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Abstract.—A creel survey of the sport fishery in Lake Superior and three tributaries (Dead, Carp, and Chocolay rivers) at Marquette, Michigan, during 1984-87 revealed an intensive fishery, mainly for naturally produced trout and salmon. Annual fishing effort in the lake and three tributaries averaged 119,000 and 37,000 angler hours, respectively. Most effort in the lake was by boat (68-84%) but fishing from shore was substantial (16-20%), especially in Marquette Bay (41-51%). Ice-fishing effort fluctuated considerably among years (1-14%). Effort in the tributaries was mainly by shore angling (69-100%). The Lake Superior sport fishery was particularly active during March-September, with the highest effort in April. Lake Superior anglers fished an average 3.2 hours per trip, whereas those fishing the tributaries averaged 2.1-2.5 hours. Fishing in the tributaries was mainly during April-May and September-October. More fishing was done in the Dead River than in the Carp and Chocolay rivers combined. Over 90% of all anglers surveyed were from Marquette County. Anglers sought mainly lake trout and coho salmon in Lake Superior, and rainbow trout and coho salmon in the tributaries. Salmonid fishes made up most of the catch and were represented by eight species of trout and salmon, one trout hybrid, and two species of whitefish. Most numerous in the catch were coho salmon, lake trout, and round whitefish in Lake Superior, coho salmon and chinook salmon in the Dead River, rainbow trout and coho salmon in the Carp River, and coho salmon and rainbow trout in the Chocolay River. Most trout and salmon caught in Lake Superior were immature, whereas those caught in the tributaries were usually mature fish. In the Lake Superior sport fishery, lake trout averaged 23.5 inches, 4.4 pounds, 8 years old, and the highest monthly catch was in August; coho salmon averaged 16.6 inches, 1.4 pounds, 2 years old, and the highest monthly catch was in April; chinook salmon averaged 25.4 inches, 6.8 pounds, 3 years old, and the highest monthly catch was August; rainbow trout averaged 21.1 inches, 3.6 pounds, 4 years old, and the highest monthly catch was in May; brown trout averaged 17.2 inches, 2.2 pounds, 3 years old, and the highest monthly catch was in March; splake averaged 13.6 inches, 0.9 pound, 2 years old, and the highest monthly catch was in February.

The majority of fish in the catch were naturally produced with the exception of splake and Atlantic salmon at all sites, coho salmon in the Dead River, and brown trout in the Carp River. Hatchery coho salmon provided 80% of the coho catch in the Dead River but 6% or less in Lake Superior, and the Carp and Chocolay rivers. Hatchery rainbow trout made up 15% of the Lake Superior catch and 10-44% of the catch in the tributaries. Hatchery brown trout made up 40% of the catch in Lake Superior and 4-50% in the tributaries. The contribution of hatchery lake trout decreased from 38% in 1984 to 18% in 1987.

Returns from hatchery planting to the sport fishery were less than 2% except for one plant of large yearling splake which was about 13%. Steelhead strains planted in the Chocolay River provided a better return (0.64-1.44%) than either steelhead or domestic rainbow trout planted in Lake Superior (0.08-0.52%). The returns of Siletz steelhead and coho salmon were about 1.4%. Brown trout returns were all less than 1%. These low returns prevented a conclusive assessment of the performance of domestic versus steelhead strains of rainbow trout and yearling versus fall-fingerling brown trout planted in Lake Superior. Straying and mortality both likely contributed to the poor return. Coho salmon planted in Lake Superior strayed as far as Lake Erie and were abundant in the sport fishery and in at least one tributary of Lake Michigan. Michigan should (1) maintain an annual sport fishery creel survey, (2) protect and enhance spawning habitat and populations of native and naturalized trout and salmon, (3) cease planting hatchery trout and salmon, or (4) if some planting is judged necessary, apply documented strategies for improving return to the fishery.

Management efforts such as reduction of sea lamprey populations, controls on the commercial fishery, introduction of Pacific salmon, and rehabilitation of previously existing trout populations resulted in a substantial and increasing sport fishery on the Great Lakes during the late 1960s and early 1970s (Rybicki 1973). A mail creel survey of a 2-4% sample of licensed anglers was employed during 1967-82 to gather information on this fishery (G. C. Jamsen, Michigan Department of Natural Resources (MDNR), personal communication; and Jamsen 1985). This survey provided a much-needed picture of the growing lakewide fishery, but estimates for specific ports were found to be imprecise. The small sample size and biases associated with voluntary recall for a 1- to 3-month period contributed to variation in estimates for specific ports and usually resulted in overestimates of catch and effort when compared to concurrent on-site creel surveys (Rybicki and Keller 1978; Patriarche 1980). In addition, no biological data were obtained on fish in the catch.

As management needs for the Great Lakes sport fishery required more information on catches at individual ports and on individual fish in the catch, survey efforts shifted to on-site creel surveys. Some on-site creel surveys were conducted at a few sites in lakes Michigan, Huron, and Erie during 1974-82 (Ryckman and Lockwood 1985). There have been only two published and one unpublished creel surveys on Lake Superior and tributaries prior to this study. Stauffer (1966) estimated the lake trout catch in Keweenaw Bay with an on-site creel survey in 1964, and Wagner and Stauffer (1978) estimated the rainbow trout catch in a Lake Superior tributary (Huron River) with a similar method during the early 1970s (see Table 1 for common and scientific names of fishes). An unpublished on-site creel survey was conducted between Keweenaw Bay and Grand Marais in 1967 and 1968 (R. W. Rybicki, MDNR, personal communication).

The MDNR initiated a Great Lakes catch sampling program at major fishing ports on Lake Superior and the other Great Lakes in 1983 (G. P. Rakoczy, MDNR, personal communication). This program gathered on-site data on catch per unit effort and catch composition, but there was no estimate of effort so total catch could not be determined. The catch-sampling program was upgraded to a full on-site creel survey in Lake Michigan in 1985, lakes Huron and Erie were included in 1986, with Lake Superior added in 1987 (Rakoczy and Lockwood 1988; Rakoczy and Rogers 1987 and 1988a).

Salmonid populations and the sport fishery in Lake Superior responded to the management strategies initiated in the 1960s much like in lakes Michigan and Huron, but to a lesser degree. Although sea lamprey control efforts and commercial fishing restrictions were similar to those in the lower lakes, fewer trout and salmon were planted in Lake Superior because forage was considered to be less abundant and fishing pressure was much less. Coho salmon plants were reduced in 1971 because growth, survival, and contribution to the fishery had not met

expectations (Rybicki 1973). Still, Lake Superior accounted for 10-12% of Michigan's total Great Lakes salmonid catch during 1980-82 despite fewer hatchery fish planted and much less fishing effort (Jamsen 1985).

Although not as large as fisheries in the other Great Lakes, the sport fishery in Lake Superior is an important recreational resource, especially to local anglers. Chapters of the Michigan Steelhead and Salmon Fisherman's Association were formed in the central and western Upper Peninsula by the early 1980s. These organizations lobbied for recognition of this fishery, regulations to protect the fish stocks, and enhancement through the planting of more hatchery trout and salmon. Fisheries managers welcomed this support but lacked the quantitative creel data necessary to measure the fishery and determine the contribution of hatchery fish. Prudence with regard to planting hatchery fish was necessary because of great demand for the existing supply in Michigan hatcheries, concerns arising from a recent decline in rainbow smelt abundance (Selgeby 1985), and possible adverse competition by introduced trout and salmon with native lake trout stocks for available forage in Lake Superior (Hansen 1990).

This study was initiated in Lake Superior and three tributaries in 1983 with the objectives of measuring sport-fishery parameters and evaluating the contribution of hatchery trout and salmon to the sport catch.

Methods

A creel survey was conducted on Lake Superior and a portion of the Dead, Carp, and Chocolay rivers in and near Marquette, Michigan (Figure 1). Lake Superior anglers fishing nearshore waters within 30 miles of Marquette were surveyed at Presque Isle Harbor and Marquette Bay. The few anglers fishing more distant offshore fishing grounds such as Stannard Rock and Big Reef were identified and not used in the survey. Tributaries were surveyed from the mouth upstream to a designated limit. These upstream limits and inclusive miles of stream were the M-28 bridge on the Chocolay River (about 1.5 miles), and impassable barriers on the Dead River and Carp River (about 1 and 4 miles of stream, respectively).

The data were analyzed using the CREEL.ANALYSIS program created by R. D. Clark and J. R. Ryckman (MDNR, Ann Arbor). Estimates of catch and effort were based on stratified on-site angler interviews and instantaneous counts of individual anglers (shore and ice) or angler groups (car, boat, or ice shanty) using the method described by Ryckman (1981). The estimates were stratified by site, mode of fishery (ice, shore, or boat), month, and day type (weekend or weekday). Holidays were classified as weekend days. These stratified estimates were combined for monthly and seasonal estimates. The survey began on April 4, 1984, was year-round in 1985, 1986, and 1987, and ended on December 31, 1987. It was done by roving clerks (two during March-November and one during December-February). Total effort and effort distribution by mode of fishery, and total catch and catch distribution by month are presented for the entire 1984-87 period. Monthly distribution of effort and comparisons of angler data are presented as means for the 3 full years of the survey (1985-87). The season catch per unit of effort (CPE) of each species was determined by dividing the total catch (number) of that species by the total effort (angler hours). Fishing effort was targeted at certain species during certain times of the year, so target CPEs were determined by utilizing catch and effort data from months when most fishing was done for a particular species. Other angling data collected in this survey were duration of trip, county of residence, and species sought. Two standard errors (SE) were calculated for all estimates.

Survey clerks recorded total length and fin clip for all fish in the surveyed catches. Clerks collected additional data on a monthly quota of 50-100 lake trout and 30 of most other species which included total weight, sex, maturity, sea lamprey marks, and a scale sample for age determination. Age (in years) was determined for all salmonids and most of the other fishes based on the number of

annuli on the scales. For rainbow trout, the number of stream or hatchery annuli were separated from the number of lake annuli by a slash (/), with the two numbers added together representing total age. I did not do the same for the other anadromous species because brown trout samples were few, chinook had no stream or hatchery annuli, and most coho were 1/1. Scales were used on occasion to identify the origin (hatchery or wild) of unmarked trout and salmon based on the criteria presented by Seelbach and Whelan (1988).

The contribution of hatchery rainbow trout, brown trout, coho salmon, lake trout, and splake to the 1984-87 sport-fish catch at Marquette was determined from the percentage of marked fish in the estimated catch. These data represent minimum values because strays from some unmarked plants in other areas of Lake Superior could be part of the Marquette catch; and the marks on some fish planted at Marquette were missed or poorly done, so these might not be recognized as hatchery fish. The return to the sport fishery (number caught as a percent of number planted) of recognizably marked hatchery rainbow trout, brown trout, coho salmon, and splake planted during 1983-85 were also evaluated.

All of the fish planted at Marquette during 1983-85 except splake were fin clipped to identify them as hatchery fish. Splake are hybrids resulting from a cross between male brook trout and female lake trout that usually do not occur naturally, so all splake were assumed to be hatchery fish and assigned to specific plants on the basis of age. The domestic rainbow trout, brown trout, and splake came from Thompson State Fish Hatchery and the Lake Michigan and Siletz steelhead came from Wolf Lake State Fish Hatchery; the former is 87 miles and the latter 437 miles from Marquette. Coho salmon came from the Platte River State Fish Hatchery (269 miles from Marquette). Mean total length (mm) at planting was either measured directly or estimated from weight of samples. A sample of 100-200 fish from each plant was examined to determine the percentage of fish with good fin clips, with exception of the Siletz summer steelhead plant in 1984. Good clips were judged to be those with at least 50% of the adipose fin removed and at least 75% of the ventral or pectoral fin removed. Only the total number of fish with good fin clips was used to determine return to the sport fishery creel.

Domestic and Lake Michigan steelhead strains of rainbow trout were planted in Marquette Bay in 1983 and in Presque Isle Harbor in 1984 to compare returns from these two strains at the two sites. Each plant consisted of 10,000 yearlings of each strain. Approximately 20,000 Lake Michigan steelhead yearlings were planted each year in Chocolay River during 1983-85 as part of a separate study, but contribution to the creel in Lake Superior and the surveyed portion of Chocolay River were also determined. About 18,500 Siletz summer steelhead were planted in Chocolay River in 1984 and, although this plant was not a planned part of the study, its contribution to the creel was measured. The egg source for domestic rainbow trout was broodstock at Michigan's Oden State Fish Hatchery. Lake Michigan steelhead eggs were obtained from the natural spawning run on the Little Manistee River, a Lake Michigan tributary. Siletz summer steelhead eggs were obtained from the spawning run on the Siletz River in Oregon (Fielder 1987). The contribution to the catch of hatchery fish planted in 1986 and 1987 was also determined, but the survey ended too soon to evaluate return to the creel. These plants included 20,000-26,000 fin-clipped yearling Skamania summer steelhead planted in Chocolay River in 1986 and 1987 and 16,000-20,000 unmarked yearling Lake Michigan steelhead planted in Carp River in 1986 and 1987. Although unmarked, these fish were recognized in the Carp River catch samples based on scale circuli patterns (Seelbach and Whelan 1988).

Yearling and fall-fingerling brown trout were planted in Presque Isle Harbor and Marquette Bay in 1983-85 to evaluate the return from these two age groups at the two sites. The egg source was broodstock at Wisconsin's St. Croix Falls hatchery and the strain was Wild Rose x Nashua (W. Yoder, MDNR, personal communication). Yearling

plants numbered about 15,000, and those for fall fingerlings about 30,000. The contribution to the catch, but not total return, was also determined for a plant of about 20,000 unmarked yearling brown trout planted in the Carp River in 1987.

Annual plants of 135,000-150,000 yearling coho salmon were made in the Dead River. An additional 150,000-160,000 were planted annually among 2-3 other sites 40-200 miles from Marquette. The egg source was the spawning run on Lake Michigan's Platte River. These adult coho were believed to be mainly hatchery fish because the Platte was planted with coho each year. Coho planted at all sites in Lake Superior in 1984 and 1985 were fin clipped.

The 7,800 yearling splake and 10,000 fall-fingerling splake planted in 1985 were produced from Lake Superior strain lake trout eggs (from broodstock at the Marquette State Fish Hatchery) and fertilized with brook trout sperm (provided by Oden State Fish Hatchery). These splake were hatched and reared at Thompson State Fish Hatchery.

Temperature of the transport (planting unit) and receiving (lake or stream) water, and the number of fish that died during transport were recorded on a Fish Planting Work Sheet for each fish plant. In addition, transport and receiving water pH, alkalinity, and non-ionized ammonia (NH_3) were measured for one of the domestic rainbow plants in Marquette Bay from Thompson State Fish Hatchery, and for one of the Lake Michigan steelhead plants in the Chocolay River from Wolf Lake State Fish Hatchery in 1983. Non-ionized ammonia is a component of one of the principal products of fish excretion (ammonia nitrogen), NH_3 concentrations increase with increasing temperature and pH (Trussell 1972), and NH_3 has been found to be lethal to rainbow trout (McKee and Wolf 1963).

Results

Lake Superior Sport Fishery

Total annual sportfishing effort estimated for the Presque Isle Harbor and Marquette Bay sites in Lake Superior at Marquette ranged from 82,733 to 145,758 angler hours during 1984-87 (Table 2). The estimated effort in 1984 was lowest, but included only April-December. Mean annual effort was 118,898 angler hours for 1985-87. Annual effort was almost identical in 1985 and 1987, but significantly higher in 1986. Most fishing was done from boats (68-84%), with fluctuations in boat-fishing effort inversely related to the amount of ice fishing. Ice fishing accounted for 13-14% of total effort in 1985 and 1986, but was insignificant during the warm winter of 1987 and underestimated in 1984 due to the late start of the survey. Shore-fishing effort accounted for 16-20% of total effort during 1984-87.

Almost twice as much fishing effort was estimated for the Presque Isle Harbor site than for the Marquette Bay site (Table 2). Fishing from boats accounted for the greatest share of Presque Isle Harbor fishing effort. Shore fishing contributed less than 10% of the effort, and the range of ice-fishing effort was 0-16%. Shore fishing was a major component of the Marquette Bay sport fishery, and contributed 41-51% of the total effort during 1984-87. Boat fishing contributed significantly more effort only in 1986 and 1987. Ice-fishing effort in Marquette Bay exceeded 10% only in 1986.

Sportfishing occurred in Lake Superior at Marquette every month of the year, with most effort in April and the least effort in December and January during 1985-87 (Figure 2). The within-year distribution of effort at the two Lake Superior sites differed somewhat in that most of the fishing effort in Presque Isle Harbor was distributed over 7 months (March-September), whereas almost half of the fishing effort in Marquette Bay occurred during 2 months (April-May). Effort in Presque Isle Harbor exceeded that in Marquette Bay most months. Effort was greater in Marquette Bay during November and December and comparable during April and May. The mean duration of an angler trip on Lake Superior was 3.2 hours with a range of 3.1 to 3.4 hours for individual years (Table 3). Monthly mean duration of angler

trips ranged from 2.0 hours in January and December to 4.1 hours in June.

Most of the anglers fishing Lake Superior were residents of Michigan (Table 4). Only 1-2% of the anglers were from other states, and for Michigan residents, only 2-3% were from counties other than Marquette. A majority of anglers expressed a preference for a particular species (Table 5), with most seeking lake trout (27-37%) and coho salmon (12-31%). Those specifying one of the other species usually amounted to less than 5% of the total number of anglers. Many anglers (29-45%) were fishing for any species of trout or salmon.

The sport-fish catch in Lake Superior at Marquette was dominated by salmonid fishes (Table 6). The only non-salmonids in the catch were a few northern pike, yellow perch, carp, and burbot. Coho salmon, lake trout, and round whitefish were the most abundant; lake whitefish and chinook salmon were next in abundance; and rainbow trout, splake, and brown trout were the least abundant. Other fishes occasionally caught were brook trout, Atlantic salmon, and the aforementioned non-salmonids. The number caught per angler hour (CPE) was determined for coho, lake trout, round whitefish, and chinook during months when most fishing was targeted at these species (Table 6). Lake trout and round whitefish CPEs were consistent throughout 1984-87, but CPEs for the salmon fluctuated considerably. Coho CPEs in 1985 and 1986 were significantly greater than in 1984 and 1987. Chinook CPE was significantly greater in 1985 than in 1984 and 1987. Mean annual CPEs were much less than target CPEs, and mean monthly CPEs varied considerably (Table 7). CPEs were highest for coho salmon in January, lake trout in June-July, round whitefish in November, lake whitefish in December, chinook salmon in August, rainbow trout in May, splake in November, and brown trout in February.

Fish were caught year-round with individual species predominating at various times of the year (Table 8). About 90% of the total coho catch was made during February-May, with 51% during April. Good catches of lake trout occurred over a longer period (June-September), with the highest monthly catch (August) accounting for 22% of the total catch. Round whitefish and lake whitefish were caught every month except August-September, but most round whitefish (68%) were taken during November, and most lake whitefish (53%) were caught during February-April. Chinook were caught throughout the year, but almost half (48%) of the total catch was made during August-September. Rainbow trout were caught every month except January and August, but over half the catch was made during April-May. Splake were caught every month except July, but most were caught during February-March. Brown trout were caught every month except December, but most were captured during February-March.

There were differences in catch composition between the two Lake Superior survey sites. Most of the coho (62%), lake trout (92%), and chinook (90%) were landed at Presque Isle Harbor, whereas most of the round whitefish (98%), rainbow trout (79%), and splake (96%) were landed at Marquette Bay. The catch of lake whitefish and brown trout was about equal at the two sites.

Dead River Sport Fishery

Sportfishing effort on the approximately 1 mile of Dead River averaged just over 20,000 angler hours per year during 1984-87 (Table 9). There was no significant difference in effort among years. Shore fishing was the predominant mode (94-97%), followed by ice fishing and boat fishing. Although some fishing occurred every month, 70% of the total effort occurred during September-October (Figure 3). The mean duration of an angler trip was 2.5 hours during 1985-87. Trip duration was shortest in March (1.4 hours) and longest in October (3.0 hours). Marquette County anglers made up 91% of those fishing the Dead River during 1985-87 (Table 10). Most of the remaining anglers were from other states (5%). Anglers were mainly fishing for any trout or salmon in the Dead River (Table 11). Coho salmon (10%), chinook salmon (8%), northern pike (6%), and rainbow trout (5%) were the most sought

after by those who expressed a preference for a particular species, but there was considerable variation from year to year.

The total numbers of coho and chinook salmon caught in the Dead River during 1984-87 were nearly identical, and together they made up 88% of the total catch of all species. The proportion of coho and chinook in annual catches fluctuated with more coho caught in 1984 and 1987, and more chinook caught in 1985 and 1986 (Table 12). Anglers caught a few other salmonids and a number of cool-water and warmwater species, but the catches of these other species were significantly less than of coho or chinook. Most coho were taken in September and most chinook were caught in October (Table 13). Coho and chinook were part of the Dead River creel through the winter months and into early spring. All coho and chinook caught in the Dead River fishery were mature spawning-run fish, even those caught during January-April. Pink salmon were taken only during September. Rainbow trout and northern pike were sought by a number of anglers but contributed only a few fish to the catch. Most of the rainbow trout were taken in May and most of the northern pike were caught in June. White suckers provided a fishery during April and May most years, especially in 1987. Centrarchid species pro-vided most of the fish in the creel during the summer months.

Carp River Sport Fishery

Only shore fishing was done on the Carp River, and this averaged just over 6,600 angler hours per year during 1984-87 (Table 9). Effort in 1986 was significantly higher than in the other years. The within-year distribution of fishing effort during 1985-87 was bimodal, with peaks in April-May and September-October (Figure 4). Fall fishing effort in 1987 was much lower than in 1985 and 1986. Duration of an angler trip averaged 2.1 hours during 1985-87, with the shortest duration in January (1.0 hours) and the longest duration in June (2.6 hours). Marquette County anglers accounted for 95% of those fishing the Carp River during 1985-87 (Table 14). Residents of other Michigan counties (2%) and other states (3%) made up the remainder. The percentage of anglers from other states was the same each year, but the residence of Michigan anglers varied, especially in 1987 when all Michigan anglers interviewed were from Marquette County. Rainbow trout (29%) and coho salmon (4%) were the most sought-after individual species, but 64% of the anglers were fishing for any trout or salmon (Table 15). Species preference was similar in 1985 and 1987, but more anglers were fishing for any trout and salmon in 1986.

Rainbow trout made up 43% of the total catch in the Carp River sport fishery (Table 16). Coho salmon (27%) and brown trout (13%) were also important components. Rainbow trout were caught during March-November, with 33% in May (Table 17). The rainbow trout catch during March-May and October-November was made up of mostly large fish (16 inches and longer), most of which were mature. The rainbow trout catch during June-September was mainly juveniles, most of which were hatchery yearlings in 1986 and 1987. The coho salmon catch occurred during September-November, mostly in October, and was composed entirely of mature spawning-run fish. Hatchery yearlings planted in 1987 contributed most of the brown trout in the 1987 Carp River creel, especially during May and June. Lake trout were the fourth most abundant fish in the Carp River creel, which was unusual considering the small volume and steep gradient of this stream. All of the lake trout were caught during October, and mostly in 1985. These fish were mature and in spawning condition. Some chinook salmon were taken during the September-November spawning period in 1984-87. A few stream-resident brook trout were harvested each year. Bullheads and northern pike were present and caught in the Carp in 1985 and 1986. The presence of these fish was attributed to drainage of an upstream impoundment. Lesser numbers of white suckers, splake, and round whitefish also contributed to the catch.

Chocolay River Sport Fishery

Sportfishing effort on the 2 miles of the Chocolay River surveyed averaged just over 10,000 angler hours for 1984-87 (Table 9). Effort was significantly lower in 1985 and significantly higher in 1987. Shore fishing was the principal mode, but boat fishing on the Chocolay was substantial (8-31%) compared to the Dead and Carp rivers. The within-year distribution of fishing effort was bimodal, with most fishing in March-May and September-October during 1985-87 (Figure 5). Warm weather resulted in higher than average fishing effort during February-March 1987, and the fishery for Siletz summer steelhead is believed responsible for the increased fishing effort during August in 1986 and 1987. Duration of an angler trip averaged 2.3 hours during 1985-87. Trip duration was shortest in July (1.3 hours) and longest in February (3.7 hours). Marquette County residents accounted for 93% of those fishing the Chocolay River during 1985-87, with 5% from other Michigan counties and 2% from other states (Table 18). Rainbow trout (27%) and coho salmon (5%) were the most sought-after individual species, with 64% of the anglers fishing for any trout or salmon (Table 19). More anglers expressed a preference for a particular species in 1985 than in 1986 and 1987.

Coho salmon were most numerous (42%) in the Chocolay River sport-fish catch (Table 20). Other important species were rainbow trout (23%), brown trout (10%), and white sucker (10%). Coho were caught every month except June and July, but most (82%) were taken as mature spawning-run fish during September-October (Table 21). Coho caught during January-May were mainly immature fish that were attracted to the lower river by availability of food and/or warmer water. Anglers harvested rainbow trout every month except June but most were taken during May (27%) and October (21%). Most of the rainbow trout were 16 inches and larger except in May when recently planted hatchery yearling fish predominated (Table 21). Brown trout were caught each year and every month except January and December. These were both resident and anadromous fish mostly 16 inches and larger. White suckers were caught during the spring spawning run most years, especially in 1987. Lake trout were caught during May and July-October. Other fish taken in the Chocolay River were round whitefish, northern pike, chinook salmon, pink salmon, splake, and brook trout. Most northern pike were taken during May-July, and all the chinook were caught during September-October.

Biological Parameters of Major Sport Fish

Coho salmon.—Practically all of the coho salmon in the sport fishery in Lake Superior and tributaries at Marquette were age 2. Age-1, age-3, and age-4 coho were rarely captured. Because the fishery was essentially for age-2 coho, mean size in the catch increased as the year progressed. Mean size of age-2 coho increased from 15-16 inches and 1 pound in January-February to 21-22 inches and 3 pounds in November-December (Table 22). Because most coho were caught during a relatively small portion of the year (February-May) and mean size increased during the year, annual mean lengths and weights were determined from monthly sample mean lengths and weights that were weighted by estimated monthly catch (Table 23). Coho mean size ranged from 16 inches and 1.2 pounds in 1986 to 18 inches and 2.0 pounds in 1984, with an overall mean of 16.6 inches and 1.4 pounds for 1984-87. The size of coho caught in the tributaries was within the range from the lake during September-November.

Lake trout.—Wild lake trout entered the Marquette sport fishery at age 4, with age 8 being the modal-age group in the catch most years (Table 24). Hatchery lake trout entered the fishery as early as age 3, modal age increased from age 6 in 1984 to age 9 in 1987. Age-10 lake trout were well represented all 4 years and age-11 fish were abundant in 1986 and 1987. The maximum age determined for either wild or hatchery lake trout was 15 years. The representation of older age groups increased for wild and hatchery lake trout between 1984 and 1987. Lake trout mean total length averaged 23.5 inches with a range of 13 to 39 inches, and total weight averaged

4.4 pounds with a range of 0.4 to 23.2 pounds (Table 23). There was no significant difference in lake trout length and little difference in weight among years. There was little variation in length and weight among months when most lake trout were caught (June-September). In June-September 1985, mean length ranged from 22.4 inches to 23.5 inches, and mean weight ranged from 4.1 pounds to 4.8 pounds. Lake trout caught in the Carp and Chocolay rivers during 1984-87 were larger, averaging 26.0 inches long and 5.6 pounds, but these were mature fish in spawning condition caught during September and October.

Rainbow trout.—Rainbow trout entered the sport fishery in Lake Superior at Marquette as age-1/0 juveniles, but a majority were adults at ages 2/2 and 2/3 (Table 25). The oldest rainbow in the lake catch was age 7 represented by 1/6 and 2/5 age categories. Total length ranged from 11 to 33 inches with a mean of 21.1 inches, and total weight ranged from 0.4 to 12.4 pounds with a mean of 3.6 pounds in the Lake Superior sport fishery (Table 23). Mean lengths and weights among years were similar, except in 1984 when the values were significantly less. Ages 2/2, 2/3, and 2/4 contributed most to the catch of mature rainbow trout in the Carp River. Juvenile fish (1/0, 1/1, and 2/0) made up a larger proportion of the total catch, but most of these juveniles were hatchery fish planted in 1986 and 1987. The oldest rainbow trout in the Carp River catch were age 2/5. Large (16 inches and longer) rainbow trout in the Carp River catch averaged 22.9 inches long and weighed 4.0 pounds, and most were mature. In the Chocolay River, ages 1/2 and 1/3 predominated in the catch of mature rainbow trout and many of these were hatchery fish planted during 1983-85. The modal-age group for wild rainbow was 2/2. The oldest rainbow in the Chocolay River catch were age 2/5. Yearling (1/0) hatchery rainbow trout contributed most of the juvenile fish in the Chocolay River sport catch. Mature rainbow in the Chocolay River catch averaged 24.0 inches long and weighed 4.7 pounds. Insufficient biological data were obtained from the meager catch of rainbow trout in the Dead River.

Chinook salmon.—Some chinook salmon grew to the 10-inch minimum size limit by the end of their first summer in the lake and entered the Lake Superior sport fishery at Marquette at age 0. Age 5 was the oldest age group reported. Ages 2 and 3 made up most of the catch during the first half of the year, ages 3 and 4 predominated during the second half except in 1985 when age-2 chinook were quite abundant (Table 26). There was no significant change in size of age groups 2-4 among years. Chinook salmon total length ranged from 10 to 38 inches with a mean of 24.4 inches, and total weight ranged from 0.2 to 22.0 pounds with a mean of 6.8 pounds (Table 23). There were no significant differences in mean length and weight among years.

Splake.—Splake entered the sport fishery at Marquette as yearlings with the mean age in the 1984-87 catch being 2 years. Splake total length ranged from 9 to 24 inches with a mean of 13.6 inches, and total weight ranged from 0.2 to 5.8 pounds with a mean of 0.9 pounds (Table 23). Mean lengths and weights were significantly different among some years because splake were not planted every year. The catch in 1984 consisted mainly of age-3 fish from a plant made in 1982. No splake were planted in 1983 and 1984. The mean size of catches in 1985-87 was influenced mainly by the plant of yearlings in 1985 and their progression through the fishery in 1986 and 1987.

Brown trout.—Brown trout in the sport fishery in Lake Superior at Marquette ranged in age from 1 to 8 years, with most contributing to the creel at ages 2 and 3. Brown trout total length ranged from 10 to 28 inches with a mean of 17.2 inches, and total weight ranged from 0.2 to 9.6 pounds with a mean of 2.2 pounds (Table 22). Mean lengths and weights were not significantly different among years. Brown trout captured in the Carp and Chocolay sport fisheries averaged smaller than those caught in Lake Superior.

Round whitefish.—Round whitefish in the Lake Superior sport fishery at Marquette

ranged in age from 2 to 9 years, but age composition was older with age 3 the modal group in 1984 and age 5 the modal group for 1985-87 (Table 27). Round whitefish total length ranged from 8 to 15 inches with a mean of 11.1 inches, and total weight ranged from 0.1 to 0.8 pounds with a mean of 0.4 pound (Table 23). There was no significant difference in mean length and weight among years.

Lake whitefish.—The sport catch of lake whitefish in Lake Superior at Marquette during 1984-87 ranged in age from 2 to 9 years. Age 3 was the modal-age group every year except 1986 (Table 28). Mean length and weight at age was similar among all years except 1984 when values were larger. Total length ranged from 8 to 27 inches with a mean of 14.7 inches, and total weight ranged from 0.1 to 7.1 pounds with a mean of 1.0 pounds (Table 23). There was no significant difference in mean length and weight among years.

Contribution of Hatchery Fish to the Sport Fishery

Rainbow trout.—Hatchery rainbow trout comprised 15% of the sport-fish catch of 1,658 rainbow trout in Lake Superior at Marquette during 1984-87, with the contribution in the tributaries ranging from 10% of 191 caught in the Dead River to 44% of 1,155 caught in the Chocolay River (Table 29). Most (67%) of the hatchery fish caught in the lake at Marquette were those planted in the lake or tributaries at Marquette, with the remainder identified by age and clip as mainly fish planted in Minnesota and Wisconsin waters of Lake Superior. The most abundant of this latter group were the Kamloops strain of rainbow trout planted in Minnesota. Hatchery rainbow made up 10% of the few rainbow trout that were caught in the Dead River; all were strays from the 1983 plant of Lake Michigan strain steelhead in the Chocolay River. Hatchery rainbow trout made up 25% of the catch of 1,935 rainbow trout in the Carp River during 1984-87, but this was largely due to the contribution of juveniles planted in 1986 and 1987. The greatest contribution of hatchery rainbow trout was to the catch in the Chocolay River (44%), and most of these were fish planted in the river.

Rainbow trout planted in Lake Superior at Marquette provided a meager return to the sport fishery (number caught as a percent of number planted). The contribution of Lake Michigan steelhead strain was better than that by the domestic strain, but both returns were less than 1% (Table 30). Domestic strain rainbow trout planted in Marquette Bay in 1983 contributed nothing to the catch in Lake Superior, but a few were caught in the Chocolay River. The return to the fishery at all sites was 0.14%. Domestic strain fish planted in Presque Isle Harbor in 1984 contributed nothing to the creel at any of the sites surveyed at Marquette. The total return from both plants of domestic rainbow trout was 0.08%. Lake Michigan steelhead strain rainbow trout planted in Marquette Bay in 1983 provided a total return to the creel of 0.92%, with most of the return coming from Marquette Bay (Table 30). This plant contributed 4.1% of the rainbow trout catch in Lake Superior at Marquette and 0.8% of the Carp River catch. Lake Michigan steelhead strain fish planted in Presque Isle Harbor in 1984 provided a return of 0.13%, all from Presque Isle Harbor. This plant contributed only 0.7% to the lake catch. The total return from the two Lake Michigan strain steelhead plants was 0.52%. The hatchery rainbow trout planted in Lake Superior contributed to the catch mainly as juveniles during the first and second year after planting. In fact, none of these rainbow trout were captured at Marquette after 1985.

Rainbow trout planted in the Chocolay River provided a better return to the sport-fish catch than those planted in Lake Superior, especially the Siletz strain (Table 30). The Siletz summer steelhead planted in 1984 comprised 22.9% of the total Chocolay River catch of 1,155 rainbow trout, with a return to the fishery of 1.21% in the Chocolay River and 1.44% at all sites. Lake Michigan steelhead strain planted in 1983, 1984, and 1985 contributed 9.3%, 17.8%, and 3.9% of the Chocolay River rainbow trout catch, respectively. Returns to the fishery of the 1983, 1984, and 1985 plants were 0.32%,

0.90%, and 0.23% to the Chocolay River and 0.56%, 1.18%, and 0.23% to all sites, respectively. Most of the return from both strains (Siletz and Lake Michigan) were large mature fish.

Brown trout.—Hatchery brown trout contributed 40% of the 1,091 brown trout caught in Lake Superior at Marquette during 1984-87, with 36% being those planted at Marquette (Table 29). The remainder were identified by age and mark as brown trout planted in Wisconsin waters of Lake Superior. Yearling brown trout planted in the Carp River in 1987 made up 95% of the 404 brown trout caught that year, with most caught during the summer months immediately following planting. Because few brown trout were caught in the Carp River prior to 1987, the plant of hatchery fish in 1987 contributed 67% to the 1984-87 total catch of 575 brown trout. The Chocolay River had a better natural population of brown trout and had not been planted, so the only contribution by hatchery fish to the total catch of 511 brown trout was by strays from a Wisconsin and a Marquette Bay plant in 1986.

Fall-fingerling and yearling hatchery brown trout planted in Presque Isle Harbor and Marquette Bay during 1983-85 provided variable returns to the 1984-87 sport fishery that were all below 1% (Table 30). The 1983 plant of yearlings in Presque Isle Harbor provided the greatest return (0.95%) even though the creel survey did not start until a year after the plant was made. This plant provided 12.3% of the 1984-87 total brown trout catch of 1,091 in Lake Superior at Marquette, all from Presque Isle Harbor. This plant made its biggest impact in 1985 when it made up 38% of the 266 brown trout caught that year. The 1984 fall-fingerling plant in Marquette Bay provided the second highest return (0.54%), with most caught in Marquette Bay. The 1984 fall fingerlings provided 11.7% of the 1984-87 total brown trout catch with its greatest contribution (23%) in 1986. This plant also provided a few fish to catches in the Carp and Chocolay rivers in 1984. The poorest brown trout returns were from the 1983 fall fingerling (0.03%) and 1984 yearling (0.15%) plants in Presque Isle Harbor.

Coho salmon.—Hatchery coho salmon provided 80% of the 1,869 coho caught in the Dead River during 1985-86, but 10% or less of the catch in the non-planted Carp (1,166) and Chocolay (1,335) rivers and Lake Superior (38,906) at Marquette (Table 29). The return of hatchery coho to the sport fishery in 1985 and 1986 at Marquette averaged less than 2% (Table 30). This return was higher than for other planted salmonids except splake and Siletz rainbow trout, but the return at Marquette may be biased high because the same clip was used on all coho each year and some of those caught at Marquette could have been coho planted at other sites in Lake Superior.

Splake.—All splake caught in the sport fishery at Marquette during 1984-87 were considered to be hatchery fish. The 1985 plant of 7,800 yearling splake provided almost a 13% return to the fishery, which was the highest for any trout or salmon plant in this study (Table 30). The return or fall fingerling splake planted in 1985 was less than 1%. Most splake entered the creel during the first fall and winter following planting.

Lake trout.—The contribution by lake trout to the sport-fish catch in Lake Superior at Marquette decreased from 38% to 18% with a mean of 29% during 1984-87 (Table 29). Hatchery lake trout made up the majority of lake trout only in the Carp River (62%) and Chocolay River (100%) catches. No attempt was made to determine the return of specific lake trout plants to the sport fishery because the same fin clip was used for most plants in Michigan waters each year, and because lake trout year classes could be vulnerable to the sport fishery for 10 years or more.

Other.—Hatchery chinook salmon were planted annually in Lake Superior by Michigan, Minnesota, and Wisconsin. None of the hatchery chinook year classes planted in Michigan waters that could have contributed to the 1984-87 sport fishery at Marquette were marked, so the contribution of hatchery chinook could not be determined. The Dead River has been planted annually and has little

substrate suitable for natural reproduction, so it was likely that most of the chinook catch was of hatchery origin. Atlantic salmon have been planted in Lake Superior by Minnesota most years since the late 1970s. No Atlantic salmon natural reproduction has been reported, so all of those in the Marquette creel were probably of hatchery origin. Pink salmon were all naturally produced as none have been planted since the original introduction in 1956.

Mortality Due to Fish Planting

Transport of rainbow trout and brown trout from Thompson State Fish Hatchery required 2-3 hours, whereas that for steelhead from Wolf Lake State Fish Hatchery required 10-11 hours, but the difference in transport time appeared to have little effect on observed mortality. The number of rainbow and brown trout that died en route between hatchery and planting site was usually less than 100 and exceeded 200 only for a 1984 plant of steelhead strain rainbow in the Chocolay River (400). Even in the latter case the mortality rate was less than 2%. No mortality was reported for some plants by both hatcheries. Little or no mortality was reported for splake transported 2-3 hours and planted in Marquette Bay by Thompson State Fish Hatchery, and very little mortality was reported for coho salmon yearlings transported about 6 hours from Platte River State Fish Hatchery to the Dead River (<1%). Transport water temperatures were less than 15°C for all spring yearling plants and less than 20°C for all fall fingerling plants. Receiving water temperatures were less than 10°C for all spring yearling plants and less than 20°C for all fall fingerling plants. The temperature difference between transport and receiving water was usually 5°C or less. An exception was the 1984 plant of yearling steelhead strain rainbow trout in Presque Isle Harbor where transport water was 14°C and receiving water was 1°C. These fish may have been stressed by the temperature difference. Although none had died during transport, a few dead fish were observed at the planting site the following day.

For the 1983 plant of 10,000 yearling domestic rainbow trout from Thompson to Marquette Bay, transport water had a temperature of 9°C, pH of 6.9, alkalinity of 117 ppm, and NH_3 level of 0.004 ppm; receiving water had a temperature of 5°C, pH of 7.0, alkalinity of 14 ppm, and NH_3 level of 0.0006 ppm. For the 1983 plant of 20,000 yearling steelhead from Wolf Lake to Chocolay River, transport water had a temperature of 10°C, pH of 7.3, alkalinity of 200 ppm, and NH_3 level of 0.003 ppm; receiving water had a temperature of 7°C, pH of 6.9, alkalinity of 35 ppm, and NH_3 level of 0.0003 ppm.

Discussion

The Lake Superior Sport Fishery

Fishing in Lake Superior during 1984-87 appeared to be better than in the 1960s, but perhaps not as good as during the 1970s. No judgement could be made about fishing in the Dead, Carp, and Chocolay rivers because no creel survey had been done prior to 1984. In Lake Superior, data from the undocumented creel survey in 1968 indicated that fishing for some species in Lake Superior was not as good then as during my study. The catch of major sport fish at Marquette in 1968 was 7,229 lake trout, 1,198 brook trout, 1,037 whitefish, 539 coho salmon, 7 chinook salmon, 88 rainbow trout, and 62 brown trout (R. W. Rybicki, MDNR, personal communication). This is not surprising because during the late 1960s the fish populations were recovering from the effects of sea lamprey depredation, and angling for the newly introduced coho and chinook salmon was just catching on. Sportfishing effort in Lake Superior at Marquette in 1968 appears to be comparable to that in the 1980s, assuming 3-4 angler hours per angler day for the 26,000 angler days reported by Rybicki. Sport-fish catches reported by the mail creel survey during the 1970s were generally higher than in my on-site survey. Estimated catches during 1975-79 were 17,000-86,000 for lake trout, 10,000-47,000 for coho salmon, 600-14,000 for

chinook salmon, 4,000-14,000 for rainbow trout, and 3,000-13,000 for brown trout in Marquette County waters of Lake Superior (G. C. Jamsen, MDNR, personal communication). Lake trout fishing certainly should have been better then because annual assessment of lake trout stocks indicated that abundance of lake trout was greater in the 1970s than in the 1980s (Peck and Schorfhaar 1991), and anglers could harvest five fish per day prior to 1978 versus three fish per day since then. However, it is doubtful that fishing was better to the degree indicated by mail-survey catches, because the mail-survey estimates were found to be as much as five times higher than some concurrent on-site-survey estimates (Rybicki and Keller 1978; Patriarche 1980). Inflating the catch estimates from my study by a factor of five would make them comparable to those from the 1970s in most cases.

In the 1987 survey, more fishing was done at Marquette than at any other port on Michigan waters of Lake Superior (Rakoczy and Rogers 1988b). Marquette is the major population center along this shoreline and has good facilities for accessing the lake's sport fishery. Boat launching and mooring facilities at Presque Isle Harbor and Marquette Bay encourage the boat fishery, most of the shoreline is accessible to shore anglers, and some of the shoreline can be used for boat launching during winter when designated launch sites are ice bound.

Monthly effort at Marquette in 1987 was exceeded only in February at Munising Bay and Huron Bay in Lake Superior (G. P. Rakoczy, MDNR, personal communication). This probably occurs most years because of the reliable formation of ice and the resulting ice fishery at Munising and Huron bays; and the infrequent occurrence of ice and an associated fishery at Marquette. Ice fishing is popular along the Lake Superior shoreline. Ice fishing accounted for over 13% of the total fishing effort at Marquette in 1985 and 1986, and more angler hours were recorded during the February-March ice fishery than during the April-October open-water fishery at Munising in 1987 (G. P. Rakoczy, MDNR, personal communication).

The difference in fishing effort between Presque Isle Harbor and Marquette Bay during June-September was influenced by facilities and access to fish. Launching and mooring facilities on Marquette Bay were not as suitable for large boats as facilities at Presque Isle Harbor, and the distance to lake trout fishing grounds was greater from Marquette Bay than from Presque Isle Harbor. Marquette Bay was unique because of the large amount of shore angling. Anglers had access to most of the bay shoreline, and much of it consisted of piers or breakwaters which provided access to deep water. I know of no other site on Lake Superior or elsewhere in the Great Lakes where fishing from shore exceeded 20,000 angler hours and made up nearly half of the total effort.

Angling effort at Marquette, although considerably less than at the major ports on lakes Michigan and Huron, did equal or exceed some ports on these lakes (Rakoczy and Rogers 1988b). The comparable ports were on the northern portions of the lakes where human population densities were similar to Marquette. Monthly distribution of effort, fishing mode, and duration of trip at Marquette differed from that in lakes Michigan and Huron (Rakoczy and Rogers 1988a and 1988b). March-April fishing effort was around 30% of the total at Marquette, but was only 10-15% of the total effort in lakes Michigan and Huron in 1987. Fishing mode and duration of trip in Lake Superior during April-September was comparable to Lake Huron although still lower than Lake Michigan.

The predominance of coho salmon and lake trout in Marquette's 1987 sport fishery was similar to that at other Lake Superior ports, except at Munising where coho salmon and lake whitefish made up most of the catch (G. P. Rakoczy, MDNR, personal communication). Coho salmon did exceed lake trout at Marquette in 1985 and 1986, but I do not know if this occurred at other Lake Superior ports because creel survey data were not available. Round whitefish contributed much more to the catch at Marquette than elsewhere, but most of the other ports were not surveyed during November-December, when

most round whitefish were caught at Marquette.

If the Lake Superior catch were ranked on the basis of weight, the order of the top five species would be lake trout, coho salmon, chinook salmon, rainbow trout, and round whitefish. In lakes Michigan and Huron, chinook salmon and lake trout made up most of the salmonid catch in 1987 (Rakoczy and Rogers 1988a). Coho salmon were a major contributor to the Lake Michigan fishery, but few were caught in Lake Huron.

Sportfishing CPE at Marquette in 1984-87, compared to the mean for other Lake Superior sites in 1987 (Rakoczy and Rogers 1988a), was greater for coho salmon, round whitefish, lake whitefish, splake, and brown trout, but less for lake trout and chinook salmon. Compared to Lake Michigan, CPE at Marquette was less for all species except lake trout and the whitefishes (Rakoczy and Rogers 1988a).

Trout and salmon in the Lake Superior sport-fish catch were smaller than in the Lake Michigan and Lake Huron fisheries. Lake Superior is the most oligotrophic of the Great Lakes and therefore has the lowest potential for fish growth. In addition, the greater percentage of winter and early spring fishing in Lake Superior tends to harvest younger and smaller fish. In Wisconsin's 1969-84 Lake Michigan sport fishery, mean weights (pounds) of major sport fishes were: lake trout—6.3; coho salmon—4.8; chinook salmon—10.4; rainbow trout—5.4; and brown trout—4.8 (Hansen 1986). Mean size of salmonids has not been documented for sport fisheries in Michigan waters of Lake Michigan and Lake Huron, except that Rakoczy (1991) reported 12.0-12.4 pounds for chinook and 4.0 pounds for coho in the 1986-88 Lake Huron sport fishery. These weights are around 2-3 pounds heavier than mean weights observed in the sport fishery at Marquette. Adult rainbow trout in Lake Superior and tributaries averaged 4 inches or more shorter than Seelbach (1989) reported for comparable age groups in Lake Michigan. Lake Superior anglers do catch bigger lake trout as indicated by the number entered each year in Fisheries Division's Master Angler Program.

Age and size composition of most sport-fish species caught in the Lake Superior sport fishery has changed little over the past 20-30 years. Lake trout in the 1984-87 sport-fish catch at Marquette were the same size as those in the Lake Superior fishery in 1968 (R. W. Rybicki, MDNR, personal communication). Coho and chinook salmon in the sport-fish catch were the same size in 1984-87 as they were in 1967-71 (Rybicki 1973), whereas coho and chinook in Lake Michigan have decreased in size. Mean weights of adult coho and chinook collected at weirs on Lake Michigan's Platte and Manistee rivers decreased about 3 pounds and 5 pounds, respectively, between 1967-71 and 1986 (Rybicki 1973; Pecor 1987). Thus, the salmon size gap between Lake Superior and Lake Michigan appears to have narrowed over the past 20 years. Although a decrease in lake trout growth rate in Lake Superior during the 1980s has been reported (Hansen 1990), no decrease in mean size of lake trout or any other salmonid was observed in the Marquette sport fishery during 1984-87. Rainbow trout spawning runs in Lake Superior tributaries during the 1960s and 1970s were dominated by age-2/2 and age-2/3 fish that averaged less than 25 inches long (Biette et al. 1981), just as they were in the 1980s (Edinger 1987; this study).

Tributary Sport Fisheries

Angling effort in the tributaries was greatest during spring and fall because it was targeted at spawning runs of anadromous rainbow trout and salmon. Effort during summer was low because the available fish were small or were low-valued species, and effort during winter was low due to unpleasant weather.

The Dead River lacked substrate for salmonid reproduction, but produced more angler hours than the Carp and Chocolay rivers combined, and a greater chinook salmon harvest than at all other sites including Lake Superior. The duration of angler trips was also longer than on the Carp and Chocolay rivers. Contributing to the high catch and effort on the Dead River were plants of

hatchery coho and chinook, concentrations of fish in fishable pools (fish are blocked by a dam), proximity to a highly populated portion of Marquette, and accessibility of much of the stream. The Dead River was the only site where hatchery coho made up most of the coho catch. Although the catches of coho and chinook were numerically equal, the chinook catch was at least twice that of coho on the basis of weight. The presence of a warmwater fish population provided angling for those interested in fish other than trout and salmon.

Effort on the Carp River was mainly for spawning runs of naturally produced trout and salmon. The Carp River provided the best catch of rainbow trout most years and a substantial run of lake trout in 1985. Although the yearling rainbow and brown trout planted in 1986 and 1987 were likely responsible for increased June-August effort during those years, little of the total fishing effort in the Carp River was targeted at the hatchery yearlings. Although much of the Carp River was accessible to anglers, fishing was more restricted than in the Dead River because of the smaller volume of water, steeper gradient, fewer pools, and a less diversified fish population. These factors, plus poor salmon spawning runs in 1984 and 1987, probably contributed to the Carp River having the lowest fishing effort of the three tributaries surveyed. In addition, the Michigan Department of Public Health had issued a "No Consumption" advisory for fish from this stream which was publicized in the Michigan Fishing Guide.

Fishing in the Chocolay River was enhanced by deep pools that held fish year-round, a good natural population of trout and salmon, and plants of hatchery rainbow trout that attracted anglers and provided large fish to the catch in 1986 and 1987. Although most Siletz summer steelhead were caught during the fall, their presence during August was likely responsible for the increase in August effort from 305 angler hours in 1984 to 1,647 angler hours in 1987. The Siletz also provided a good catch during August in a Lake Michigan tributary (Fielder 1987). Lake Michigan strain steelhead also contributed to the Chocolay River catch during the fall and winter months. The availability of these hatchery fish, along with a warm winter, contributed to the much higher estimate of fishing effort in 1987. Considering the year-round availability of trout and salmon, I believe that fishing effort on the surveyed section of the Chocolay River would have equaled or exceeded that on the Dead River had fishing access been comparable. Most of the stream bank in the surveyed section of the Chocolay was privately owned and deep water prohibited wading in many areas.

Although anglers fishing these tributaries generally did not harvest as many chinook and rainbow as their counterparts on the better Lake Michigan and Lake Huron tributaries, the catch rates were comparable (Rakoczy and Rogers 1988b). For coho salmon, catch and catch rates in the Lake Superior tributaries were usually higher than in Lake Michigan or Lake Huron tributaries.

Hatchery Trout and Salmon Contribution and Percentage Return

I assumed equal catchability among species, and between hatchery and wild fish, in making comparisons of their contributions to total catch and percentage return. My only basis for this assumption was that my creel survey was year-round and surveyed all modes of fishing. I also assumed that fish planted in a specific area were to provide fishing for that area, so I did not include hatchery fish reported from outside the surveyed area in the calculations. Comparisons of percentage return for rainbow trout and brown trout plants were obfuscated by considerable variation associated with low catch estimates for these species. That hatchery trout and salmon (splake excepted) did not contribute most of the fish in the total sport-fish catch, nor provided a high percentage return of the number planted to the fishery at Marquette, was not surprising considering the amount of natural reproduction in these waters, the low numbers planted, and the reported straying and other problems associated with hatchery fish.

That hatchery rainbow trout contributed less than hatchery brown trout to their respective catches (15% versus 40%) could be due to greater straying by hatchery rainbow and larger natural populations. I suspect larger natural populations is the primary factor.

Rainbow trout were introduced into Lake Superior in the 1880s and have reproduced successfully in many tributaries throughout the lake (Lawrie 1978). Rainbow trout have been found in 88 of Michigan's 120 Lake Superior tributaries (Moore and Braem 1965). Brown trout were also introduced into Lake Superior during the 1880s, but naturally reproducing populations did not become as widely distributed as for rainbow trout (Lawrie 1978). According to Lawrie, these populations were largely confined to the south shore, especially in the west end of the lake. Only 22 of 120 Michigan tributaries have been reported to contain brown trout (Moore and Braem 1965).

Planting more hatchery rainbows could increase their representation in the catch, but might result in lower survival and more straying if the rainbow trout niche in Lake Superior has already been filled by wild fish. Hatchery rainbow trout did provide nearly half of the catch in the Chocolay River. This appeared to be a situation where the rainbow trout niche was not full, and planting in the river resulted in a better imprint and homing by hatchery fish. Natural reproduction in the Chocolay River in the early 1980s was less than in the early 1950s (Marquette Fisheries Station, unpublished data). This is probably due to depredation of adult rainbow by sea lamprey during the late 1950s, and possibly to disruption of subsequent spawning runs by a sea lamprey barrier weir that was on the river through 1979.

Returns to the sport fishery for rainbow plants in Lake Superior and tributaries at Marquette, although low, were within the range reported from other documented studies in Michigan waters of Lake Superior. Hansen and Stauffer (1971) reported an overall return of 1.0% from plants of three strains of tagged rainbow trout in Lake Superior and tributaries during 1955-79. They reported better returns from the domestic strain of rainbow than from two strains of wild anadromous rainbow, and better returns from lake plants versus stream plants. This was contrary to the results of my study where the return of domestic strain was less than for the steelhead (Lake Michigan) strain, and stream plants provided a better return than lake plants. This difference might be explained by their use of older (age-2 and age-3) fish that likely had a higher survival rate, and a Great Lakes basin-wide tag-return strategy that would provide returns regardless of the distance strayed. Hansen and Stauffer were able to obtain return information from some rainbow trout that were caught as far as 500 miles from the planting site. Wagner and Stauffer (1978) reported a very low return (0.06%) from plants of domestic and Lake Michigan steelhead strain rainbow trout in a Lake Superior tributary (Huron River) during the early 1970s. As in my study, they only solicited return information from the planting site and vicinity. Wagner and Stauffer also found that domestic rainbow provided most of their meager return, but the domestic rainbows were larger than the steelhead and may have had a higher survival rate.

Close and Hassinger (1981) reported returns to the sport fishery that ranged from 3% to almost 28% for Kamloops, Donaldson, and Madison strains of rainbow trout planted in Minnesota waters of Lake Superior. These higher returns were likely due to intensive fishing mentioned by Close and Hassinger and large size (240-260 mm) of most of the planted fish, but behavior of these strains may also have influenced return.

Strain behavior is one reason why Siletz steelhead provided a higher estimated return in the Chocolay River than Lake Michigan steelhead. These summer steelhead entered the Chocolay at least as early as August, so were concentrated and available to anglers for a longer period than the Lake Michigan steelhead. In addition, the Siletz were planted a much shorter distance from the lake, near the creel-surveyed portion of the river, likely experienced less mortality during out migration as juveniles, and were more likely to return to the surveyed portion of the river as adults. Siletz summer steelhead are currently

unavailable for plants in Great Lakes waters because no eggs were obtained from Siletz that matured in Great Lakes waters, and disease in West Coast salmonid populations precluded further transfer of fish or eggs to the Great Lakes.

Much higher returns have been reported from Lake Michigan strain steelhead plants in Lake Michigan tributaries. Returns of 10-20% have been recorded for two rivers during the mid-1980s and early 1990s (P. W. Seelbach, MDNR, personal communication). Seelbach (1989) reported that returns to the St. Joseph and Grand rivers during the early 1980s ranged from less than 1% to 7%. However, these steelhead were planted as small parr (pre-smolts) and were believed to have had very poor survival to smolting.

The return of brown trout to the Lake Superior sport-fish catch was no better than that for rainbow trout. This similarity could be an artifact resulting from high variability in the catch estimates for brown and rainbow trout, it could be due to similar survival and degree of straying, or offsetting differences among these factors. Brown trout yearlings were generally smaller than rainbow trout yearlings and could have had a lower survival rate. On the other hand, brown trout are thought to be not as wide-ranging as rainbow trout (Lawrie 1978), so perhaps less staying compensated for this possible lower survival. Brown trout could have ranged widely enough to take them out of my census area. Although no straying data were obtained for the brown trout planted at Marquette, browns from a small plant (3,000 fish) by Wisconsin in the western end of Lake Superior were captured in the Marquette sport fishery in 1985, a distance of almost 300 miles.

The meager catch of hatchery brown trout in Lake Superior at Marquette prohibited a definitive comparison of returns of fall-fingerling and yearling plants. Returns from the plants at Marquette indicated that fall fingerlings would be at least as good as yearlings. Although yearlings provided twice the return of fall fingerlings, the cost of production was four times greater (51 cents for yearlings versus 13 cents for fall fingerlings, Harrietta State Fish Hatchery, unpublished). However, Weber (1988) found that fall fingerlings provided only 4% of the total return from matched plants of yearlings and fall fingerlings in Thunder Bay, Lake Huron.

There was no evidence that indicated hatchery brown trout contributed to natural reproduction in Lake Superior tributaries. No mature hatchery brown trout were reported in the sport-fish catch from the surveyed tributaries, and none were found during fall electrofishing surveys on tributaries near Marquette (Marquette Fisheries Station, unpublished data).

The questions raised in the mid-1960s about the freshwater adaptability of coho salmon (Tody and Tanner 1966) have been answered in the Great Lakes and especially in Lake Superior. The first coho plants in 1966 and 1967 strayed and reproduced successfully in most Lake Superior tributaries (Peck 1970). Coho continued to reproduce successfully in the 1970s (Stauffer 1977), and also in the 1980s as evidenced by large catches of over 90% wild coho in the sport fishery during 1984-87. The percentage of wild coho was somewhat less in Lake Huron where Rakoczy (1991) concluded that 76% of coho in the 1987 sport catch were either naturally produced or unmarked hatchery fish that strayed from one of the other Great Lakes; and much less in Lake Michigan where Patriarche (1980) reported that only about 9% of the sport-caught coho in 1979 were wild. However, despite these lower percentages, coho natural populations could actually be greater in these lakes because many more hatchery coho were planted in these lakes than in Lake Superior.

The return to the sport fishery of coho salmon planted at Marquette in 1984 and 1985 was considerably less than the 7.4% reported for Lake Michigan in 1979 by Patriarche (1980). The two factors likely responsible for this difference are lower survival of hatchery coho and poorer imprinting. Hatchery coho planted in Lake Superior must compete with much greater numbers of wild coho than those planted in Lake Michigan. It is also possible that continuous use of Lake Michigan coho as an egg source has resulted in a loss of genetic

fitness in subsequent generations of planted fish. Disease also could have reduced survival of hatchery coho. Symptoms of bacterial kidney disease have been identified in Michigan coho since the late 1960s (MacLean and Yoder 1970), and this disease was associated with coho mortality in Lake Michigan in 1988 (Johnson and Hnath 1991). A viral disease similar to viral erythrocytic necrosis (VEN) was identified in Michigan hatchery coho in 1984 and implicated in mortality that was formerly attributed to cold water disease (Hnath and Pecor 1988). This disease is thought to cause anemia and may be transmitted from fish to fish through the water. Hatchery coho salmon are also afflicted with eye diseases such as cataracts (J. G. Hnath, MDNR, personal communication).

Coho salmon planted in Lake Superior apparently were not well imprinted. Coho planting strategy associated with this study involved planting a mile upstream (Dead River), whereas plants at the other sites were near a river mouth (Black River) or directly into the lake (Munising). Some homing did occur in the Dead River, but the fin-clipped coho planted in 1984 provided evidence that straying was widespread and substantial. In the fall of 1984, 10 Lake Superior hatchery coho jacks (sexually mature age-1 fish) were reported in a Lake Erie tributary in western Ohio (K. Paxton, Ohio Department of Natural Resources, personal communication), a distance of around 500 miles. In 1985, Lake Superior hatchery coho contributed 12.5% (48 of 385) of a sample from Wisconsin's Lake Michigan sport fishery (M. J. Hansen, Wisconsin Department of Natural Resources, personal communication), and made up 5.5% of the spawning run on the Platte River, a Lake Michigan tributary in the northwestern Lower Peninsula of Michigan (Pecor 1986). Since coho planted in Lake Superior were reared at Platte River State Fish Hatchery, they may have been better imprinted to the Platte River and Lake Michigan than to any of the Lake Superior planting sites. Straying of coho planted in 1984 also occurred within Lake Superior, as a few were captured in the 1985 Wisconsin (<1%) and Minnesota (2%) sport fisheries. Also, they made up 34% (13 of 38) of the spawning run on Minnesota's French River (S. R. Hulse, Wisconsin Department of Natural Resources; and J. R. Spurrier, Minnesota Department of Natural Resources; personal communications). Straying by coho planted in Lake Superior in 1985 to the other Great Lakes could not be determined because the same fin clip was used on a plant in Lake Michigan (Pecor 1987). Although many coho apparently strayed to distant waters, very few strayed to streams in the immediate vicinity of the Dead River. In 1985, only one hatchery coho was found in streams near the Dead River that were creel surveyed year-round (Carp and Chocolay rivers) or electrofished during the fall spawning period (Laughing Whitefish River, Chocolay River, Harlow Creek, and Little Garlic River). In 1986, seven hatchery coho were observed by the creel survey at the Carp (five) and Chocolay (two) rivers.

Splake are fertile hybrids and have reproduced in some inland lakes (Martin and Baldwin 1960), but reproduction in Lake Superior has not been documented. Some sexually mature splake have been found on reefs with spawning lake trout (Marquette Fisheries Station, unpublished data).

The higher return to the sport fishery of splake compared to other species planted at Marquette may have been due to the larger size of the splake yearlings, a tendency of splake to remain near the planting site, and ideal splake fishing conditions during the first year following the plant. When it comes to planting hatchery fish, bigger is better. Seelbach (1987) found this to be true for plants of steelhead in streams, and same likely applies to fish planted directly in the lake. Berst and Spangler (1970) reported that splake planted in Lake Huron tended to remain in the vicinity of the planting site. A few of these splake were recovered as far as 200 miles from the planting site, but 98% were caught within 20 miles and almost 80% within 5 miles.

Splake are readily caught by anglers. Returns to sport fisheries as high as 65% have been reported in Canadian inland lakes (Martin and Baldwin 1960). Splake seem to be particularly vulnerable to an ice fishery.

They were the only salmonid caught with any consistency through the ice in Wisconsin waters of Green Bay, Lake Michigan in the mid 1980s (B. J. Belonger, Wisconsin Department of Natural Resources, personal communication). Good ice conditions the winter following the yearling splake plant in Marquette Bay resulted in an intensive ice fishery and consistent harvest of splake. The better return of yearlings than fall fingerlings in the Marquette sport fishery was also observed in Green Bay (B. J. Belonger, Wisconsin Department of Natural Resources, personal communication).

Hatchery lake trout predominated in the Lake Superior sport fishery in the 1960s (Stauffer 1966) and in assessment gill-net catches in the Marquette area until 1985 (Peck and Schorfhaar 1991). However, natural reproduction by lake trout in the Marquette area and elsewhere in Lake Superior (Peck 1979, 1986), and a possible decrease in survival of hatchery lake trout (Peck and Schorfhaar 1991) resulted in a shift to mostly wild lake trout populations. This shift was evident in the creel survey by the decline in percentage of hatchery lake trout in the catch between 1984 and 1987.

Chinook salmon were introduced into Lake Superior by Michigan in 1967 and annual plants of about 350,000 fingerlings were made in Michigan waters during the 1980s. Chinook spawning has been reported in many Lake Superior tributaries (Hansen 1990), but this reproduction has not been quantified. Chinook natural smolt production was estimated to total 630,500 from 60 Michigan tributaries of Lake Michigan (Carl 1982). If composition of the chinook catch parallels that for coho salmon, chinook caught in the Lake Superior, Carp River, and Chocolay River sport fisheries were probably mainly wild fish and those caught in the Dead River were mainly hatchery fish.

Mortality undoubtedly contributed to the poor return of hatchery trout and salmon in this study. Factors affecting mortality of hatchery fish include transport time and water chemistry differences between hatchery and planting sites, mortality related to being fin clipped, and predation on the newly planted fish by birds, fish, and man. I was unable to identify any of the above factors as causing significant mortality in this study, and results from other studies were conflicting. Some fish died en route to the planting site, but except for 2% mortality of the 1984 plant of steelhead in the Chocolay River (about 400 fish), this mortality was always less than 1% of the number planted. I did not hold any of the fish to test for latent mortality, but some could have occurred if the fish were sufficiently stressed during transport. Water temperature differences between transport and receiving waters were usually less than 5°C, and none of the water temperatures measured for transport or receiving waters were above lethal limits for the species involved. However, the 13°C difference between transport and receiving water experienced by the 1984 plant of steelhead in Presque Isle Harbor may be partly responsible for the low percentage return of that plant. The NH_3 concentration in transport water from Thompson was slightly higher than that for transport water from Wolf Lake, but both concentrations were well below the 0.6 ppm reported as lethal for rainbow trout (McKee and Wolf 1963). Wagner and Stauffer (1978) held fish up to 9 days after planting and reported mortality rates of 20-30% for yearling domestic and steelhead rainbow trout that were transported 9 or more hours from Oden and Platte River State Fish hatcheries and planted in the Huron River, Baraga County. They observed no mortality for domestic rainbow trout transported 5 hours from Thompson State Fish Hatchery. They suspected the stress associated with time of transport and transfer from hard-water hatcheries to the soft-water planting site. No mortality was observed for steelhead yearlings transported from Wolf Lake State Fish Hatchery and held for 14 days in the Huron River each spring, 1987-89 (P. W. Seelbach, MDNR, personal communication). Wolf Lake State Fish Hatchery also has hard water and is a greater distance from the Huron River than Oden or Platte River hatcheries. In my study, there was no apparent negative effect of long transport or differences in water hardness on survival. Return to the fishery for rainbow trout from Wolf Lake was as good or better

than for rainbow trout and brown trout from Thompson.

Fin removal has been reported to cause severe mortality in fingerling rainbow trout (Nicola and Cordone 1973), but most other studies indicate no significant adverse effect on growth or survival (Stauffer and Hansen 1969, Stolte 1973, Heimer et al. 1985). I could not associate any differences in return to the creel in this study with fin removal. Siletz summer steelhead provided the second-best return but had the most severe fin clip (three fins). The adipose fin clip has been reported to cause the least mortality (Nicola and Cordone 1973), but the adipose-clipped brown trout fingerlings in this study provided one of the poorest returns. Although unclipped splake yearlings provided the highest return by far, unclipped splake fingerlings provided a meager return.

No attempt was made to assess the magnitude of predation on hatchery fish by fish and birds, but bird activity was noted at time of planting. Yearling plants were made during late April and early May and usually were attended by large numbers of herring gulls (*Larus argentatus*) and red-breasted mergansers (*Mergus serrator*). Concentrations of up to 100 of each species were observed at planting sites in Lake Superior and at the mouth of the Dead River for up to a week following the plants. Both birds are endemic to the Marquette area, but I suspect most of the mergansers were migrating to breeding grounds because their numbers greatly diminished in the area by the middle of May. Gulls were much less abundant and mergansers were generally absent when fall fingerlings were planted in Lake Superior in September, and none were observed when steelhead yearling plants in the Chocolay River. Predation by gulls was observed to be much less on fish planted in the evening than on those planted during midday. Most public complaints centered around the herring gull because they could be observed capturing the hatchery fish, but I suspect the merganser was the greater predator. Alexander (1976) found that trout made up 84% of the diet of American mergansers (*Mergus merganser americanus*) that foraged in Michigan inland trout waters, with a ration estimate of 0.86 pounds of trout per day. Alexander reported that the mergansers seemed to prefer trout 6-9 inches long, which would include the size of most hatchery yearlings planted by Michigan. Although the red-breasted merganser is smaller than the American merganser, I have no doubt that hatchery yearlings were its preferred food immediately following the plants. Alexander's study found that a host of birds, mammals, and at least one reptile preyed on trout. Although no predators were observed when steelhead were planted in the Chocolay, predation likely accounted for some in-stream mortality. Based on returns, the absence of bird predation on fall-planted fingerlings did not appear to give them an advantage over the spring-planted yearlings. Both fingerlings and yearlings were preyed upon by fish, but I suspect that fingerlings suffered greater predation. Anglers reported some large lake trout and salmon captured in Presque Isle Harbor contained newly planted chinook, coho, and rainbow trout.

Some anglers have complained that other anglers, mainly children, harvest substantial numbers of trout planted in the tributaries before they reach Lake Superior and achieve optimum growth. Although some of the rainbow and brown trout planted in the Carp and Chocolay rivers were harvested as yearlings immediately after planting, this harvest was probably not sufficient to noticeably reduce subsequent returns from these plants. In the Carp River, anglers harvested about 700 juvenile rainbow trout and 475 juvenile brown trout during 1986-87. Assuming that all were hatchery fish, this amounts to a little more than 2% of the number planted for both species. In the Chocolay River, the estimated catch of juvenile rainbow trout in the surveyed section was about 300 during 1984-87, which amounted to 0.3% of the number planted. Most, but not all, of these were hatchery fish. However, it is doubtful that the harvest of juvenile hatchery trout from the entire Chocolay River was more than 1% of the number planted. Applying an adult return to the fishery of 2% to the above juvenile catch estimates, this amounts to a loss of 10 brown

trout and 14 rainbow trout adults in the Carp River, and a loss of 6 rainbow trout adults in the Chocolay River. Hansen and Stauffer (1971) reported that as high as 10% of some rainbow trout plants were caught before reaching the lake, but a 1-month fishing closure following planting did not improve returns. They also found that the domestic strain was much more vulnerable to this pre-lake angling than steelhead strains.

Recommendations

1. Maintain an annual creel survey at Marquette and other major Lake Superior sportfishing areas in Lake Superior. With the exception of lake trout, the creel survey is currently our only means of assessing abundance, harvest, and other parameters associated with trout and salmon in Lake Superior. In addition, we currently need lake trout sport catch data to accurately allocate allowable lake trout catch between sport and tribal (Native-American) commercial fisheries. Increased tribal harvest of other trout and salmon species may require similar data.

2. Protect spawning habitat and spawning populations to increase or at least maintain the current high level of natural reproduction in Lake Superior and tributaries. This could include habitat improvements (bank stabilization, sand traps, etc.), regulation changes, and planting or not planting fish. Some Lake Superior tributaries have been affected by beaver activity, road crossings, or logging operations. These result in sand bedloads which cover spawning areas and food. Restoring these streams will increase natural reproduction, and likely be cheaper than trying to maintain or restore populations with hatchery fish, a method that only works occasionally and poses competitive and genetic threats to wild stocks. Increased habitat restoration and decreased use of hatchery fish have been recommended as management measures for endangered stocks of trout and salmon on the West Coast (Nehlsen et al. 1991).

3. I believe that a very sound biological recommendation would be to cease planting all trout and salmon in Lake Superior and tributaries. Hatchery fish initiated practically all of the wild trout and salmon stocks in Lake Superior, but subsequent planting on top of these good natural populations has rarely produced a worthwhile return. The inability of hatchery fish to provide a good return in the presence of a natural population of its own species, competition from other species, or in association with predators has been documented in other studies (Warner 1962; Cordone and Frantz 1968; Stuber et al. 1985). Some hatchery trout and salmon carry diseases, and some may have low genetic variability (and thus low fitness) due to continual use of the same broodstock. Diseases could be transmitted to the wild stocks, and breeding with genetically deficient hatchery fish could reduce the genetic fitness of wild stocks (Helle 1981). Diseases and poor genetic fitness could be spread throughout Lake Superior and the other Great Lakes because of extensive straying by hatchery trout and salmon.

   Planting to rehabilitate natural populations is likely unnecessary in Lake Superior and most tributaries. Rainbow trout and brown trout, and even the recently introduced Pacific Salmon, have had ample time to occupy most of the available habitat. Exceptions would be where natural populations do not exist (splake in Lake Superior, trout and salmon in the Dead River), to utilize stream habitat above natural or man-made barriers, or to speed colonization of stream habitat made accessible by removal of the barrier or installation of a fish ladder (steelhead in the Chocolay River). However, even in these situations prudent consideration should be given to the impact of these hatchery fish on populations of forage fish and wild trout and salmon in Lake Superior.

Planting to enhance fisheries could result in elimination of the natural populations. The enhanced fisheries attract and maintain increased effort which results in the overharvest and eventual elimination of the natural population (Larkin 1981). This has happened to lake trout in Canadian inland lakes (Olver et al. 1991) and to some West Coast salmon populations (McDonald 1981, Nehlsen et al. 1991). Overharvest of lake trout has happened in some Michigan waters of Lake Superior where tribal commercial gill-net fisheries for whitefish have intensified (Peck and Schorfhaar 1991).

4. If hatchery trout and salmon are planted, plant to maximize return and minimize contamination of natural populations. All fish plants should be justified, with goals and objectives, and plans for evaluation. Since plants are usually made to enhance fishing or reproduction at specific sites, every effort should be made to maximize survival and minimize straying. This would include planting at the appropriate time, at the appropriate place, and the appropriate strain at the appropriate size and age. May appears to be the appropriate month to plant rainbow trout (Biette et al. 1981; Seelbach 1987), but may not be so for other salmonids. Hemmingsen et al. (1986) reported better returns of coho salmon from July releases than May releases in an Oregon stream, and Bilton et al. (1982) had maximum returns from coho released in June. Planting fish upstream rather than at the mouth, or holding the fish in net pens at the site for a period of time, are strategies which should improve return of hatchery fish (Seelbach 1987; Rensel et al. 1988). Another strategy would be the use of an imprinting chemical which has proven successful with coho in the Great Lakes and on the West Coast (Hassler and Kucas 1988). Michigan hatcheries have been planting larger rainbow trout, but those planted in this study were still smaller than the 200-mm yearlings that provided the best return according to Seelbach (1987). The mortality rate for even these large yearlings was about 50% prior to leaving the planted stream, but these fish were planted 2 months earlier than the usual May planting time. Seelbach (MDNR, personal communication) believes that most of this mortality could be avoided by planting in May. This 50% mortality was still much better than the over 90% mortality suffered by smaller fish. Size may similarly influence mortality of planted brown trout. Brown trout were smaller than the rainbows planted in this study. The size of yearling coho planted by Michigan might also be increased to improve returns. Bilton et al. (1982) reported the best return from 25-g coho, which were 25% heavier than those planted in this study. It may be no coincidence that the best return found in this study was from 200-mm fish (splake), and that the highest returns for other species were generally from the larger fish. Michigan and other agencies facing a shortage of hatchery capacity would be advised to explore more of the documented strategies that have produced better returns from planting fewer but larger fish. Planting in the evening or at night may reduce the toll taken by birds on newly planted trout and salmon and would reduce negative publicity associated with this predation, but some bird predation would occur and this strategy would have little effect on predation by resident fish. Another strategy would be to plant when and where predators are least abundant. Considering that these strategies will often be difficult to schedule, perhaps the best strategy would be to plant large, healthy, non-stressed fish, and only when absolutely necessary. Pending the results of future planting-strategy evaluations, the following are specific recommendations for selected species and strains:

a) Plant steelhead strains of rainbow trout several miles upstream and only in tributaries which have low levels of natural reproduction. Planting upstream in the tributaries should result in better

imprinting and subsequent return, and the hatchery fish should make a significant contribution to the sport catch in the absence of a large natural population. If rehabilitation of a natural population is a major goal, then plants should be made in that portion of the stream containing spawning substrate. Plant yearlings that average 200 mm or larger in May. Planting should be reduced as production of wild yearlings increases, and eventually eliminated as the stream's carrying capacity is reached (production of wild fish levels off).

b) Plant brown trout if diversity in the sport catch is desired. Hatchery brown trout can provide a substantial portion of the brown trout catch in Michigan waters of Lake Superior because natural reproduction is low. Plant large yearlings in May.

c) Plant large coho salmon yearlings (25 g) and chinook fingerlings primarily for harvest in tributaries that lack natural spawning runs. Tributaries that are located in or near population centers should be first priority so that harvest will be maximized. Conduct studies to determine the optimum planting time, and whether holding in net pens at the release site will improve returns.

d) Plant yearling splake 200 mm or larger in harbors and bays to enhance ice fisheries and spring and fall open-water fisheries. Splake have provided high returns to sport fisheries, and being a hybrid, may have the least impact on natural populations of any species.

Acknowledgments

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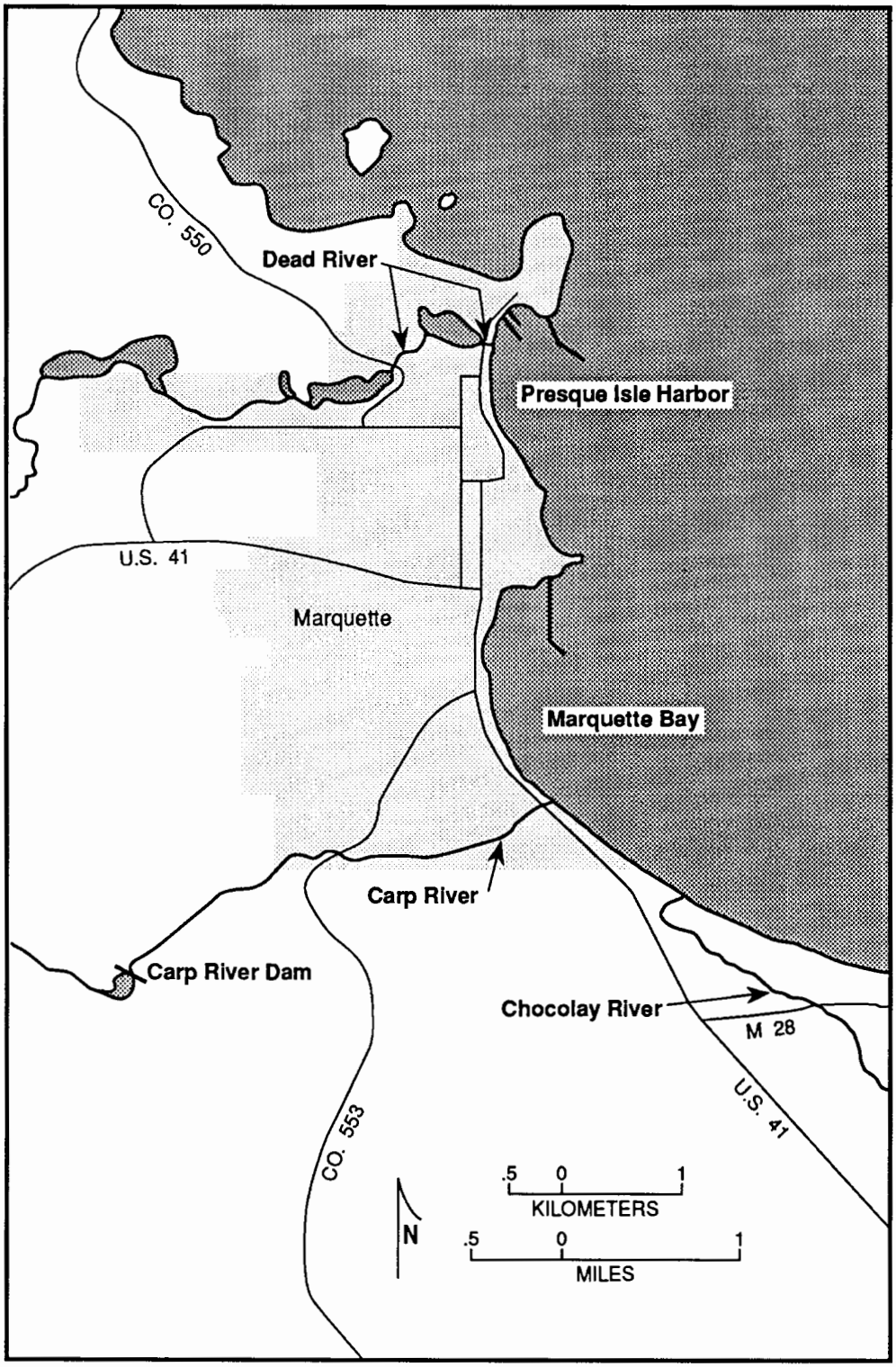

Figure 1.—Sportfishing survey sites on Lake Superior (Presque Isle Harbor and Marquette Bay), and surveyed portions of the Dead, Carp, and Chocolay rivers at Marquette, Michigan, 1984-87.

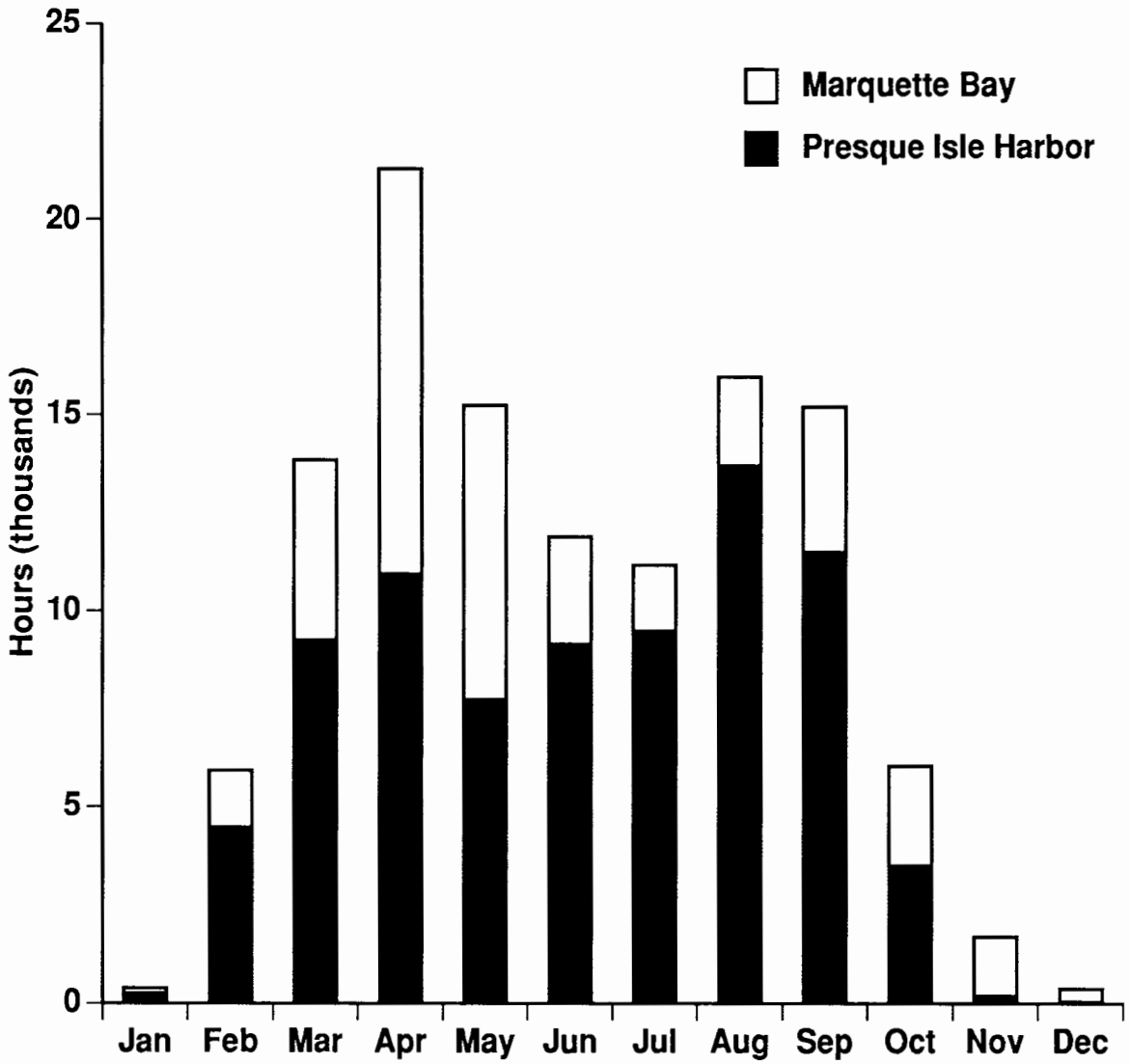

Figure 2.—Distribution of mean angler hours in Presque Isle Harbor and Marquette Bay, Lake Superior, 1985-87.

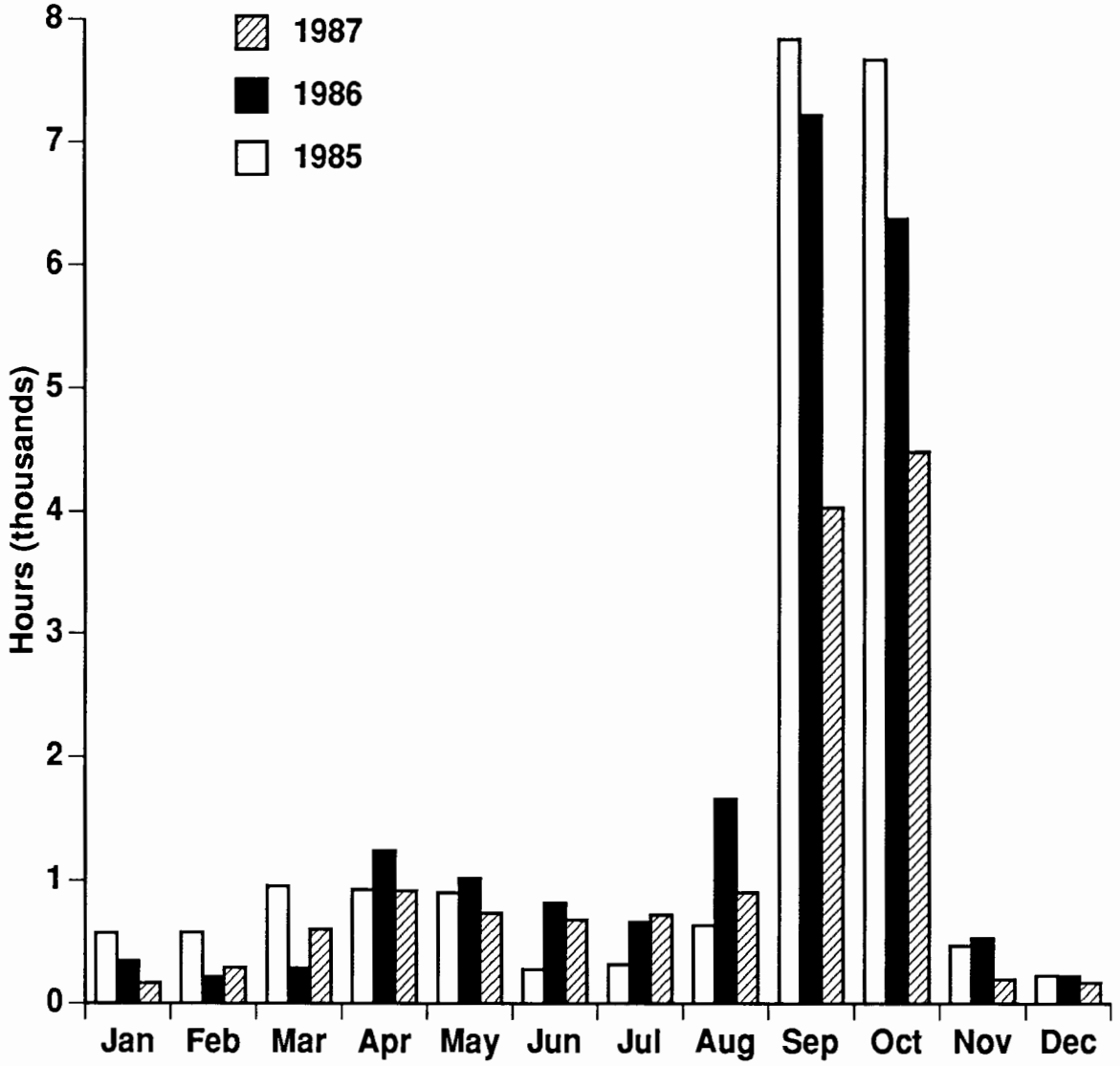

Figure 3.—Monthly distribution of angler hours in Dead River, 1985-87.

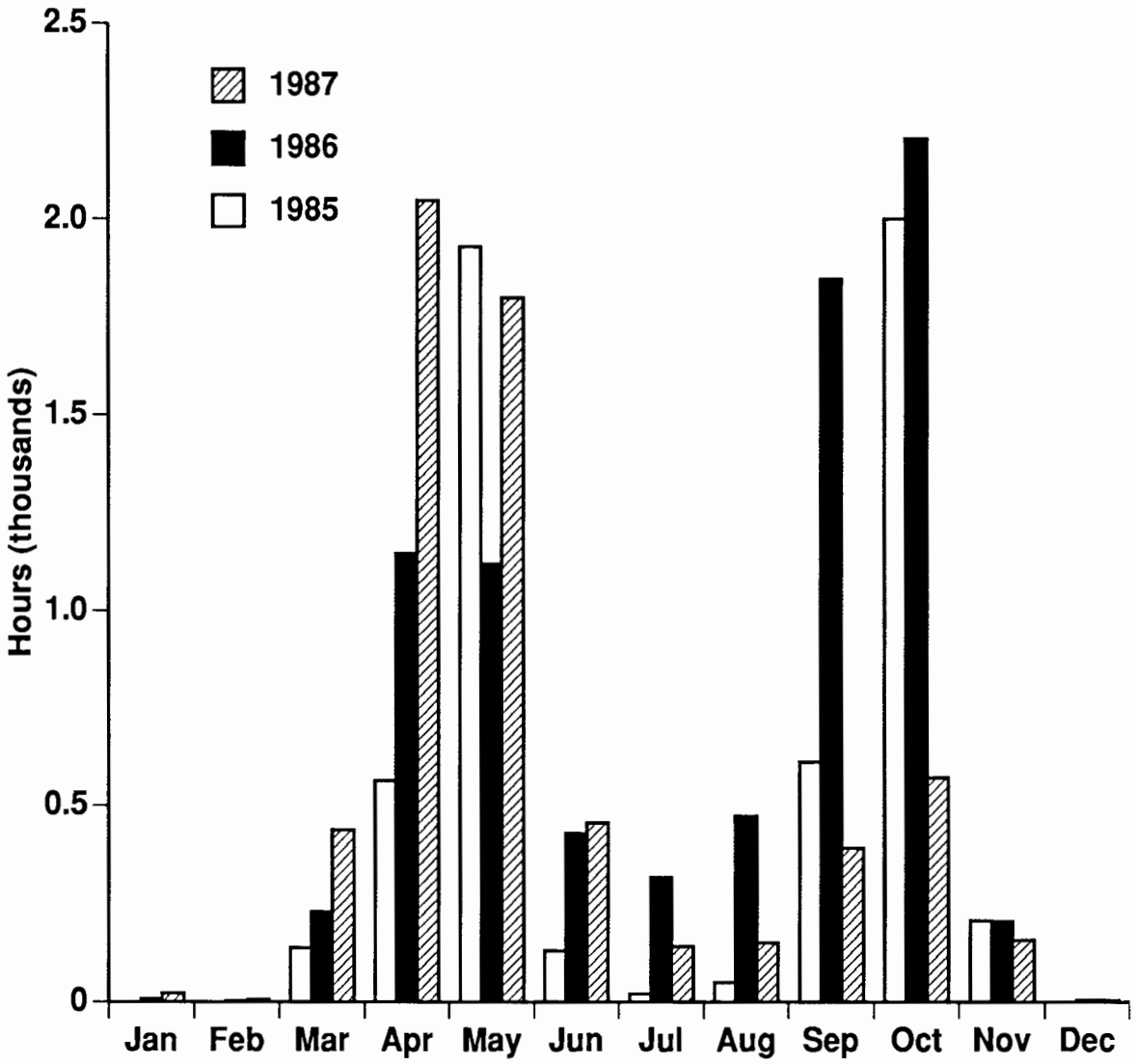

Figure 4.—Monthly distribution of angler hours in Carp River, 1985-87.

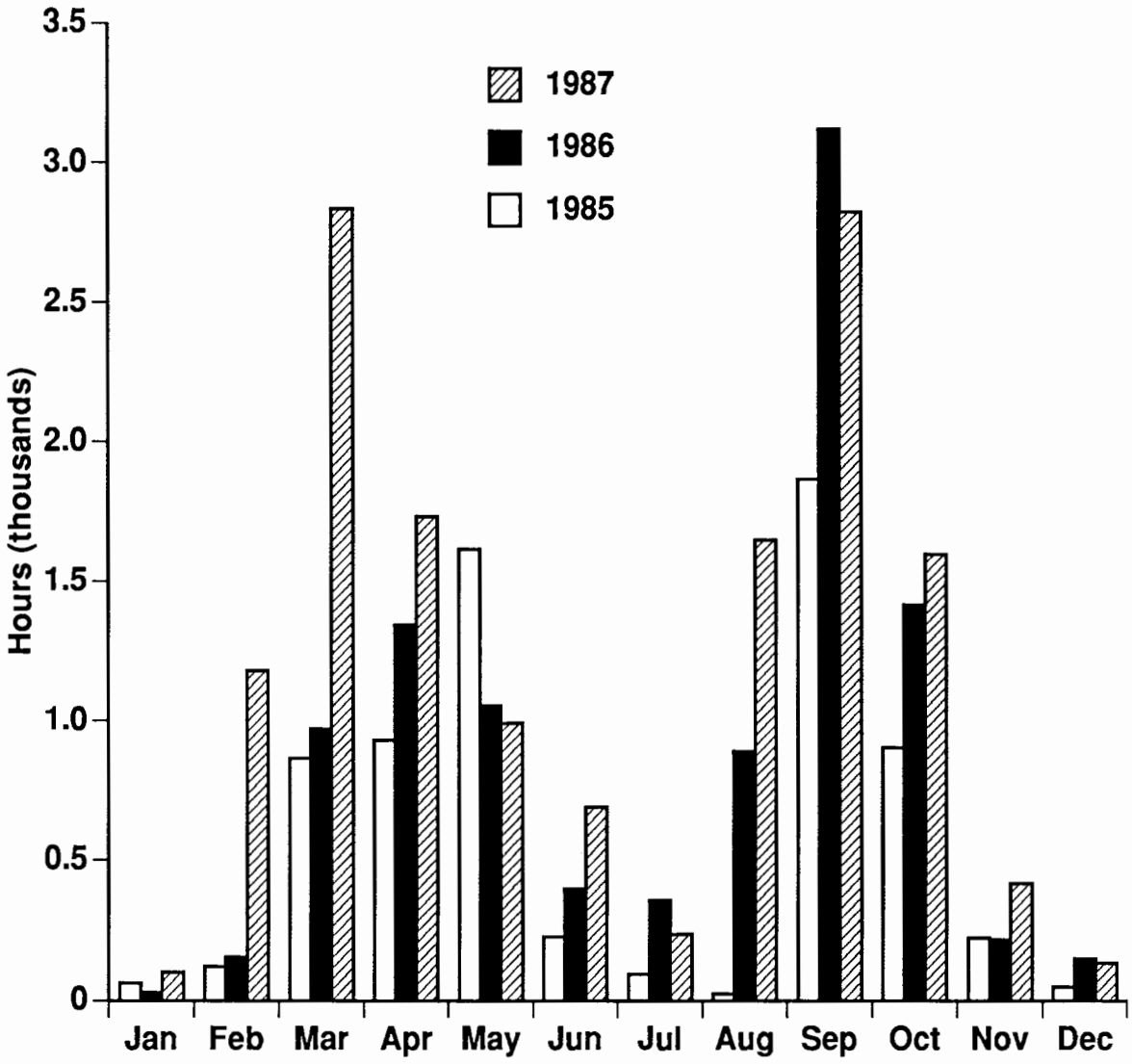

Figure 5.—Monthly distribution of angler hours in Chocolay River, 1985-87.

Table 1.—List of common and scientific names of fishes in the sport fish catch in Lake Superior and tributaries[1] at Marquette, Michigan during 1984-87.

Common name	Scientific name
Lake whitefish	*Coregonus clupeaformis*
Pink salmon	*Oncorhynchus gorbuscha*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
Round whitefish	*Prosopium cylindraceum*
Rainbow trout	*Oncorhynchus mykiss*
Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
Splake	*Salvelinus fontinalis x namaycush*
Rainbow smelt	*Osmerus mordax*
Northern pike	*Esox lucius*
Carp	*Cyprinus carpio*
White sucker	*Catostomus commersoni*
Bullhead	*Ameiurus* spp.
Burbot	*Lota lota*
Rock bass	*Ambloplites rupestris*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieu*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Sea lamprey	*Petromyzon marinus*

[1]Dead River, Carp River, and Chocolay River

Table 2.—Sportfishing effort (angler hours ±2 SE) and distribution by mode (percent) in Lake Superior at Marquette, Michigan, 1984-87.

Site and mode	1984[1]		1985		1986		1987	
	Effort	Percent	Effort	Percent	Effort	Percent	Effort	Percent
Presque Isle Harbor								
Boat	52,536 ±3,456	95.0	59,807 ±4,234	74.8	75,354 ±5,967	82.0	67,783 ±5,537	98.8
Shore	2,636 ±408	4.8	7,119 ±821	8.9	3,282 ±576	3.6	801 ±187	1.2
Ice	112 ±74	0.2	13,045 ±1,528	16.3	13,283 ±2,073	14.4	0 —	0.0
Total	55,284 ±3,480		79,971 ±4,576		91,919 ±6,343		68,584 ±5,546	
Marquette Bay								
Boat	13,305 ±1,372	48.5	12,568 ±1,231	48.5	26,015 ±2,320	48.3	20,138 ±2,405	55.2
Shore	13,954 ±766	50.8	11,768 ±868	45.4	21,863 ±1,780	40.6	16,177 ±1,334	44.4
Ice	190 ±162	0.7	1,572 ±291	6.1	5,961 ±625	11.1	157 ±191	0.4
Total	27,449 ±1,572		25,908 ±1,534		53,839 ±2,990		36,472 ±2,757	
Grand Total								
Boat	65,841 ±3,718	79.6	72,375 ±4,409	68.4	101,369 ±6,402	69.5	87,921 ±6,037	83.7
Shore	16,590 ±868	20.0	18,887 ±1,195	17.8	25,145 ±1,871	17.3	16,978 ±1,347	16.2
Ice	302 ±178	0.4	14,617 ±1,555	13.8	19,244 ±2,165	13.2	157 ±191	0.1
Total	82,733 ±3,822		105,879 ±4,826		145,758 ±7,013		105,056 ±6,188	

[1]Only April-December was surveyed in 1984.

Table 3.—Duration (hours) of angler-trips on Lake Superior at Marquette, Michigan (Presque Isle Harbor and Marquette Bay) during January-December, 1985-87.

Month	1985	1986	1987	1985-87 Mean
Jan	1.8	1.8	2.5	2.0
Feb	3.3	3.1	2.9	3.1
Mar	2.9	2.9	2.9	2.9
Apr	2.8	2.8	3.1	2.9
May	3.6	3.3	3.4	3.4
Jun	4.2	3.8	4.4	4.1
Jul	3.8	4.2	4.1	4.0
Aug	3.7	4.1	3.7	3.8
Sep	3.7	3.7	4.3	3.9
Oct	2.8	3.2	3.2	3.1
Nov	2.4	2.4	3.2	2.7
Dec	1.7	1.9	2.5	2.0
Annual mean	3.1	3.1	3.4	3.2

Table 4.—Residence of anglers (percent) fishing Lake Superior at Marquette, Michigan, 1985-87.

Residence (state or county)	1985	1986	1987	1985-87
Michigan	99	98	98	98
Marquette County	97	95	97	96
Adjacent counties[1]	1	2	1	1
Other counties	1	1	1	1
Other states	1	2	2	2
Number of anglers interviewed:	2,830	3,218	1,811	7,859

[1]Alger, Baraga, Delta, Dickinson, Iron, and Menominee.

Table 5.—Species sought by anglers (percent) fishing Lake Superior at Marquette, Michigan, 1985-87.

Species	1985	1986	1987	1985-87
Lake trout	28	37	27	31
Coho salmon	31	12	16	19
Chinook salmon	2	6	4	5
Round whitefish	3	3	3	3
Lake whitefish	4	2	4	3
Rainbow trout	2	<1	<1	1
Any trout or salmon	29	39	45	37
Miscellaneous[1]	1	1	1	1
Number of anglers interviewed:	3,656	4,889	2,767	11,312

[1]Species that individually were sought by less than 1% of the anglers were brown trout, northern pike, and splake.

Table 6.—Sport-fish catch (number ±2 SE) in the 1984-87 Lake Superior sport fishery at Marquette, Michigan; with CPE (number caught per angler hour ±2 SE) for some principal species during months when most fishing effort was targeted at these species.

Species and parameters	1984	1985	1986	1987	Total
Coho salmon					
Number	3,598	16,773	22,133	5,125	47,629
	±852	±2,721	±3,368	±1,191	±4,571
CPE	0.19[1]	0.44	0.42	0.13	
(Mar-Apr)	±0.10	±0.10	±0.15	±0.06	
Lake trout					
Number	8,612	7,430	12,955	9,592	38,589
	±1,137	±1,123	±1,541	±1,344	±2,595
CPE	0.18	0.16	0.19	0.17	
(Jun-Jul)	±0.04	±0.05	±0.04	±0.04	
Round whitefish					
Number	2,472	2,307	3,894	8,126	16,799
	±1,243	±743	±1,457	±2,217	±2,755
CPE	1.03	1.70	2.04	2.63	
(Nov)	±0.65	±0.70	±0.95	±0.93	
Lake whitefish					
Number	222	522	1,511	2,374	4,629
	±124	±277	±856	±796	±1,208
Chinook salmon					
Number	376	1,194	1,360	430	3,360
	±160	±366	±421	±172	±605
CPE	0.012	0.030	0.015	0.009	
(Aug-Sep)	±0.006	±0.011	±0.010	±0.005	
Rainbow trout					
Number	333	341	627	357	1,658
	±283	±280	±276	±260	±549

Table 6.—Continued:

Species and parameters	1984	1985	1986	1987	Total
Splake					
Number	16	211	646	491	1,348
	±19	±208	±199	±266	±392
Brown trout					
Number	109	266	408	308	1,091
	±103	±128	±183	±161	±294
Other					
Number	0	60[2]	62[3]	130[4]	252

[1]April only.

[2]Brook trout (14), Atlantic salmon (13), northern pike (13), burbot (11), carp (8), and yellow perch (1).

[3]Northern pike (42), yellow perch (16), and burbot (4).

[4]Northern pike (120), Atlantic salmon (6), and yellow perch (4).

Table 7.—Mean catch (number) per angler hour (CPE) of principal species in the Lake Superior sport fishery at Marquette, Michigan 1984-87.

Month	Coho salmon	Lake trout	Round whitefish	Lake whitefish	Chinook salmon	Rainbow trout	Splake	Brown trout
Jan	0.527	0.000	0.125	0.058	0.033	0.000	0.003	0.003
Feb	0.165	0.001	0.003	0.050	0.011	0.002	0.021	0.014
Mar	0.210	0.011	0.023	0.014	0.003	0.004	0.008	0.008
Apr	0.309	0.012	0.004	0.009	0.005	0.004	0.001	0.004
May	0.075	0.085	0.011	0.017	0.010	0.011	<0.001	0.002
Jun	0.009	0.160	0.013	0.004	0.003	0.005	0.001	0.001
Jul	0.009	0.160	0.001	<0.001	0.001	0.001	0.000	<0.001
Aug	0.008	0.131	0.000	0.000	0.014	0.000	<0.001	0.001
Sep	0.045	0.085	0.000	0.000	0.012	0.004	0.001	0.001
Oct	0.013	0.137	0.076	0.006	0.005	0.006	0.011	0.002
Nov	0.010	0.014	1.749	0.079	0.002	0.001	0.029	0.003
Dec	0.005	0.003	0.277	0.269	0.005	0.010	0.016	0.000
Mean annual CPE	0.109	0.081	0.036	0.011	0.007	0.004	0.003	0.003
Hours to catch one fish	9.2	12.3	27.8	90.9	142.9	250.0	333.3	333.3

Table 8.—Monthly mean catch (number) and percent of mean annual catch (in parentheses) for principal species in the Lake Superior sport fishery at Marquette, Michigan, 1984-87.

Month	Coho salmon	Lake trout	Round whitefish	Lake whitefish	Chinook salmon	Rainbow trout	Splake	Brown trout
Jan	207	0	49	23	13	0	1	1
	(2)	(0)	(1)	(2)	(1)	(0)	(<1)	(<1)
Feb	985	8	18	296	68	9	128	86
	(7)	(<1)	(<1)	(23)	(8)	(2)	(32)	(23)
Mar	2,901	149	318	200	37	59	117	108
	(22)	(1)	(8)	(15)	(4)	(12)	(29)	(29)
Apr	6,578	262	88	196	111	83	12	93
	(51)	(3)	(2)	(15)	(13)	(17)	(3)	(25)
May	1,144	1,292	164	252	147	170	5	33
	(9)	(13)	(4)	(20)	(17)	(35)	(1)	(9)
Jun	103	1,882	148	48	40	55	7	16
	(1)	(20)	(3)	(4)	(5)	(11)	(2)	(4)
Jul	104	1,790	14	5	13	16	0	1
	(1)	(19)	(<1)	(<1)	(1)	(3)	(0)	(<1)
Aug	122	2,085	0	0	229	0	2	8
	(1)	(22)	(0)	(0)	(27)	(0)	(<1)	(2)
Sep	676	1,297	0	0	182	55	13	11
	(5)	(13)	(0)	(0)	(21)	(11)	(3)	(3)
Oct	81	826	460	34	28	35	64	14
	(1)	(8)	(11)	(3)	(3)	(7)	(16)	(4)
Nov	16	23	2,934	132	3	1	48	5
	(<1)	(<1)	(68)	(10)	(<1)	(<1)	(12)	(1)
Dec	2	1	103	100	2	4	6	0
	(<1)	(<1)	(2)	(8)	(<1)	(1)	(1)	(0)
Mean annual catch	12,919	9,615	4,296	1,286	853	487	403	376

Table 9.—Sportfishing effort (angler-hours ±2 SE) and distribution by mode (percent) in surveyed sections of three Lake Superior tributaries at Marquette, Michigan, 1984-87.

Site and mode	1984[1]		1985		1986		1987	
	Effort	Percent	Effort	Percent	Effort	Percent	Effort	Percent
Dead River								
Boat	263 ±183	1.3	299 ±185	1.4	631 ±315	3.1	131 ±63	0.7
Shore	20,036 ±1,036	97.2	20,593 ±1,254	96.5	19,233 ±1,577	93.7	18,248 ±1,346	96.9
Ice	315 ±165	1.5	439 ±199	2.1	667 ±183	3.2	457 ±109	2.4
Total	20,614 ±1,053		21,331 ±1,283		20,531 ±1,619		18,836 ±1,352	
Carp River								
Shore	5,650 ±643	100.0	5,469 ±786	100.0	7,983 ±667	100.0	6,185 ±715	100.0
Chocolay River								
Boat	776 ±283	8.2	2,138 ±595	30.7	1,985 ±441	19.7	2,633 ±457	18.3
Shore	8,740 ±882	91.8	4,828 ±470	69.3	8,089 ±709	80.3	11,732 ±918	81.7
Total	9,516 ±927		6,966 ±757		10,074 ±835		14,365 ±1,025	
Grand total								
Boat	1,039 ±337	2.9	2,437 ±623	7.2	2,616 ±542	6.8	2,764 ±461	7.0
Shore	34,426 ±1,505	96.2	31,070 ±1,553	91.5	35,305 ±1,853	91.5	36,165 ±1,779	91.8
Ice	315 ±165	0.9	439 ±199	1.3	667 ±183	1.7	457 ±109	1.2
Total	35,780 ±1,543		33,946 ±1,684		38,588 ±1,940		39,386 ±1,841	

[1]Only April-December was surveyed in 1984.

Table 10.—Residence of anglers (percent) fishing the Dead River at Marquette, Michigan, 1985-87.

Residence (state or county)	1985	1986	1987	1985-87
Michigan	95	95	94	95
Marquette County	92	92	90	91
Adjacent counties[1]	<1	1	1	1
Other counties	3	2	3	3
Other states	5	5	6	5
Number of anglers interviewed:	618	538	521	1,677

[1]Alger, Baraga, Delta, Dickinson, Iron, and Menominee.

Table 11.—Species sought by anglers (percent) fishing the Dead River at Marquette, Michigan, 1985-87.

Species	1985	1986	1987	1985-87
Coho salmon	17	3	9	10
Chinook salmon	2	16	8	8
Northern pike	4	10	4	6
Rainbow trout	9	5	2	5
Any trout or salmon	63	64	74	67
Miscellaneous[1]	5	2	3	4
Number of anglers interviewed:	612	531	521	1,664

[1]Species that individually were sought by less than 1% of the anglers were brown trout, brook trout, yellow perch, largemouth bass, smallmouth bass, rock bass, white sucker, bullhead, and carp.

Table 12.—Sport-fish catch (number ±2 SE) in the 1984-87 Dead River sport fishery at Marquette, Michigan; with CPE (number caught per angler hour) of principal species during months when most fishing effort was targeted at these species.[1]

Species and parameters	1984[2]	1985	1986	1987	Total
Coho salmon					
Number	1,505	1,263	606	1,142	4,516
	±534	±424	±345	±449	±886
CPE	0.08	0.04	0.04	0.08	
(Sep-Oct)	±0.03	±0.02	±0.03	±0.03	
Chinook salmon					
Number	328	1,458	1,771	861	4,418
	±271	±506	±554	±358	874
CPE	0.02	0.09	0.12	0.05	
(Sep-Oct)	±0.02	±0.03	±0.04	±0.03	
White sucker					
Number	15	37	0	612	664
	±30	±45	—	±596	±598
Pink salmon					
Number	0	27	56	129	212
	—	±55	±78	±139	±219
Rainbow trout					
Number	109	37	6	39	191
	±219	±65	±11	±67	±238
Northern pike					
Number	20	12	84	11	127
	±42	±15	±71	±19	±86
Other					
Number	77[3]	93[4]	138[5]	444[6]	752

[1]Area surveyed was from mouth upstream to dam (1 mile).

[2]Only April-December was surveyed in 1984.

[3]Lake trout (67) and splake (10)

[4]Bullhead (56), largemouth bass (12), smallmouth bass (9), rock bass (9), and carp (7).

[5]Smallmouth bass (72) and black crappie (66)

[6]Rock bass (214), bullhead (149), bluegill (37), yellow perch (23), and smallmouth bass (21).

Table 13.—Monthly mean catch (number) and percentage of mean annual catch (in parentheses) for principal species in the Dead River sport fishery at Marquette, Michigan 1984-87.

Month	Coho salmon	Chinook salmon	White sucker	Rainbow trout		Pink salmon	Northern pike
				All	≥16 inches		
Jan	45	0	—	0	0	—	4
	(4)	(0)	—	(0)	(0)	—	(13)
Feb	106	0	—	2	2	—	0
	(9)	(0)	—	(4)	(5)	—	(0)
Mar	37	0	—	10	0	—	—
	(3)	(0)	—	(20)	(0)	—	—
Apr	—	11	112	0	0	—	—
	—	(1)	(67)	(0)	(0)	—	—
May	—	0	46	27	27	—	—
	—	(0)	(28)	(54)	(71)	—	—
Jun	—	0	2	0	0	—	16
	—	(0)	(1)	(0)	(0)	—	(50)
Jul	—	0	—	0	0	—	2
	—	(0)	—	(0)	(0)	—	(6)
Aug	—	2	—	0	0	—	—
	—	(<1)	—	(0)	(0)	—	—
Sep	705	253	6	1	1	53	—
	(60)	(23)	(4)	(2)	(3)	(100)	—
Oct	212	767	—	8	8	—	—
	(18)	(70)	—	(16)	(21)	—	—
Nov	20	65	—	0	0	—	2
	(2)	(6)	—	(0)	(0)	—	(6)
Dec	51	6	—	2	0	—	8
	(4)	(<1)	—	(4)	(0)	—	(25)
Mean annual catch	1,176	1,104	166	50	38	53	32

Table 14.—Residence of anglers (percent) fishing the Carp River at Marquette, Michigan, 1985-87.

Residence (state or county)	1985	1986	1987	1985-87
Michigan	97	97	97	97
Marquette County	92	95	97	95
Adjacent counties[1]	2	<1	0	1
Other counties	3	1	0	1
Other states	3	3	3	3
Number of anglers interviewed:	366	566	263	1,195

[1]Alger, Baraga, Delta, Dickinson, Iron, and Menominee.

Table 15.—Species sought by anglers (percent) fishing the Carp River at Marquette, Michigan, 1985-87.

Species	1985	1986	1987	1985-87
Rainbow trout	35	23	35	29
Coho salmon	1	7	2	4
Brown trout	1	1	0	1
Brook trout	2	<1	<1	1
Any trout or salmon	59	68	61	64
Miscellaneous[1]	2	1	2	1
Number of anglers interviewed:	366	565	263	1,194

[1]Species that were sought by less than 1% of the anglers were lake trout, chinook salmon, northern pike, and white sucker.

Table 16.—Sport-fish catch (number ±2 SE) in the 1984-87 Carp River sport fishery at Marquette, Michigan; with CPE (number caught per angler hour ±2 SE) for some principal species during months when most fishing effort was targeted at these species.[1]

Species and parameters	1984[2]	1985	1986	1987	Total
Rainbow trout					
Number	306	258	962	409	1,935
	±218	±130	±392	±199	±1,075
CPE	0.09	0.07	0.08	0.06	
(Apr-May)	±0.07	±0.05	±0.05	±0.04	
Coho salmon					
Number	31	311	855	15	1,212
	±62	±128	±292	±24	±326
CPE	—	0.14	0.20	—	
(Sep-Oct)	—	±0.06	±0.08	—	
Brown trout					
Number	20	52	99	404	575
	±22	±59	±135	±321	±421
Lake trout					
Number	0	240	10	0	250
	—	±135	±15	—	±136
Chinook salmon					
Number	0	128	41	2	171
	—	±86	±51	±5	±100
Brook trout					
Number	1	57	2	22	82
	±3	±188	±5	±34	±191
White sucker					
Number	7	14	32	5	58
	±14	±29	±40	±10	±44
Splake					
Number	0	4	5	6	15
	—	±5	±10	±11	±16
Other					
Number	9[3]	25[4]	122[5]	0	156

[1]Area surveyed was from mouth upstream to dam (4 miles).
[2]Only April-December was surveyed in 1984.
[3]Round whitefish (9).
[4]Northern pike (14) and bullhead (11).
[5]Northern pike (50) and bullhead (72).

Table 17.—Monthly mean catch (number) and percentage of mean annual catch (in parentheses) for principal species in the Carp River sport fishery at Marquette, Michigan, 1984-87.

Month	Rainbow trout		Coho salmon	Brown trout	Lake trout	Chinook salmon
	All	≥16 inches				
Jan	0	0	0	0	0	0
Feb	0	0	0	0	0	0
Mar	9	9	0	2	0	0
	(2)	(4)	(0)	(2)	(0)	(0)
Apr	66	61	0	8	0	0
	(14)	(24)	(0)	(5)	(0)	(0)
May	160	124	0	73	0	0
	(33)	(49)	(0)	(50)	(0)	(0)
Jun	70	4	0	46	0	0
	(14)	(1)	(0)	(31)	(0)	(0)
Jul	60	0	0	0	0	0
	(12)	(0)	(0)	(0)	(0)	(0)
Aug	48	0	0	8	0	0
	(10)	(0)	(0)	(5)	(0)	(0)
Sep	16	0	73	7	0	14
	3	(0)	(24)	(5)	(0)	(33)
Oct	46	44	211	2	62	28
	(10)	(18)	(70)	(2)	(100)	(65)
Nov	10	9	19	0	0	1
	(2)	(4)	(6)	(0)	(0)	(2)
Dec	0	0	0	0	0	0
Mean annual catch	485	251	303	146	62	43

Table 18.—Residence of anglers (percent) fishing the Chocolay River at Marquette, Michigan, 1985-87.

Residence (state or county)	1985	1986	1987	1985-87
Michigan	99	95	98	98
Marquette County	96	88	95	93
Adjacent counties[1]	<1	1	1	1
Other counties	3	6	2	4
Other states	1	5	2	2
Number of anglers interviewed:	436	610	826	1,872

[1]Alger, Baraga, Delta, Dickinson, Iron and Menominee.

Table 19.—Species sought by anglers (percent) fishing the Chocolay River at Marquette, Michigan, 1985-87.

Species	1985	1986	1987	1985-87
Rainbow trout	48	16	24	27
Coho salmon	7	5	4	5
Northern pike	0	<1	2	1
Brown trout	2	1	<1	1
Lake trout	1	1	0	1
Any trout or salmon	41	76	68	64
Miscellaneous[1]	1	1	2	1
Number of anglers interviewed:	435	606	824	1,865

[1]Species that were sought by less than one percent of the anglers were brook trout, chinook salmon, pink salmon, round whitefish, white sucker, longnose sucker, yellow perch, and carp.

Table 20.—Sport-fish catch (number ±2 SE) in the 1984-87 Chocolay River sport fishery at Marquette, Michigan; with CPE (number caught per angler hour ±2 SE) for some principal species during months when most fishing effort was targeted at these species.[1]

Species and parameters	1984[2]	1985	1986	1987	Total
Coho salmon					
Number	157	343	992	624	2,116
	±115	±236	±308	±233	±467
CPE	0.04	0.11	0.20	0.11	
(Sep-Oct)	±0.03	±0.08	±0.07	±0.05	
Rainbow trout					
Number	156	290	201	508	1,155
	±135	±270	±135	±184	±378
CPE	0.17	0.20	0.10	0.10	
(Nov-Dec)	±0.30	±0.16	±0.11	±0.07	
Brown trout					
Number	56	79	101	275	511
	±60	±92	±68	±178	±220
White sucker					
Number	0	47	105	345	497
	—	±97	±133	±245	±295
Round whitefish					
Number	212	2	0	59	275
	±335	±4	—	±55	±340
Lake trout					
Number	35	122	57	5	219
	±52	±247	±57	±10	±258
Northern pike					
Number	25	33	80	45	183
	±42	±69	±135	±87	±162
Chinook salmon					
Number	30	12	0	5	47
	±47	±25	—	±10	±54
Other					
Number	0	47[3]	11[4]	7[5]	65

[1]Area surveyed was from mouth upstream to M-28 bridge (1.5 miles).
[2]Only April-December was surveyed in 1984.
[3]Pink salmon (47).
[4]Splake (9) and brook trout (2).
[5]Splake (7).

Table 21.—Monthly mean catch (number) and percentage of mean annual catch (in parentheses) for some principal species in the Chocolay River sport fishery at Marquette, Michigan, 1984-87.

Month	Coho salmon	Rainbow trout		Brown trout	Lake trout	Northern pike	Chinook salmon
		All	≥16 inches				
Jan	2	6	6	0	0	0	0
	(<1)	(2)	(3)	(0)	(0)	(0)	(0)
Feb	25	14	14	22	0	0	2
	(5)	(4)	(6)	(16)	(0)	(0)	(15)
Mar	15	47	47	38	0	0	0
	(3)	(15)	(20)	(27)	(0)	(0)	(0)
Apr	11	31	17	5	0	0	0
	(2)	(10)	(7)	(3)	(0)	(0)	(0)
May	10	78	23	21	27	6	0
	(2)	(26)	(10)	(15)	(49)	(13)	(0)
Jun	0	0	0	18	0	8	0
	(0)	(0)	(0)	(13)	(0)	(18)	
Jul	0	<1	<1	<1	1	20	0
	(0)	(<1)	(<1)	(<1)	(2)	(44)	(0)
Aug	1	12	12	10	6	0	0
	(<1)	(4)	(5)	(7)	(11)	(0)	(0)
Sep	270	8	8	7	9	11	8
	(50)	(3)	(3)	(5)	(16)	(24)	(62)
Oct	176	60	56	6	12	<1	3
	(32)	(20)	(24)	(4)	(22)	(1)	(23)
Nov	26	43	43	14	0	0	0
	(5)	(14)	(19)	(10)	(0)	(0)	(0)
Dec	4	6	6	0	0	0	0
	(1)	(2)	(3)	(0)	(0)	(0)	(0)
Mean annual catch	540	305	232	141	55	45	13

Table 22.—Age-2 coho salmon mean total length (inches) and mean total weight (pounds), ±95% confidence intervals, by month in the Lake Superior sport fishery at Marquette, Michigan, 1985-87.

Month	1985		1986		1987	
	Length	Weight	Length	Weight	Length	Weight
Jan	—	—	15.0±0.4	1.1±0.1	14.8±0.9	1.0±0.2
Feb	16.2±0.8	1.3±0.2	15.2±0.3	1.1±0.1	15.9±0.5	1.2±0.1
Mar	16.7±0.2	1.5±0.1	15.9±0.2	1.2±0.1	16.5±0.3	1.3±0.1
Apr	16.7±0.2	1.4±0.1	15.6±0.4	1.1±0.1	16.9±0.2	1.4±0.1
May	16.9±0.2	1.5±0.1	16.1±0.3	1.2±0.1	17.6±0.7	1.6±0.2
Jun	18.0±0.3	1.8±0.1	17.1±0.3	1.5±0.2	19.2±24.1	2.1±6.4
Jul	19.4±1.2	2.2±0.5	19.3±0.4	2.2±0.2	20.6±1.1	2.6±0.5
Aug	20.5±1.0	2.9±0.5	20.5±0.4	2.8±0.2	21.0±0.6	2.9±0.3
Sep	21.6±0.3	3.4±0.2	20.8±0.3	3.0±0.1	21.3±0.4	3.0±0.2
Oct	22.0±0.4	3.4±0.2	20.7±0.3	2.8±0.1	21.3±0.6	2.9±0.2
Nov	22.0±0.4	3.2±0.3	21.2±1.2	2.7±0.4	21.8±0.7	3.2±0.3
Dec	—	—	21.6±0.8	2.9±0.4	—	—

Table 23.—Mean total length (inches) and mean total weight (pounds) ±95% confidence intervals of principal species in the 1984-87 sport fishery in Lake Superior at Marquette, Michigan, 1984-87.

Species and parameters	1984	1985	1986	1987	1984-87 Mean
Coho salmon					
Number[1]	111	284	475	324	
Length	18.0±0.1	17.2±[2]	16.0±[2]	17.4±[2]	16.6±[2]
Range	14-25	13-25	13-24	12-25	
Weight	2.0±[2]	1.5±[2]	1.2±[2]	1.6±[2]	1.4±[2]
Range	0.7-5.2	0.8-6.1	0.6-4.1	0.5-5.4	
Lake trout					
Number	308	361	633	584	
Length	23.4±0.2	23.7±0.4	23.6±0.3	23.4±0.2	23.5±[2]
Range	14-38	14-39	14-36	13-38	
Weight	4.2±0.1	4.6±0.2	4.4±0.3	4.2±0.1	4.4±[2]
Range	0.9-18.6	1.1-13.2	0.4-17.1	0.7-23.2	
Rainbow trout					
Number	22	31	53	19	
Length	17.6±2.4	21.6±1.7	22.2±0.9	21.1±2.8	21.1±0.8
Range	11-27	11-33	14-28	11-27	
Weight	2.4±1.0	4.1±0.8	3.8±0.4	3.5±1.0	3.6±0.4
Range	0.5-7.8	0.5-12.4	1.1-7.5	0.4-6.3	
Chinook salmon					
Number	35	122	117	34	
Length	24.6±2.4	24.2±1.3	24.4±1.3	25.1±2.7	24.4±0.8
Range	10-36	11-38	10-35	10-37	
Weight	7.0±1.7	6.5±0.8	6.6±1.0	7.7±2.1	6.8±0.6
Range	0.3-17.5	0.4-22.0	0.2-17.0	0.3-19.0	
Splake					
Number	5	26	55	38	
Length	18.4±4.2	11.6±0.4	13.5±0.6	14.9±0.8	13.6±0.4
Range	16-20	10-24	9-18	10-20	
Weight	2.1±2.4	0.5±0.1	0.9±0.1	1.2±0.2	0.9±0.1
Range	1.1-3.0	0.2-5.8	0.3-2.4	0.3-3.4	
Brown trout					
Number	9	42	30	57	
Length	18.4±2.7	17.4±1.1	16.5±1.2	17.4±1.5	17.2±0.7
Range	14-22	10-28	12-28	12-23	
Weigh	1.9±0.6	2.5±0.6	1.9±0.6	2.2±0.5	2.2±0.3
Range	1.1-2.9	0.2-9.6	0.7-8.5	0.6-4.9	

Table 23.—Continued:

Species and parameters	1984	1985	1986	1987	1984-87 Mean
Round whitefish					
Number	58	44	63	174	
Length	11.2±0.4	11.6±0.4	11.1±0.2	11.0±0.2	11.1±0.1
Range	10-14	10-15	8-14	7-13	
Weight	0.4±0.1	0.4±0.1	0.3±[2]	0.3±[2]	0.4±[2]
Range	0.2-1.1	0.2-1.0	0.1-0.8	0.1-0.7	
Lake whitefish					
Number	31	74	123	115	
Length	15.2±1.0	14.0±0.4	14.9±0.3	14.9±0.4	14.7±0.2
Range	8-22	9-18	9-22	10-27	
Weight	1.0±0.2	0.9±0.1	1.0±0.1	1.0±0.1	1.0±[2]
Range	0.1-3.5	0.2-1.7	0.2-3.5	0.2-7.1	

[1]Number sampled, but annual mean length and weight was determined by weighting monthly sample mean lengths and weights by estimated monthly catch.

[2]Less than 0.1.

Table 24.—Age composition (number) of wild and hatchery lake trout in the Lake Superior sport fishery at Marquette, Michigan, 1984-87.

Year and source	Age (year)												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1984													
Wild	—	3	20	35	78	46	11	2	—	—	—	—	—
Hatchery	—	—	10	31	24	14	18	20	3	1	—	—	—
1985													
Wild	—	10	16	44	57	65	23	3	1	2	2	—	—
Hatchery	—	—	4	5	13	36	26	35	18	2	—	1	1
1986													
Wild	—	2	13	51	80	99	70	27	20	6	1	—	—
Hatchery	—	—	30	26	29	78	41	30	20	3	2	3	—
1987													
Wild	—	5	14	42	80	116	91	43	20	6	1	2	1
Hatchery	3	2	6	21	19	18	38	32	19	6	2	1	1
Total													
Wild	—	20	63	172	295	326	195	75	41	14	4	2	1
Hatchery	3	6	51	91	108	136	132	100	44	10	5	5	1

Table 25.—Rainbow trout mean total length (inches) and mean total weight (pounds) at age, ±95% confidence intervals, in the sport fishery in Lake Superior and two tributaries at Marquette, Michigan, 1984-87.

Age[1] (year)	Lake Superior			Carp River			Chocolay River		
	Number	Length	Weight	Number	Length	Weight	Number	Length	Weight
1/0	1	12.3	0.6	23	8.6±0.6	0.3±0.1	20	8.8±0.5	0.2±[2]
1/1	15	14.4±1.4	1.2±0.3	2	17.8±1.9	2.1±[2]	9	19.7±1.4	2.8±0.2
1/2	5	17.8±3.6	1.8±1.0	7	20.8±1.6	3.2±0.7	20	22.6±1.0	4.1±0.4
1/3	7	22.7±2.3	4.0±1.2	10	23.0±1.0	3.6±0.5	27	26.2±0.6	5.6±0.4
1/4	4	23.6±4.1	4.2±2.1	7	24.4±1.1	4.8±1.2	3	26.1±3.1	5.9±5.1
1/5	5	27.5±4.0	7.6±3.5	2	23.4±20.3	3.8±4.4	0	—	—
1/6	3	27.5±1.4	6.3±1.9	0	—	—	0	—	—
2/0	8	14.1±1.4	1.1±0.4	32	9.8±1.1	0.4±0.2	9	10.0±1.4	0.4±[2]
2/1	9	18.1±1.9	2.4±1.2	7	18.5±3.6	2.5±1.3	7	20.5±2.6	3.0±1.1
2/2	21	21.4±0.6	3.4±0.4	13	22.3±1.3	3.6±0.4	18	22.3±1.2	4.1±0.9
2/3	16	23.5±1.0	4.4±0.5	18	23.1±1.0	3.9±0.4	11	24.5±1.6	5.0±1.1
2/4	13	25.0±1.1	5.0±0.7	14	25.5±1.1	5.2±0.8	9	25.4±0.5	5.4±0.4
2/5	5	25.9±2.2	6.1±1.7	6	25.8±1.1	5.2±0.7	2	25.8±24.1	5.8±16.5
3/0	1	14.0	1.0	2	11.4±17.2	0.7±3.8	1	14.9	1.4
3/1	0	—	—	0	—	—	1	24.3	5.8
4/0	0	—	—	1	13.9	0.8	0	—	—

[1]Age presented as stream years/lake years, with numerals representing number of annuli.

[2]Less than 0.1.

Table 26.—Chinook salmon age composition (number), mean total length (inches), and mean total weight (pounds) at age, ±95% confidence intervals, in the January-June and July-December sport fishery in Lake Superior at Marquette, Michigan, 1984-87.

	Age (year)										
	Jan-Jun					Jul-Dec					
	1	2	3	4	5	0	1	2	3	4	5
1984											
Number	3	3	3	1	0	1	6	7	4	7	1
Length	11.5±2.8	20.2±3.0	26.2±5.4	27.0	—	12.3	17.6±1.6	25.7±1.1	31.3±2.2	32.2±1.1	34.5
Weight	0.5±0.3	2.5±1.6	5.1±4.3	5.1	—	0.7	2.1±0.9	7.5±1.1	11.5±2.7	12.7±2.5	15.6
1985											
Number	16	16	6	4	0	2	4	15	15	2	1
Length	12.0±0.7	19.8±0.9	24.7±2.1	28.2±7.8	—	12.8±13.3	15.4±3.6	25.2±1.8	30.4±1.4	33.5±6.4	34.0
Weight	0.6±0.1	2.6±0.3	4.8±0.9	6.8±3.8	—	0.8±3.2	1.0±0.7	5.9±1.2	11.0±2.0	14.0±0.6	13.9
1986											
Number	11	29	24	2	0	0	2	7	42	35	1
Length	11.6±0.7	17.8±0.5	26.1±1.0	32.6±21.0	—	—	15.2±28.6	24.6±2.0	30.8±0.7	33.1±0.8	34.2
Weight	0.5±0.1	1.6±0.2	6.1±0.9	11.8±5.1	—	—	1.4±7.0	5.4±1.4	10.8±0.9	13.1±1.0	17.7
1987											
Number	2	2	8	4	0	2	5	7	11	12	0
Length	12.2±13.3	20.4±12.7	25.1±2.3	30.8±2.4	—	10.2±0	18.5±2.5	28.7±4.1	32.1±0.9	33.2±1.4	—
Weight	0.6±2.5	2.8±2.5	5.2±1.4	9.6±3.6	—	0.3±0	2.2±1.1	8.6±3.4	12.6±2.0	14.9±1.7	—

Table 27.—Round whitefish age composition (number), total length (inches), and total weight (pounds), ±95% confidence intervals, in the Lake Superior sport fishery at Marquette, Michigan, 1984-87.

	Age (year)							
	2	3	4	5	6	7	8	9
1984								
Number	7	22	19	6	3	1	0	0
Length	10.7	10.9	11.7	12.0	11.3	10.5	—	—
	±0.7	±0.8	±0.5	±0.5	±4.5	—	—	—
Weight	0.28	0.40	0.40	0.40	0.33	0.30	—	—
	±0.09	±0.11	±0.11	±0.20	±0.37	—	—	—
1985								
Number	0	0	10	13	12	5	2	1
Length	—	—	11.0	11.3	11.3	12.0	13.5	14.5
	—	—	±0.3	±0.4	±0.8	±1.0	±6.4	—
Weight	—	—	0.32	0.43	0.41	0.56	0.85	0.50
	—	—	±0.08	±0.05	±0.10	±0.20	±0.63	—
1986								
Number	2	5	18	20	12	3	2	0
Length	9.0	9.8	11.1	11.1	11.6	12.4	13.0	—
	±8.3	±0.6	±0.3	±0.3	±0.4	±0.5	±10.2	—
Weight	0.15	0.21	0.33	0.34	0.37	0.46	0.65	—
	±0.63	±0.04	±0.04	±0.04	±0.06	±0.14	±1.90	—
1987								
Number	6	33	34	35	32	12	12	0
Length	8.7	10.3	10.8	11.3	11.4	11.6	12.3	—
	±1.2	±0.5	±0.3	±0.2	±0.2	±0.4	±0.4	—
Weight	0.16	0.27	0.29	0.37	0.37	0.39	0.48	—
	±0.05	±0.05	±0.03	±0.03	±0.03	±0.05	±0.05	—

Table 28.—Lake whitefish age composition (number), mean total length (inches), and mean total weight (pounds) with 95% confidence intervals, in the Lake Superior sport fishery at Marquette, Michigan, 1984-87.

	Age (year)							
	2	3	4	5	6	7	8	9
1984								
Number	5	17	4	1	1	1	0	0
Length	12.4	14.6	17.0	19.2	22.5	21.3	—	—
	±2.1	±0.3	±1.8	—	—	—	—	—
Weight	0.51	0.85	1.36	2.1	3.5	2.7	—	—
	±0.27	±0.11	±0.54	—	—	—	—	—
1985								
Number	4	32	28	7	0	0	0	0
Length	10.9	13.3	15.0	17.0	—	—	—	—
	±1.6	±0.3	±0.4	±0.9	—	—	—	—
Weight	0.40	0.72	1.01	1.47	—	—	—	—
	±0.12	±0.05	±0.06	±0.16	—	—	—	—
1986								
Number	7	42	49	19	4	2	0	0
Length	11.0	13.8	15.5	16.0	17.7	20.6	—	—
	±1.3	±0.2	±0.3	±0.5	±1.4	±17.2	—	—
Weight	0.44	0.71	1.10	1.15	1.37	2.85	—	—
	±0.20	±0.05	±0.08	±0.10	±0.27	±8.26	—	—
1987								
Number	4	57	24	20	7	1	0	1
Length	11.4	13.7	15.6	16.5	16.5	21.8	—	16.9
	±2.4	±0.3	±0.4	±0.8	±1.0	—	—	—
Weight	0.04	0.68	1.00	1.28	1.20	3.00	—	1.20
	±0.29	±0.05	±0.06	±0.20	±0.20	—	—	—

Table 29.—Contribution of hatchery fish (percent) to the sport fishery in Lake Superior and tributaries at Marquette, Michigan during 1984-87, with the contribution of hatchery fish planted at Marquette[1] in parentheses.

Species	Year	Lake Superior	Site: Dead River	Site: Carp River	Site: Chocolay River
Rainbow trout	1984	26 (13)	0	8 (0)	47 (47)
	1985	17 (7)	50 (50)	0	27 (23)
	1986	9 (8)	0	40 (40)	54 (54)
	1987	16 (11)	0	29 (29)	50 (50)
	1984-87	15 (10)	10 (10)	25 (24)	44 (43)
Brown trout	1984	20 (20)	—	0	0
	1985	57 (48)	—	0	0
	1986	42 (32)	—	11 (11)	15 (8)
	1987	30 (30)	—	95 (95)	0
	1984-87	40 (35)	—	67 (67)	4 (2)
Coho salmon	1985	10	87	2	0
	1986	3	71	4	2
	1985-86	6	80	3	1
Lake trout					
	1984	38	—	—	0
	1985	34	—	62	100
	1986	27	—	100	100
	1987	18	—	—	100
	1984-87	29	—	67	88

[1] Contribution of coho salmon and lake trout planted at Marquette could not be determined with certainty because the same fin clips were used on fish planted at other sites in Lake Superior.

Table 30.—Percentage return to the 1984-87 sport fishery of trout and salmon planted in Lake Superior and three tributaries at Marquette, Michigan during 1983-85; with the estimated number caught in parentheses.

Species, strain, and planting site	Year planted	Number[1] and age[2]	Fin clip[3]	Total length[4] (mm) ±95% confidence interval	Survey sites: Lake Superior: Presque Isle Harbor	Lake Superior: Marquette Bay	Dead River	Carp River	Chocolay River	All sites
Rainbow trout - Domestic (Oden)										
Marquette Bay	1983	8,100 Y	RP	186 ±4	0	0	0	0	0.17 (14)	0.17 (14)
Presque Isle Harbor	1984	9,300 Y	BV	154 ±5	0	0	0	0	0	0
Total		17,400			0	0	0	0 (14)	0.08 (14)	0.08
Steelhead (Lake Michigan)										
Marquette Bay	1983	9,016 Y	AdLP	166 ±8	0.16 (14)	0.60 (54)	0	0.17 (15)	0	0.92 (83)
Presque Isle Harbor	1984	9,100 Y	D	186 ±6	0.13 (12)	0	0	0	0	0.13 (12)
Total		18,116		(26)	0.14 (54)	0.30 (15)	0 (95)	0.08	0	0.52
Chocolay River	1983	19,428 Y	LP	176 ±6	0	0	0.14 (27)	0.09 (18)	0.32 (63)	0.56 (108)
	1984	17,400 Y	LV	184 ±5	0.16 (28)	0.13 (22)	0	0	0.90 (156)	1.18 (206)
	1985	19,270 Y	LP	175 ±9	0	0	0	0	0.23 (45)	0.23 (45)
Total		56,098		(28)	0.05 (22)	0.04 (27)	0.05 (18)	0.03 (264)	0.47 (359)	0.64
Steelhead (Siletz)										
Chocolay River	1984	18,400 Y	AdBV	194	0.06 (11)	0.17 (31)	0	0	1.21 (223)	1.44 (265)
Brown trout										
Wild Rose x Nashua										
Presque Isle Harbor	1983	14,100 Y	RP	165 ±6	0.95 (13)	0	0	0	0	0.95 (134)
	1983	29,400 F	Ad	88 ±2	0	0.03 (9)	0	0	0	0.03 (9)
	1984	13,350 Y	AdLV	147 ±4	0.15 (20)	0	0	0	0	0.15 (20)

Table 30.—Continued:

Species, strain, and planting site	Year planted	Number[1] and age[2]	Fin clip[3]	Total length[4] (mm) ±95% confidence interval	Survey sites: Lake Superior: Presque Isle Harbor	Lake Superior: Marquette Bay	Dead River	Carp River	Chocolay River	All sites
Marquette Bay	1984	27,300 F	LP	97 ±2	0.15 (42)	0.31 (84)	0	0.04 (12)	0.03 (9)	0.54 (147)
	1985	12,639 Y	AdLP	166 ±6	0.12 (15)	0.31 (39)	0	0	0	0.43 (54)
Yearling total		40,089			0.42 (169)	0.10 (39)	0	0	0	0.52 (208)
Fingerling total		56,700			0.07 (42)	0.16 (93)	0	0.02 (12)	0.02 (9)	0.28 (156)
Coho salmon (Lake Michigan)										
Dead River	1984	147,017	Ad	128	0.92 (1,350)	0.11 (165)	0.74 (1,095)	0.01 (15)	0	1.79 (2,625)
	1985	118,850	LV	123 ±1	0.35 (419)	0.19 (230)	0.36 (432)	0.03 (41)	0.01 (14)	0.96 (1,136)
Total		265,867			0.67 (1,769)	0.15 (395)	0.57 (1,527)	0.02 (56)	0.01 (14)	1.41 (3,761)
Splake										
Marquette-Oden										
Marquette Bay	1985	7,800 Y	NC	213	0.50 (39)	12.22 (953)	0	0.12 (9)	0.10 (8)	12.94 (1,009)
	1985	10,000 F	NC	127	0.14 (14)	0.55 (55)	0	0	0	0.69 (69)

[1]Number = number planted less the number of fish not clipped and/or those with clips that were judged likely to regenerate and become unrecognizable, except that Siletz steelhead clip was not checked.

[2]Y = yearling (13-16 months old), F = fall fingerling (8-10 months old).

[3]NC = not clipped, Ad = adipose, LP = left pectoral, RP = right pectoral, LV = left ventral, BV = left and right ventral, D = Dorsal.

[4]Lengths without confidence intervals from Michigan Fish Stocking Record, Michigan Department of Natural Resources, Fisheries Division, Lansing, Michigan.

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