were assigned to ages 3, 4, and 5, respectively, in modeling predator populations in western Lake Superior (M. P. Ebener, Chippewa/Ottawa Treaty Fisheries Management Authority, personal communication). High mortality rates estimated in my study and similar rates used by Ebener in bioenergetics modeling were not unusual because most or all fish in these age groups were mature and most death was likely associated with spawning. Chinook mortality in ages 0, 1, and 2 were not estimated in this study, but Negus (1995) reported rates of 90%, 50%, and 50%, respectively for these ages. Although age composition indicated better survival of adult chinook in recent years, there is evidence of decreased overall survival. A decrease in chinook CPE in Dead River between 1993 and 1994 may indicate decreased survival of stocked fish. Number of chinook per 10,000 stocked returning to Minnesota's French River decreased from 189 for the 1981 year class to 27 for the 1990 year class (D. R. Schreiner, Minnesota Department of Natural Resources, personal communication). Young hatchery chinook salmon may be experiencing increased mortality due to competition from and/or predation by naturally-produced salmonines, especially increasingly abundant lake trout.

Michigan should cooperate with other agencies to maintain or increase lake-wide chinook stocking in Lake Superior. Michigan's chinook sport fishery in the lake apparently would be affected as much or more by changes to stocking in Minnesota than changes in Michigan. In Michigan, lake sport fisheries caught Michigan hatchery chinook in nearly equal abundance in stocked (Black River - Ontonagon, Marquette) and non-stocked locations (Keweenaw-Huron bays, AuTrain-Munising bays). On the other hand, stocking to enhance tributary sport fisheries was successful in at least two stocked tributaries in Michigan where conditions were suitable for a high sport harvest. Although straying by chinook was widespread, enough returned to Black and Dead rivers to provide returns to anglers several times greater than returns to the lake fishery. In Black and Dead rivers, barriers confined chinook to a mile or less of stream resulting in much higher returns to anglers than in Ontonagon and Carp rivers where returning chinook could spread over miles of stream. Black and Dead rivers have little spawning substrate and would not have much of a chinook run without stocking. Stocked chinook provided most fish in spawning runs on Carp River but did not attract much of a sport fishery. These enhanced spawning runs in Carp River may have been smaller than non-enhanced runs during the mid-1980s, because estimated sport catch during September-October 1995 was identical to mean catch during these months in 1984-87 even though angler-hours were higher in 1995 (Peck 1992; Charlevoix Fisheries Station, unpublished data). Return of CWTs from the sport fishery per 100,000 stocked was much lower in Lake Superior than in Lake Michigan and Lake Huron where numbers returned were around 200-800 per year in 1990-93 (Clark 1996). However, fishing effort was almost 20 times greater in those lakes than in Lake Superior (Rakoczy and Svoboda 1995), so returns in Lake Superior would likely be higher on a return per angler-hour basis.

Whether the contribution of hatchery chinook salmon to Michigan's Lake Superior sport fisheries is sufficient to justify continuation of stocking is not determined in this report. Stocking coho salmon and lake trout has been eliminated or curtailed in Michigan waters where hatchery-fish contribution rates have been 5-15%. Although contribution of Michigan chinook salmon was less than 10% , total contribution of hatchery fish was 24% and managers might consider this to represent a significant portion of the fishery. Cost per fish returned to the sport fishery is another means of evaluating contribution of stocked fish. Cost to stock fingerling chinook salmon in Lake Superior from Thompson State Fish Hatchery was estimated to be $0.10 per fish (J. Driver, Michigan Department of Natural Resources, personal communication), or a total cost of $89,381 in 1988-90. This figure divided by the estimated catch of 1988-90 year-class Michigan hatchery chinook in sport fishery (591) equaled a cost of $151 per fish. Cost per Michigan chinook caught in Dead River was $45. Schreiner (1995) estimated cost to stock a Minnesota chinook fingerling to be $0.25 per fish and cost per fish caught in Minnesota's Lake Superior sport fishery at $63. Minnesota has ceased stocking Atlantic salmon, perhaps because of the estimated cost of $720 per fish (Schreiner 1995).

Contribution of hatchery chinook salmon to fisheries can possibly be increased by changing strategies to improve imprinting and increase survival, or simply by stocking more fish. Use of net-pens to hold and grow chinook might improve imprint and increase survival, but net-pen studies in Lake Michigan tributaries have produced mixed results regarding returns (Clark 1996). Rehabilitation of naturally-producing lake trout stocks in much of Lake Superior, with some approaching restoration levels (Hansen et al. 1995), has dissipated some concern regarding effect of chinook on lake trout. Recent bioenergetics modeling in the western third of Lake Superior indicates that lean and siscowet lake trout make up 96% and hatchery and naturally-produced chinook make up less than 3% of the total predator biomass (Mark Ebener, Chippewa/Ottawa Treaty Fisheries Management Authority, personal communication). Predator biomass composition may also be similar in other areas of the lake. Considering relative abundance of chinook salmon and lake trout, it is much more likely that lake trout are negatively affecting chinook salmon than chinook affecting lake trout. Burgeoning natural lake trout populations may very well be responsible for decreased abundance of chinook salmon and other salmonines in Lake Superior since the mid-1980s (Peck et al. 1994). An increase in chinook stocking levels probably would have no noticeable effect on lake trout abundance and growth, and may increase the catch of hatchery fish, especially in stocked tributaries. If lake trout numbers continue to increase, increased chinook stocking may be necessary just to maintain contemporary population levels. Further bioenergetics modeling is needed to assess current status of fish stocks and effect of management actions throughout Lake Superior. This modeling will require additional data for chinook salmon including estimates of smolt abundance, better estimates of mortality rates at various life stages, and better diet data than is currently available.

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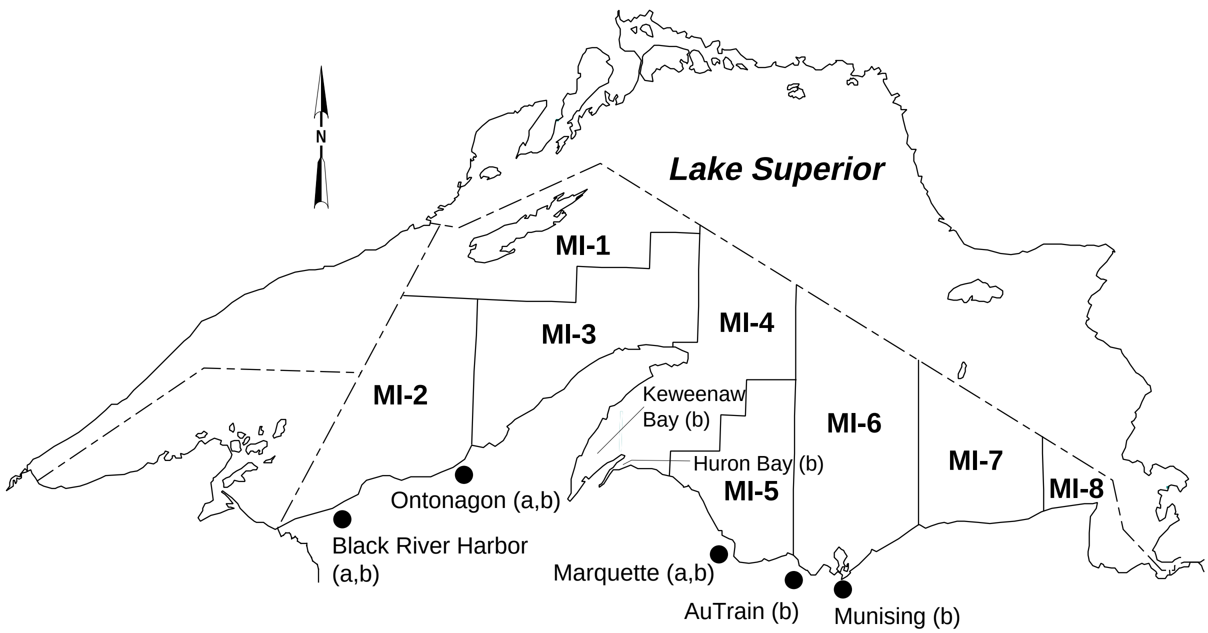


Figure 1.–Chinook salmon stocking sites during 1988-90 (a) and creel survey sites during 1990-94 (b) along Michigan's Lake Superior shoreline.

Table 1.–Chinook salmon fingerlings[a] marked[b] and stocked in Michigan waters of Lake Superior, 1988-90.

| Year | Site and distance from stream site (km) to lake | Number stocked (1,000s) | Hatchery[c] and distance to stocking site (km) | Age and size when stocked | | | Date stocked (m/d) |
|---|---|---|---|---|---|---|---|
| | | | | Age (mo) | Number per kg | Mean weight (g)[d] | |
| 1988 | Black River (<1) | 56,949 | TSFH (387) | 4 | 238 | 4.2 | 5/2 |
| | Black River (<1) | 20,000 | WLSFH (930) | 4 | 124 | 8.1 | 4/14 |
| | Ontonagon River (<1) | 55,789 | TSFH (323) | 4 | 240 | 4.2 | 5/2 |
| | Ontonagon River (<1) | 20,000 | WLSFH (882) | 4 | 124 | 8.1 | 4/14 |
| | Dead River (2) | 101,005 | TSFH (140) | 4 | 224 | 4.5 | 5/2 |
| | Carp River (3) | 81,390 | TSFH (135) | 4 | 211 | 4.7 | 5/3 |
| | Carp River (3) | 21,000 | WLSFH (695) | 4 | 126 | 7.9 | 4/14 |
| | Total | 356,133 | | | 198 | 5.1 | |
| 1989 | Black River (<1) | 77,734 | TSFH(387) | 4 | 255 | 3.9 | 5/3 |
| | Ontonagon River (<1) | 66,766 | TSFH (323) | 4 | 250 | 4.0 | 5/4 |
| | Ontonagon River (<1) | 10,000 | WLSFH (882) | 4 | 218 | 4.6 | 4/19 |
| | Dead River (2) | 102,557 | TSFH (140) | 4 | 261 | 3.8 | 5/4 |
| | Carp River (3) | 91,732 | TSFH (135) | 4 | 329 | 3.0 | 5/4 |
| | Carp River (3) | 9,000 | WLSFH (695) | 4 | 268 | 3.7 | 4/19 |
| | Total | 357,789 | | | 272 | 3.7 | |
| 1990 | Black River (<1) | 79,713 | TSFH (387) | 4.5 | 209 | 4.8 | 5/16 |
| | Ontonagon River (<1) | 64,161 | TSFH (323) | 4.5 | 240 | 4.2 | 5/14 |
| | Dead River (2) | 101,173 | TSFH (140) | 4.5 | 218 | 4.6 | 5/15 |
| | Carp River (3) | 92,461 | TSFH (135) | 4.5 | 225 | 4.4 | 5/15 |
| | Total | 337,508 | | | 217 | 4.6 | |

[a] All stocked chinook were Lake Michigan strain with gametes collected from Little Manistee River spawning run.
[b] Adipose fin clip with coded-wire tag (AdCWT).
[c] Most chinook reared at Thompson State Fish Hatchery (TSFH). Those reared at Wolf Lake State Fish Hatchery (WLSFH) had been heat-shocked as eggs to induce triploidy.
[d] Mean weight based on number per kg reported by hatcheries.

Table 2.–Fin-clip quality[a] and coded-wire tag (CWT) retention[b] for chinook salmon fingerlings marked with an adipose fin clip and tagged at Thompson State Fish Hatchery in April, 1988-90.

| Stocking site/year | Total number stocked | Number and (%) checked for good clips | Number and (%) with good clips | Number and (%) checked for CWT retention | Number and (%) CWT retention | Days from tagging to CWT retention check | Number with good clip | Number with good clip and CWT |
|---|---|---|---|---|---|---|---|---|
| Black River Harbor | | | | | | | | |
| 1988 | 56,949 | 126 (0.2) | 108 (86) | 516 (0.9) | 428 (83) | 16 | 48,976 | 40,650 |
| 1989 | 77,734 | 227 (0.3) | 168 (74) | 529 (0.7) | 497 (94) | 22 | 57,523 | 54,072 |
| 1990 | 79,713 | 472 (0.6) | 467 (99) | 797 (1.0) | 725 (91) | 27 | 78,916 | 71,813 |
| Total | 214,396 | 825 (0.4) | 743 (90) | 1,842 (0.9) | 1,650 (90) | | 185,415 | 166,535 |
| Ontonagon River | | | | | | | | |
| 1988 | 55,789 | 105 (0.2) | 93 (89) | 500 (0.9) | 485 (97) | 14 | 49,652 | 48,163 |
| 1989 | 66,766 | 124 (0.2) | 117 (94) | 505 (0.8) | 485 (96) | 9 | 62,760 | 60,250 |
| 1990 | 64,161 | 223 (0.3) | 221 (99) | 389 (0.6) | 370 (95) | 17 | 63,519 | 60,343 |
| Total | 186,716 | 452 (0.2) | 431 (95) | 1,394 (0.7) | 1,340 (96) | | 175,931 | 168,756 |
| Carp River | | | | | | | | |
| 1988 | 81,390 | 113 (0.1) | 106 (94) | 503 (0.6) | 478 (95) | 9 | 76,507 | 72,681 |
| 1989 | 91,732 | 113 (0.1) | 98 (87) | 517 (0.6) | 501 (97) | 14 | 79,807 | 77,413 |
| 1990 | 92,461 | 276 (0.3) | 265 (96) | 800 (0.9) | 696 (87) | 20 | 88,763 | 77,223 |
| Total | 265,583 | 502 (0.2) | 469 (93) | 1,820 (0.7) | 1,675 (92) | | 245,077 | 227,317 |
| Dead River | | | | | | | | |
| 1988 | 101,005 | 119 (0.1) | 117 (98) | 500 (0.5) | 465 (93) | 12 | 98,985 | 92,056 |
| 1989 | 102,557 | 226 (0.2) | 201 (89) | 796 (0.8) | 748 (94) | 16 | 91,276 | 85,799 |
| 1990 | 101,173 | 418 (0.4) | 401 (96) | 896 (0.9) | 780 (87) | 23 | 97,126 | 84,500 |
| Total | 304,735 | 763 (0.2) | 719 (94) | 2,192 (0.7) | 1,993 (91) | | 287,387 | 262,355 |
| Grand total | 971,430 | 2,542 (0.3) | 2,362 (93) | 7,248 (0.7) | 6,658 (92) | | 893,810 | 824,963 |

[a] A good adipose clip was through the stem resulting in complete removal of the lobe as described by Jones 1979), and should be recognizable throughout the life of the fish.
[b] Estimated number stocked with tags based on percent with tags at last check prior to stocking.

Table 3.–Estimated fishing effort (angler-hours), chinook salmon sport catch (number), and chinook salmon CPE (number per 1,000 angler-hours) at creel-surveyed[a] sites in Michigan management areas (Figure 1) of Lake Superior, 1990-94.

| Year | Area | Site | Months surveyed | Effort | Catch | CPE |
|---|---|---|---|---|---|---|
| 1990 | MI-2 | Black River Harbor | Jun-Sep | 10,325 | 124 | 120 |
| | | Ontonagon | Jun-Sep | 25,501 | 82 | 32 |
| | MI-4 | Keweenaw Bay | May-Aug | 11,835 | 120 | 101 |
| | | Huron Bay | Jul-Aug | 5,466 | 66 | 121 |
| | MI-5 | Marquette | May-Oct | 48,255 | 462 | 96 |
| | MI-6 | Munising | May-Oct | 13,844 | 231 | 167 |
| Total | | | | 115,226 | 1,085 | 94 |
| 1991 | MI-2 | Black River Harbor | May-Sep | 9,931 | 490 | 493 |
| | | Ontonagon | May-Sep | 36,024 | 766 | 213 |
| | MI-4 | Keweenaw Bay | Feb-Oct | 46,337 | 683 | 147 |
| | | Huron Bay | Jun-Sep | 6,829 | 37 | 54 |
| | MI-5 | Marquette | Mar-Oct | 92,284 | 761 | 82 |
| | MI-6 | AuTrain | Apr-Sep | 19,279 | 94 | 49 |
| | | Munising | Feb-Sep | 52,479 | 128 | 24 |
| Total | | | | 263,163 | 2,959 | 112 |
| 1992 | MI-2 | Black River Harbor | May-Oct | 9,826 | 57 | 58 |
| | | Ontonagon | May-Sep | 36,122 | 109 | 30 |
| | MI-4 | Keweenaw Bay | Feb-Oct | 61,753 | 1,489 | 241 |
| | MI-5 | Marquette | Mar-Oct | 88,729 | 720 | 81 |
| | MI-6 | AuTrain | Apr-Sep | 15,301 | 174 | 114 |
| | | Munising | Feb-Sep | 75,928 | 535 | 70 |
| Total | | | | 287,659 | 3,084 | 107 |
| 1993 | MI-2 | Black River Harbor | May-Sep | 12,895 | 43 | 33 |
| | | Ontonagon | May-Sep | 31,293 | 220 | 70 |
| | MI-4 | Keweenaw Bay | Feb-Oct | 93,305 | 2,115 | 227 |
| | MI-5 | Marquette | Mar-Oct | 80,871 | 624 | 77 |
| | MI-6 | AuTrain | Apr-Aug | 12,176 | 18 | 15 |
| | | Munising | Feb-Sep | 65,659 | 726 | 111 |
| Total | | | | 296,199 | 3,746 | 126 |
| 1994 | MI-2 | Black River Harbor | May-Jul | 4,795 | 15 | 31 |
| | | Ontonagon | May-Jul | 19,123 | 127 | 66 |
| | MI-4 | Keweenaw Bay | Jan-Oct | 124,986 | 751 | 60 |
| | MI-5 | Marquette | Mar-Oct | 59,400 | 589 | 99 |
| | MI-6 | AuTrain | Mar-Aug | 21,643 | 47 | 22 |
| | | Munising | Feb-Sep | 48,909 | 250 | 51 |
| Total | | | | 278,856 | 1,779 | 64 |

[a] Creel-survey data from Rakoczy (1992), Rakoczy and Svoboda (1995), and Charlevoix Fisheries Station, unpublished data

Table 4.–Chinook salmon estimated catch by age in Michigan's Lake Superior sport fishery, 1990-94.

| Year | Number and (%) at age | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1990 | 108 (10) | 315 (29) | 521 (48) | 141 (13) | | |
| 1991 | 326 (11) | 1,657 (56) | 621 (21) | 207 (7) | 118 (4) | 30 (1) |
| 1992 | 802 (26) | 678 (22) | 1,450 (47) | 154 (5) | | |
| 1993 | 599 (16) | 1,424 (38) | 937 (25) | 749 (20) | 37 (1) | |
| 1994 | 71 (4) | 587 (33) | 854 (48) | 213 (12) | 36 (2) | 18 (1) |
| Total | 1,906 (15) | 4,661 (37) | 4,383 (35) | 1,464 (12) | 191 (1) | 48 (<1) |

Table 5.–Estimated fishing effort (angler-hours), chinook salmon sport catch (number), and chinook salmon CPE (number per 10,000 angler-hours) in the sport fishery in Dead River, a stocked Lake Superior tributary in management area MI-5 at Marquette, during September-October 1990-94.

| | Fishery parameters ±2 SE | | |
|---|---|---|---|
| Year | Effort | Catch | CPE |
| 1990 | 9,516<br>±919 | 1,122<br>±529 | 1,179<br>±597 |
| 1991 | 8,377<br>±740 | 489<br>±231 | 584<br>±281 |
| 1992 | 7,933<br>±795 | 317<br>±179 | 400<br>±229 |
| 1993 | 4,852<br>±585 | 214<br>±195 | 441<br>±405 |
| 1994 | 3,734<br>±530 | 104<br>±52 | 279<br>±145 |

Table 6.–Estimated sport catch of 1988-90 year class chinook salmon by origin at creel-surveyed sites in Michigan's management areas of Lake Superior, 1990-94.

| Area | Creel-survey sites | Year | Total | Catch (number) by origin and (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Michigan | Wisconsin | Minnesota | Ontario | Wild |
| MI-2 | Black River-Ontonagon | 1990 | 103 | | | | | 103 (100) |
| | | 1991 | 1,256 | 35 (3) | | | | 1,221 (97) |
| | | 1992 | 166 | 55 (33) | | | | 111 (67) |
| | | 1993 | 224 | 53 (24) | | | | 171 (76) |
| | | 1994 | 21 | 11 (52) | | | | 10 (48) |
| | | Total | 1,770 | 154 (9) | | | | 1,616 (91) |
| MI-4 | Keweenaw-Huron bays | 1990 | 99 | 5 (5) | | | | 94 (95) |
| | | 1991 | 683 | 74 (11) | 45 (7) | 119 (17) | 15 (2) | 430 (63) |
| | | 1992 | 1,236 | 149 (12) | 90 (7) | 209 (17) | 50 (4) | 738 (60) |
| | | 1993 | 888 | | 43 (5) | 87 (10) | | 758 (85) |
| | | 1994 | 53 | | | 18 (34) | 9 (17) | 26 (49) |
| | | Total | 2,959 | 228 (8) | 178 (6) | 433 (15) | 74 (2) | 2,046 (69) |
| MI-5 | Marquette | 1990 | 148 | 37 (25) | | | | 111 (75) |
| | | 1991 | 677 | 31 (5) | 42 (6) | 62 (9) | 31 (5) | 511 (75) |
| | | 1992 | 648 | 37 (6) | 62 (9) | 75 (12) | 25 (4) | 449 (69) |
| | | 1993 | 490 | 33 (7) | 33 (7) | 98 (20) | 33 (7) | 293 (59) |
| | | 1994 | 130 | | 9 (7) | | | 121 (93) |
| | | Total | 2,093 | 138 (7) | 146 (7) | 235 (11) | 89 (4) | 1,485 (71) |
| MI-6 | Munising-AuTrain | 1990 | 74 | | 4 (6) | 9 (12) | | 61 (82) |
| | | 1991 | 184 | 9 (5) | 28 (15) | 28 (15) | | 119 (65) |
| | | 1992 | 695 | 35 (5) | 46 (7) | 70 (10) | | 544 (78) |
| | | 1993 | 454 | 15 (3) | | 28 (6) | | 411 (91) |
| | | 1994 | 36 | 12 (33) | | | | 24 (67) |
| | | Total | 1,443 | 71 (5) | 78 (5) | 135 (9) | | 1,159 (81) |
| All areas and sites | | 1990 | 424 | 42 (10) | 4 (1) | 9 (2) | | 369 (87) |
| | | 1991 | 2,800 | 149 (5) | 115 (4) | 209 (8) | 46 (2) | 2,281 (81) |
| | | 1992 | 2,745 | 276 (10) | 198 (7) | 354 (13) | 75 (3) | 1,842 (67) |
| | | 1993 | 2,056 | 101 (5) | 76 (4) | 213 (10) | 33 (2) | 1,633 (79) |
| | | 1994 | 240 | 23 (10) | 9 (4) | 18 (7) | 9 (4) | 181 (75) |
| | | Total | 8,265 | 591 (7) | 402 (5) | 803 (10) | 163 (2) | 6,306 (76) |

Table 7.–Estimated total catch of 1988-90 year-class Michigan hatchery chinook salmon by year-class in Michigan sport fisheries in Lake Superior and a tributary, Dead River, during 1990-94, with return to Michigan's sport fishery presented as number caught as a percentage of number stocked.

| | Year-class | | | |
|---|---|---|---|---|
| | 1988 | 1989 | 1990 | Total |
| Lake Superior | | | | |
| Number stocked[a] | 274,120 | 291,366 | 328,324 | 893,810 |
| Estimated total catch | 1,145 | 4,000 | 2,154 | 7,299 |
| Estimated Michigan hatchery catch | 80 | 294 | 217 | 591 |
| Return of Michigan hatchery fish | 0.03% | 0.10% | 0.07% | 0.07% |
| Dead River | | | | |
| Number stocked[a] | 98,985 | 91,276 | 97,126 | 286,451 |
| Estimated total catch | 465 | 194 | 199 | 858 |
| Estimated Michigan hatchery catch | 370 | 178 | 90 | 638 |
| Return of Michigan hatchery fish | 0.37% | 0.20% | 0.09% | 0.22% |

[a] Number stocked by Thompson State Fish Hatchery with good clip (from Table 2).

Table 8.–Number of coded-wire tags recovered from chinook salmon tagged in 1988-90 and captured in Michigan sport fisheries in Lake Superior and stocked tributaries during 1990-94.

| Tag recovery by year | Stocking sites | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Black River | | Ontonagon River | | Dead River | | Carp River | |
| | Trib. | Lake | Trib | Lake | Trib. | Lake | Trib. | Lake |
| 1990 | | 3 | | 5 | | 3 | | 10 |
| 1991 | 8 | 4 | 2 | 6 | 8 | 9 | 3 | 17 |
| 1992 | 29 | 15 | 5 | 23 | 39 | 6 | 6 | 18 |
| 1993 | 56 | 9 | 3 | 6 | 20 | 1 | 1 | 3 |
| 1994 | | | | | | | 1 | |
| Total number | 93 | 31 | 10 | 40 | 67 | 19 | 11 | 48 |
| Number/100,000[a] | 54 | 18 | 6 | 23 | 26 | 7 | 5 | 21 |

[a] Number of tags recovered per 100,000 chinook salmon fingerlings stocked with a recognizable adipose fin clip and carrying a CWT when stocked (from Table 2).

Table 9.–Evidence of chinook salmon spawning runs and composition (percent by fin clip) of 1988-90 year-class chinook in Michigan tributaries to Lake Superior, 1990-1994.

| | | | Evidence of chinook spawning | | | | % by fin clip of 1988-90 year-class chinook in spawing runs[a] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Visual survey[b] | | Electro- | | | | | | |
| Management area | Tributary | Year | Angler reports[c] | Fish | Redds | fishing survey | # of fish | No clip | Ad | LV | LP | RP |
| MI-2 | Black River[d,e] | 1990 | X | X | | | | | | | | |
| | | 1991 | X | X | | X | 1 | | 100 | | | |
| | | 1992 | X | | | | | | | | | |
| | | 1993 | X | X | | | | | | | | |
| | | 1994 | X | | | | | | | | | |
| | Big Iron River[e] | 1990 | X | | | | | | | | | |
| | | 1991 | X | X | | | | | | | | |
| | | 1992 | | X | | | | | | | | |
| | | 1993 | X | | | | 1 | 100 | | | | |
| | Ontonagon River[d] | 1991 | X | | | | | | | | | |
| | | 1992 | X | | | | | | | | | |
| | | 1993 | X | | | | | | | | | |
| MI-4 | Falls River | 1990 | | X | | | | | | | | |
| | | 1993 | | X | | | | | | | | |
| | Silver River | 1990 | | X | X | | | | | | | |
| | | 1991 | | | X | | | | | | | |
| | | 1992 | | X | X | X | 4 | 100 | | | | |
| | | 1993 | | X | X | | | | | | | |
| | | 1994 | | X | X | | | | | | | |
| MI-5 | Dead River[d,e] | 1990 | X | | | | 1 | 100 | | | | |
| | | 1991 | X | | | | 38 | 26 | 68 | 3 | 3 | |
| | | 1992 | X | | | | 37 | 8 | 76 | 11 | 5 | |
| | | 1993 | X | | | | 25 | 20 | 72 | 4 | 4 | |
| | | 1994 | X | | | | 13 | 23 | 62 | 15 | | |
| | Carp River[d,e] | 1990 | | X | X | | | | | | | |
| | | 1991 | X | X | X | X | 20 | 20 | 75 | 5 | | |
| | | 1992 | X | X | X | X | 50 | 3 | 86 | 11 | | |
| | | 1993 | X | X | X | X | 21 | 33 | 62 | | | 5 |
| | | 1994 | X | X | X | X | 6 | 33 | 67 | | | |
| | Laughing Whitefish R. | 1991 | | | | X | 1 | 100 | | | | |
| | | 1993 | | | X | | | | | | | |
| MI-6 | AuTrain River | 1991 | | X | X | X | 19 | 74 | 5 | 21 | | |
| | | 1992 | | X | X | X | 59 | 73 | 8 | 17 | 2 | |
| | | 1993 | | X | X | X | 9 | 67 | 11 | 22 | | |
| | | 1994 | | | X | | | | | | | |
| MI-7 | Blind Sucker River | 1992 | | X | | | | | | | | |

[a] Percent by fin clip in electrofishing-surveyed or creel-surveyed catches.
[b] Visual surveys by MIDNR personnel.
[c] Angler reports confirmed by MIDNR personnel, collection of chinook heads, or creel survey in Black and Dead rivers.
[d] Stocked during 1988-90.
[e] Stocked prior to 1988-90.

Table 10.–Age composition (number with percent in parentheses) of adult chinook salmon in spawning runs on three Michigan Lake Superior tributaries, 1992-94

| Tributary | Year | Age (year) | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 |
| Dead River | 1992 | | 11 (61) | 7 (39) | |
| | 1993 | | 9 (60) | 6 (40) | |
| | 1994 | | 7 (35) | 12 (60) | 1 (5) |
| | Total | | 27 (51) | 25 (47) | 1 (2) |
| Carp River | 1992 | 5 (14) | 27 (72) | 5 (14) | |
| | 1993 | 2 (8) | 13 (57) | 8 (35) | |
| | 1994 | | 10 (62) | 6 (38) | |
| | Total | 7 (9) | 50 (66) | 19 (25) | |
| AuTrain River | 1992 | 10 (18) | 35 (62) | 9 (16) | 2 (4) |
| | 1993 | 1 (10) | 4 (40) | 5 (50) | |
| | Total | 11 (17) | 39 (59) | 14 (21) | 2 (3) |

Table 11.–Mean total length (in) and weight (lb), ±95% CI, for ages of chinook salmon sampled in the Lake Superior sport fishery in management areas MI-5 and MI-6 during Feb-Jun and Jul-Oct, 1991-94.

| | | | Age (year) | | | | |
|---|---|---|---|---|---|---|---|
| Year | Season | Parameter | 1 | 2 | 3 | 4 | 5 |
| 1991 | Feb-Jun | Number | 4 | 51 | 22 | 9 | |
| | | Length | 14.2±4.6 | 19.1±0.6 | 25.6±1.3 | 28.3±2.0 | |
| | | Weight | 1.02±1.03 | 2.21±0.20 | 5.70±0.95 | 7.49±2.03 | |
| | Jul-Oct | Number | | 2 | 4 | 1 | 1 |
| | | Length | | 24.9±34.3 | 30.4±2.0 | 30.4 | 32.8 |
| | | Weight | | 3.70±3.81 | 11.90±3.98 | 12.00 | 14.40 |
| 1992 | Feb-Jun | Number | 3 | 44 | 50 | 4 | |
| | | Length | 11.4±2.0 | 20.9±0.7 | 25.5±0.8 | 27.0±1.0 | |
| | | Weight | 0.43±0.14 | 2.87±0.31 | 5.48±0.60 | 5.70±1.58 | |
| | Jul-Oct | Number | 4 | 6 | 10 | | |
| | | Length | 17.4±3.1 | 20.7±2.1 | 29.3±2.6 | | |
| | | Weight | 1.90±1.03 | 2.60±0.68 | 9.75±2.62 | | |
| 1993 | Feb-Jun | Number | 2 | 35 | 29 | 10 | 1 |
| | | Length | 12.4±6.4 | 19.1±0.5 | 26.3±1.0 | 31.2±1.5 | 33.4 |
| | | Weight | 0.55±0.64 | 2.10±0.19 | 6.08±0.80 | 11.07±1.30 | 13.30 |
| | Jul-Oct | Number | 5 | 8 | 14 | 5 | |
| | | Length | 13.9±1.4 | 20.4±2.5 | 30.3±2.2 | 34.2±4.5 | |
| | | Weight | 0.96±0.37 | 3.20±1.67 | 9.15±2.01 | 13.86±5.83 | |
| 1994 | Feb-Jun | Number | 1 | 18 | 43 | 12 | 2 |
| | | Length | 14.7 | 17.5±0.9 | 24.5±0.7 | 28.8±1.4 | 32.6±36.2 |
| | | Weight | 0.70 | 1.78±0.32 | 4.85±0.50 | 8.12±1.60 | 12.60±33.04 |
| | Jul-Oct | Number | | 6 | 26 | 19 | 1 |
| | | Length | | 18.5±1.9 | 27.3±1.8 | 32.8±2.0 | 31.5 |
| | | Number | | 6 | 15 | 13 | 1 |
| | | Weight | | 2.25±1.19 | 7.23±2.13 | 14.94±3.19 | 10.0 |

Table 12.–Estimated intercept (a) and slope (b) parameters (± 95% confidence bounds) and coefficient of determination for chinook salmon weight-length regressions for 1992-94. Equation is of the form: $Log_e$ [weight (lb)] = a + b $log_e$ [length (in)].

| Year | Number | a | b | $r^2$ |
|---|---|---|---|---|
| 1992 | 121 | -8.52±0.28 | 3.14±0.09 | 0.98 |
| 1993 | 108 | -8.63±0.25 | 3.18±0.08 | 0.98 |
| 1994 | 117 | -8.76±0.31 | 3.23±0.10 | 0.97 |

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Report approved by Richard D. Clark Jr.
Alan D. Sutton, Graphics
Kathryn L. Champagne, DTP