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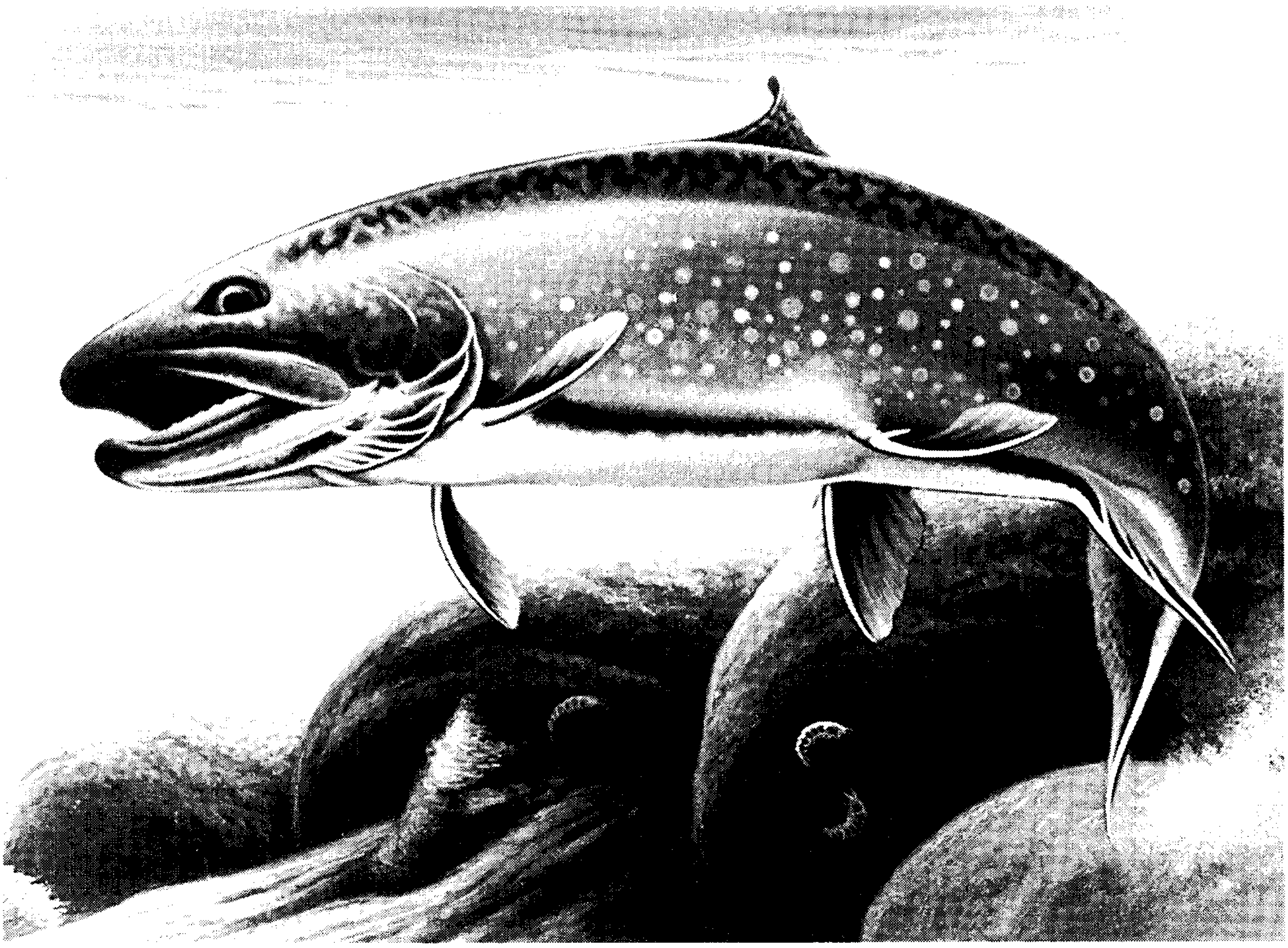

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

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FISHERIES DIVISION

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Evaluation of Hatchery-Reared Brook Trout Stocked in the Upper Peninsula of Michigan

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Abstract—Population estimates and creel surveys were conducted two years before (1988-89) and three years after (1990-92) stocking individually tagged, hatchery-reared brook trout *Salvelinus fontinalis* in three streams (East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon) in Michigan's Upper Peninsula. Similar data were collected on the Iron River, which was not stocked, as a study control. We related densities and catch rates of feral brook trout to average daily temperatures, groundwater yield and physical stream parameters. We measured fish health parameters in samples of hatchery-reared and feral brook trout for comparison. The purpose of our study was to evaluate impacts of stocked fish on sport catches and feral brook trout populations. Estimated numbers (±2 SE) of legal-sized brook trout were significantly greater during the stocking period (1990-92) than during the pre-stocking period (1988-89) and were not significantly different in the control river between the two periods. Brook trout catch per hour increased an average of 79% and catch increased an average of 72% after stocking in the East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers combined. The increase in catch per hour and catch attributable to stocking was 26% and 39%, respectively. However, due to large variances on estimates, the increases were statistically significant only at the Middle Branch Ontonagon River. Return to the creel of stocked fish was 7.8% at the Middle Branch Ontonagon River, 3.6% at the West Branch Escanaba River, and 1.8% at the East Branch Escanaba River; the average for three rivers was 4.5%. The estimated cost per harvested hatchery-reared brook trout was $9 at the Middle Branch Ontonagon River, $19 at the West Branch Escanaba River, and $38 at the East Branch Escanaba River; the average for three rivers was $16 per fish. Feral brook trout catch per hour and catch did not change in stocked rivers (1990-92 versus 1988-89) and declined 23% in the Iron River. Number of feral brook trout per acre and catch per angler hour were more closely related to an index of groundwater yield and to average daily river water temperature than to physical parameters, such as substrate, frequency and size of pools, and flow. Health parameters ranked higher for hatchery fish before stocking than feral fish, but after three months in the rivers, hatchery fish ranked lower than feral fish.

Most anglers (71%) did not catch any brook trout during an angling trip, 12% caught only one brook trout, and more anglers (0.7%) caught the 10-fish limit than caught seven, eight, or nine fish. Over 60% of angler effort and 64% of brook trout catch occurred from the beginning of the fishing season through the end of June. The majority (66%) of anglers on the Middle Branch Ontonagon River were not local residents, but 71-87% were local residents at the other three rivers.

Brook trout *Salvelinus fontinalis* is the premier salmonine species sought by anglers in rivers of the Upper Peninsula of Michigan. Michigan Sport Fisheries Surveys showed that around 624,000 brook trout, representing 79% of the total salmonine harvest, were caught each year from Upper Peninsula streams during 1975 to 1981 (Michigan Department of Natural Resources [MDNR], Lansing, unpublished data). The estimates of catch in the Michigan Sport Fisheries Surveys are biased upward by an unknown amount but the relative proportion of each species in the fishery is probably accurate (Gale Jamsen [retired], MDNR, personal communication).

Hatchery-reared brook trout have been used by managers to enhance river fisheries in the Upper Peninsula. Various forms of stocking guidelines have been in place since about 1921, and trout stocking has occurred since 1873 in Michigan (McFadden et al. 1964). Michigan fish stocking guidelines currently recommend that stocking of brook trout should be made in streams where natural reproduction is inadequate but good rearing and holding capabilities are present. In such streams, more pounds of fish are expected to be taken in the fishery than were stocked, and the fishery produced should justify the cost of the program (Borgeson 1987). The stocking guidelines also suggest stocking fingerlings, and that stocking of yearling brook trout in streams is rarely justified. Beyond consideration of the guidelines, political pressure on fisheries managers also may influence stream stocking in some cases.

During 1960-1964 most of the brook trout stocked in Michigan waters were legal-sized (≥7 in) fish and in 1965 mostly sublegal (<7 in) fish were stocked. In 1966 the classifications of stocked trout were changed to indicate their life stages. The classifications were: adult (≥7 in long), yearling (4 - 8 in), fall fingerling (3 - 6 in), and spring fingerling (≤3 in). From 1966 to 1971, nearly all brook trout were stocked as yearlings or as spring fingerlings. During 1972 to 1983, stocking of fall fingerlings predominated. During 1984 to 1987, yearlings and fall fingerlings were stocked.

Recently, anglers have reported poor brook trout fishing in many Upper Peninsula streams where they feel fisheries were formerly better. It is unclear when this perceived decline in the fishery began. Adequate data to document a decline in brook trout or to determine possible causes for poor fishing are lacking. Possible causes for declines in the fisheries include: low pH due to acid precipitation, overfishing, competition with other salmonines, sediment bedload due to improper road construction and timbering practices, warming of water due to excessive beaver damming, and changes in stocking strategies. A variety of stocking strategies have been used since 1960. We needed to determine how brook trout stocked currently are contributing to the sport catch and to the population. There had been no formal evaluations of the return to the angler in the Upper Peninsula of the various sizes or ages of brook trout stocked, but some studies have been made in other areas. Cooper (1952) reported on the returns of the legal-sized (≥7 in) brook trout stocked in late April to early June in a heavily fished stream in the Lower Peninsula of Michigan. During the first year after stocking 61% were caught but only 0.07% of the original stocking were caught the second year. Shetter et al. (1964) summarized results of 40 brook trout stocking experiments in Michigan rivers. Six experiments involved 4.0-6.9 inch fish. The average return to the creel was 1.9%. Whereas, the average return to the creel in 18 experiments with fish seven inches and longer was 41.7%. McCrimmon (1960) found that fall fingerlings stocked in two small southern Ontario streams had over winter survivals of 3% and 21% and none had grown to legal size (≥7 inches) to provide angling by the opening of the trout season the following spring.

The objective of this study was to determine the contribution of hatchery-reared yearling brook trout to the sport catch and to the brook trout populations in three Upper Peninsula streams. We also relate numbers of feral brook trout per acre and catch rates to average daily temperature, a groundwater yield index, and to several physical stream parameters.

Description Of Study Areas

The study was done in 8- to 10-mile long sections of four rivers located in Michigan's Upper Peninsula (Figure 1). The study rivers and areas (Township, Range, and Section) of study were: East Branch Escanaba in Marquette County upstream from the city of Gwinn (T 45 N, R 25 W, Section 21, SW 1/4) to near the mouth of Uncle Tom's Creek (T 46 N, R 25 W, Section 20, SE 1/4); West Branch Escanaba River in Dickinson County upstream from County Road 438 bridge at T 44 N, R 27 W, Section 25, NW 1/4 to County Road 438 bridge at T 44 N, R 28 W, Section 24, SE 1/4; Middle Branch Ontonagon River in Gogebic County upstream from Buck Lake Road (T 45 N, R 39 W, Section 13, SE 1/4) to Russ's Road in T 45 N, R 39 W, Section 19, SE 1/4; and the Iron River in Iron County upstream from the County Road 653 bridge (T 43 N, R 35 W, Section 27, SE 1/4) to about 3/4 mile upstream from the mouth of the South Branch Iron River in T 43 N, R 35 W, Section 18, NE 1/4.

Zimmerman (1968) reported pH and total alkalinity ($CaCO_3$) as 7.8 and 96 ppm, respectively in the main stem of the Escanaba River of which the East and West branches are tributary; 7.4 and 114 ppm in the Menominee River of which the Iron River is tributary; and 7.8 and 54 ppm in the Middle Branch Ontonagon River. Soil and topographic characteristics of the study watersheds are presented in Table 1, and mean physical parameters and substrate types of the study areas of the rivers and in the index stations are presented in Tables 2 and 3. Mean physical parameters for each 0.5 mile of the study areas are in Appendix 1-4.

Methods

Measure Stream Parameters

The total length and physical characteristics of the 8- to 10-mile study sections in each of the four rivers were determined by dividing the entire study section into 164-foot sections. The width was measured at the upper end of each 164-foot section. Depth was measured in three places: at the middle of the cross section and at two sites 1/6 of the width measurement from either shore. Velocity was measured using the float method at the same locations where width and depth were measured as described by Welch (1948). Discharge (ft^3/sec) was calculated in the study area of each river by multiplying average width times average depth times average velocity (ft/second) times a constant (0.85), to account for the effects of substrate type, as described by Welch (1948). Pool classification and percentage of substrate types within each 164-foot section were estimated or judged. Pool classification was judged by criteria described by Lagler (1952). He classified pools by size, type, and frequency and assigned a numeric value to each classification ranging from 1 (best) to 3 (poorest). The percentage of substrate types in each 164-foot section was estimated. A modification of Wentworth's classification of substrates was used to describe bottom material (Welch 1948). Wentworth described substrate types as boulder, cobble, pebble, granular, five sizes of sand, and silt. We added bedrock and detritus to the classifications and the five types of sand were reduced to two, fine and coarse. Mean physical parameters and substrate types in the study sections and in the index stations are presented in Tables 2 and 3.

Recording thermometers were placed in each stream in August 1988 and were left in until the end of the study in September 1992. Thermographs were retrieved and redeployed about every 90 days after changing tapes and batteries. The thermographs were placed in iron pipes for protection and to keep them near the bottom of the stream and were attached to streamside trees with cables. The pipes were placed in water that was at least 2 feet deep and the flow was at least 0.5 foot per second. Ryan Instruments Model J recording thermographs were used which recorded for 90 days on a pressure sensitive tape with a range of 0 to 30^{0}C. Accuracy of the thermographs was checked periodically using a calibrated mercury thermometer. Data from the tapes were read and entered into computer files for every 2 hours. All data were recorded in Eastern Standard Time including thermographs in the Central Time Zone.

Groundwater yield index was calculated to measure the potential for groundwater input into a stream. This index takes into account the permeability of the various soil types and gradient (or head) within a watershed. Proportions of soil type within the watershed of each river above the study area were calculated using a quaternary map by Farrand and Bell (1984), and a Keuffel & Esser model 4212 planimeter. Watershed length was the center line distance, in miles, from the downstream end of a study watershed to the upper end of the watershed (Table 1). Maximum and minimum elevations, in feet above sea level, for each watershed were taken from topographical maps (Table 1). Head was the elevation at the downstream end of study sections subtracted from the greatest elevation occurring within the watershed divided by distance between the two points. Permeability values (Table 1) are from Morris and Johnson (1967). Groundwater yield index then was calculated by the formula;

$$\sum_{i=1}^{n}(C \; x \; PsW) \; x \; \frac{(MXE - MNE)}{WL},$$

where,

n = number of soil types in the watershed,
C = permeability of soil type,
PsW = proportion of a particular soil type in the watershed,
MXE = maximum elevation in the watershed,
MNE = down stream river surface elevation,
WL = watershed length,

and was derived from Darsey's Law of discharge velocity as given by Harr (1962).

Stocking

The first two years of the study (1988 and 1989) were considered baseline, and no fish were stocked. Also, as a control, no fish were stocked in the Iron River during the entire study period. During 1990-92, hatchery-reared yearling brook trout from the Marquette State Fish Hatchery were stocked in the study sections of the East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, soon after the last Saturday in April, which is the opening day of Michigan's trout fishing season (Table 4). Stocking methods were those typically used in the Upper Peninsula, except that all fish stocked during the study were marked to distinguish them from feral fish. In 1990, 25% of the fish stocked in each of the rivers were marked using serially numbered monel band tags placed around the mandible, and by clipping the adipose fin. The remaining 75% of the stocked fish were marked by clipping a pectoral fin. In 1991 and 1992 all stocked fish were marked with the monel jaw tags and adipose clips. To minimize the possible effects of jaw tags on small fish (77% of the hatchery yearling in 1991 and 1992 were less than 6.0 inches long in April), fish were sorted in 1991 and 1992. Fish less than 5.8 inches long were not tagged or stocked in 1991, and those less than 6.0 inches were rejected in 1992. R. Haas (MDNR, Mount Clemens, personal communication) found no tag loss on jaw-tagged walleye through one full growing season using monel bird bands, so we assumed no tag loss. Signs were posted at access locations both within the study areas and outside of the areas requesting information on tagged and fin clipped fish. Anglers were asked to report fin clip, tag number, fish length, location, and date when marked fish were caught. The number of tag returns was corrected for non-reporting by a factor derived from published literature on non-reporting of tags. Haas et al. (1988) cited five papers on non-reporting of tags on brook, brown, and rainbow trout and found non-reporting rate ranged from 17 to 61% with a mean of 45%, the figure we used in this study.

Population Estimates

Population estimates of brook trout were made during mid-July to early August 1988-92 at two approximately 0.5-mile long index stations in the study section of each river. One station was located in the lower half of the study area and one in the upper half. DC electrofishing gear, operated at 250 to 300 V and 1.0 to 3.0 A, was used to collect the brook trout. Fish were marked on one day and recaptured the next. Fish were measured to 0.1 inch, the upper caudal fin was clipped, and fish were released back into the index station during the marking run. During recapture runs fish were measured to 0.1 inch and data on number marked and number not marked were obtained. Also, scale samples were collected for age analysis, and fish were kept for weights and fish health analysis during the recapture run; we attempted to sample 10 fish per 0.5-inch interval. A few samples were also taken from fish collected in late April-early May to determine when growth began.

Population estimates (± 2 SE) were made using the Bailey modification of the Peterson mark-recapture method (Ricker 1975). Separate estimates were calculated for each index station of each stream and for young-of-year (YOY), sublegal older than YOY, and legal (7 in and larger) groups. YOY fish were 3.8 inches and less at the Middle Branch Ontonagon River, 3.9 inches and less at the West Branch Escanaba River, and 4.0 inches and less at the East Branch Escanaba River and Iron River. Length-frequency distributions were used to separate the YOY and sublegal groups.

Widths were measured at 164-foot intervals within index stations of the rivers. The surface area (acres) of index stations were calculated using mean widths within the index stations times the length of the station. The population estimates and surface area of the river sections where population estimates were made were used to calculate numbers of brook trout per acre. The estimated number of YOY, sublegal (not including YOY), or legal-sized feral brook trout per acre in the combined index stations for each river were compared for years prior to stocking (1988-89) with years when stocking occurred (1990-92). We used the annual estimates (±2 SE) and mean estimates (±2 SE) for each period (1988-89 and 1990-92) to determine if stocking hatchery-reared brook trout affected the number of feral brook trout or total brook trout per acre. If the 2 SE confidence intervals did not overlap we assumed that stocking altered the brook trout population.

Creel Survey

A creel survey with a stratified random design was conducted on the study sections of the four study streams during the trout fishing season (last Saturday in April to September 30). The survey was made on every weekend day and holiday and on two or three randomly selected weekdays each week. Data collected on weekends and holidays were combined. The survey work day was from dawn to midday or midday to dusk. The times assigned as dawn and dusk were adjusted as daylight hours changed during the season.

Fishing pressure estimates were based on instantaneous car or angler counts at all access points in the study areas. Counts were made at three or four randomly selected times each day. Anglers were interviewed whenever they were encountered. The number of anglers per vehicle, number of hours each angler fished, number of fish caught, and residence of the anglers were recorded during the interviews. Anglers were considered resident if they resided in the county or adjacent county where the creel survey section was located. All other anglers were considered non-local Michigan anglers or out-of-state anglers. The number of brook trout harvested by each angler was determined during interviews and recorded on the creel survey interview form. Most of the brook trout caught by anglers were measured to 0.1 inch and scale sampled. All brook trout were examined for fin clip or tags during the years that stocked fish were present.

Estimates of fishing pressure (angler hours) and number of brook trout caught were made by methods in Appendix 9 of Merna et al. (1981).

Separate catch and pressure estimates were calculated for the opening week of the season and for each of the 5 months thereafter; estimates were then summed over the season. Estimated angler hours were the product of estimated car hours and the mean number of anglers per car. The mean number of anglers per vehicle for all periods combined was used to estimate angler hours during periods when no interviews were made. Estimated number of brook trout caught during each period was the product of estimated angler hours and the catch per hour during the period. The catch per hour was assumed to be zero during periods when no interviews were made. Separate estimates and 2 SE confidence intervals for feral and hatchery-reared fish were calculated during 1990-92. For each river, the estimated number of stocked fish caught during each period was the estimated catch for the period multiplied by the proportion of marked brook trout in the catch. The means (± 2 SE) for the years when no fish were stocked (1988-89) and for the years when hatchery-reared fish were stocked (1990-92) were calculated. We compared means (± 2 SE) between 1988-89 (pre-stocking) and 1990-92 (stocking) periods to determine if stocking brook trout significantly increased catch, catch rates, and angling pressure. If the 2 SE confidence intervals did not overlap we assumed that stocking altered fishing.

Contribution of stocked fish to the angler's creel was determined by comparing estimated catch of stocked fish from creel survey and voluntary tag returns with number of fish stocked and with the estimated catch of feral fish. Cost of stocking hatchery-reared brook trout was reported as $0.72 by Cochrane et al. (1992). Estimated cost per harvested fish was derived by multiplying the total cost of stocked fish by the proportion returned to the creel.

Growth

Age and growth was determined from scales taken from below the lateral line and just anterior to the anus. This location was recommended by Cooper (1949) for brook trout because the scales were distinctly larger and the annuli were more readily discernible. Four scales were mounted between microscope slides for examination with a compound microscope at 100X magnification. The scale with the most distinct annuli was selected for age determination and measurements. The distance from the focus to each annulus (radius) and the anterior margin was measured with an ocular micrometer. Back-calculated lengths at previous ages of feral brook trout from each river were calculated using a computer program developed by Frie (1989) assuming a straight-line body-scale relationship using the Fraser-Lee method, with $a = 1.1$, which was the average from six published papers cited by Carlander (1969). The computer program FISHPARM (Prager et al. 1989) was used to calculate von Bertalanffy growth functions (VBGF) of feral brook trout from each river using mean back-calculated lengths-at-age. Mortality of feral brook trout was determined on fully vulnerable age groups in the sport fishery using the unbiased estimator described by Robson and Chapman (1961). Weight-length relationships for hatchery-reared and feral brook trout in the four study streams were calculated from weights and total lengths collected during the population estimates and for hatchery-reared brook trout prior to stocking. The formula was: Log_{10} [weight (lb)] = Log_{10} a + b Log_{10} [length (in)].

We used linear regression to determine if fish measurements by creel survey clerks and from voluntary returns were similar. Differences between the regressions were determined by a t-test. The mean post-stocking growth of age-1 hatchery-reared brook trout collected during the population estimates, from angler-caught fish examined during creel surveys, and from voluntary returns from anglers was determined by the regression of change in length from stocking to recovery on the number of days fish were in the stream.

Fish Health

The relative health of brook trout was assessed based on the autopsy-based fish health/condition assessment system described by Goede and Houghton (1993). Parameters determined were condition factor, hematocrit, plasma protein, percentage of fat around the pyloric caeca, fin erosion, and condition of gills, eyes, kidney, liver, and gall bladder. Twenty hatchery-reared brook trout were examined prior to stocking in late April each year and up to twenty each of hatchery-reared and feral brook trout were examined in July each year during population estimate electrofishing. We compared various fish health parameters of hatchery-reared fish prior to stocking, hatchery-reared fish in the rivers, and feral fish in the rivers. We tested for differences among means of measured parameters using an overlapping 95% confidence limits test. Chi-square was used to determine differences between most ranked parameters and comparison of overlapping 95% confidence limits of the binomial distribution were used for parameters in which sample size was too small to make chi-square comparisons.

Results

Population Estimates

Estimated number (± 2 SE) per acre of feral and hatchery-reared brook trout combined during 1988-92 for combined index stations in each study river are presented in Table 5, and estimates for lower and upper index stations are in Appendix 5. Estimated number (± 2 SE) per acre of feral fish during pre-stocking (1988-89) and of feral and hatchery-reared legal-size fish during stocking years (1990-92) for combined index stations in each study river are presented in Table 6. The average number of YOY and sublegal brook trout per acre was less in the stocked rivers than in the unstocked river in years prior to and during years of stocking. The mean estimated number of YOY feral brook trout per acre in the combined index stations ranged from 37 to 194 (mean 112) in the East Branch Escanaba, from 16 to 66 (mean 42) in the West Branch Escanaba, from 130 to 649 (mean 335) in the Middle Branch Ontonagon, and from 198 to 1,615 (mean 908) in the Iron River. There were five-, four-, five-, and eight-fold yearly differences in the number of YOY fish per acre in the respective index stations. The average number of YOY fish in the Iron River index stations was 22-, 8-, and 3-times greater than in index stations in the East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, respectively. Relatively high numbers of sublegal fish in the Middle Branch Ontonagon and Iron rivers in 1990 and 1991 were associated with high numbers of YOY in 1989 and 1990. YOY estimates (all were feral fish) were not significantly different for pre-stocking (1988-89) versus stocking periods (1990-92), except the estimate for the stocking period at the Middle Branch Ontonagon River which was greater. Likewise, estimates of sublegal brook trout were similar between periods. Prior to stocking (1988-89), the average number of legal-sized brook trout per acre was less in each of the stocked rivers than in the unstocked river (Iron River). During the years of stocking (1990-92) there was no significant difference in the average number of legal-sized brook trout per acre among rivers, except in the West Branch Escanaba where they were less than in the Iron River. Estimates of legal-sized brook trout were significantly greater during the stocking period in each of the stocked rivers, but were not different in the unstocked river (Iron River). When legal-sized feral and legal-sized hatchery-reared fish are considered separately, feral fish increased significantly in the West Branch Escanaba and Middle Branch Ontonagon rivers (Table 6). No estimate could be made for the lower section of the West Branch Escanaba River in 1988 because no fish were captured. The correlation of the number per acre for the lower and upper sections of the West Branch was significant for legal and sublegal groups but not for YOY (F = 264, 21, and 1, respectively; df = 2). Thus, for legal and sublegal groups, the number estimated for the upper section in 1988 is probably representative of the sections combined.

Stocking, Creel Survey, and Tag Returns

Stocking dates, number stocked, and mean length when marked are shown in Table 4. Length of fish at stocking ranged from 3.9 to 9.4 inches and the mean length at stocking ranged from 6.4 to 6.9 inches. Although fish were not sorted before marking in 1990 the average length at stocking was larger (except in the East Branch Escanaba) than in 1991 and 1992 and the percentage of the stocked fish that were legal-sized was greater ranging from 25 to 47% in the stocked rivers. In 1991 and 1992 the proportion of legal-sized fish ranged from 9 to 17%. The difference in average size was attributed to faster growing Owhi strain brook trout used in 1990. Domestic hybrid brook trout were used in 1991 and 1992.

The number of tagged brook trout seen by the survey clerks in the anglers' catch during 1990-92 and the estimated number of tagged fish caught in the study areas are shown in Table 7. Percentage of tagged fish estimated from the creel survey in the study areas ranged from 0.0 (West Branch Escanaba, 1990; East Branch Escanaba, 1991) to 9.7 (Middle Branch Ontonagon, 1991) and averaged 4.2%. The number of tagged fish reported caught inside and outside of the study areas by volunteer anglers are also shown in Table 7. A total of 151 tagged fish were reported of which 34 were caught in the study areas, 53 were caught outside of the study areas and no location of capture for 64 fish. Of the fish for which location of capture was reported, 61% were caught outside the study area. In this study and in nearly all tagging studies it is assumed that an unknown proportion of the tags are not reported. Haas et al. (1988) cited five papers that discussed non-reporting rates of tagged brook, brown, rainbow trout, and walleye. Non-reporting ranged from 17 to 61% and averaged about 45%. We applied the 45% non-reporting rate to our data to find an estimate of the number of tagged brook trout caught outside of the study area. Estimated total returns to the creel are presented in Table 7. Return to the creel was much higher at the Middle Branch Ontonagon River (7.8%; 16% of the pounds stocked) than the West Branch Escanaba (3.7%; 8% of pounds stocked) or East Branch Escanaba (1.9%; 3% of pounds stocked) rivers. The average return to the creel was 4.6% (9% of pounds stocked). We estimated that 7.2% of the returns of stocked fish were caught outside of the study areas of the rivers, that is, estimated catch from outside the study sections divided by the total estimated catch. The estimated cost per harvested hatchery-reared brook trout was $9 for the Middle Branch Ontonagon River, $19 at the West Branch Escanaba River, and $38 at the East Branch Escanaba River and averaged $16 per fish for all rivers combined.

Estimates of angler effort, catch per angler hour, and catch of brook trout are presented in Table 8. Mean estimated effort (angler-hours) decreased at the West Branch Escanaba and Middle Branch Ontonagon rivers (stocked) and the Iron River (unstocked) and increased at the East Branch Escanaba River (stocked) during the years when hatchery-reared brook trout were stocked versus years when no stocking was done. None of the changes was statistically significant, however. Although data were insufficient to estimate catch of hatchery-reared fish in the West Branch Escanaba River in 1990 or in the East Branch Escanaba River in 1991, volunteer anglers reported five and seven fish in the respective rivers and those numbers were included to estimate total return to the creel.

Of all the study streams the Iron River received the highest fishing effort, averaging 2,804 angler hours per year and had the highest average annual catch (1,112), with an average catch rate of 0.400 fish per angler hour. The Middle Branch Ontonagon River received an average of 1,597 angler hours of fishing each year and catch averaged 792 fish per year, with the highest catch rate (0.496 fish per angler hour) of the study rivers. The East Branch Escanaba River received an average of 1,294 angler hours each year, and catch averaged 239 fish, with the lowest catch rate (0.185 fish per angler hour) of the study rivers. The West Branch Escanaba River received only 714 angler hours each year and catch averaged 168 fish, with a catch rate of 0.235 fish per angler hour.

Catch per angler hour was higher in all stocked rivers during years of stocking, but significantly so, only at the Middle Branch Ontonagon River. Average annual catch per angler hour increased from 0.126 to 0.217 at the East Branch Escanaba, from 0.179 to 0.280 at the West Branch Escanaba, and from 0.306 to 0.645 at the Middle Branch Ontonagon rivers after stocking. Catch per angler hour and catch of feral brook trout was unchanged in the Iron River. Combined feral and hatchery-reared brook trout catch increased at each of the stocked rivers, but only significantly at the Ontonagon River. Average annual catch increased from 146 to 301 fish at the East Branch Escanaba, from 141 to 186 fish at the West Branch Escanaba, and from 539 to 959 at the Middle Branch Ontonagon rivers after stocking. Hatchery-reared fish contributed 38, 35, and 41% of the catch per hour and catch in the East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, respectively. Catch per angler hour and catch of feral brook trout in the stocked rivers did not change significantly during the years of stocking.

Distribution of Catch Among Anglers and Through Season

Number and percentage of anglers achieving levels of catch from 0-10 brook trout are presented in Table 9. Most anglers caught no brook trout during their fishing trip (62-83%). As expected rivers with higher fish population levels resulted in higher percentages of anglers catching more brook trout per angler trip. At three of the four study streams the percent of interviewed anglers who caught the 10-fish limit exceeded the percent of anglers who achieved catches of seven, eight, or nine fish.

Percent of angler effort and angler catch by fishing period (week or month) is presented in Table 10. The percentage of seasonal angler effort during the first week of the fishing season was less at the West Branch Escanaba (8%) and Middle Branch Ontonagon (13%) rivers than at the other two rivers. The percentage of seasonal angler catch during the first week of the fishing season was likewise less at the West Branch Escanaba (2%) and Middle Branch Ontonagon (5%) rivers than at the other two rivers. The highest percentage of angler effort (44%) was from the opening day through May in the combined rivers. Fifty-two percent of the annual effort and 64% of the catch occurred from opening day through May at the Iron River. Only 20% of the angler effort was in August and September combined. The highest percentage of angler catch was from the opening day through May (42%). Only 21% of the angler catch was in August and September combined.

Angler Residence

Percentage of local resident, non-local Michigan anglers, and out-of-state anglers is presented in Table 11. Local resident anglers predominated on the East Branch Escanaba (87%), West Branch Escanaba (74%), and Iron (71%) rivers, while only 34% of the anglers on the Middle Branch Ontonagon River were local residents. Out-of-state anglers were more prevalent on the Middle Branch Ontonagon (55%) and Iron (22%) rivers due to these rivers being in closer proximity for Wisconsin anglers who composed 39% and 12%, respectively of the total anglers on these two streams. Percentage of non-local resident anglers was consistent among years and within stream and ranged for combined years from 5% at the East Branch Escanaba River to 12% at the Middle Branch Ontonagon River.

Age and Length Distribution

Age and length distributions of hatchery-reared and feral brook trout in the angler catch from each river are presented in Tables 12-15. Ages 1-4 were represented in the catch in each river. Age-2 was the modal age except at the Middle Branch Ontonagon River where age-1 was modal when hatchery-reared brook trout were included. Age-1 feral brook trout were only 4-15% of the feral brook trout catch while age-1 hatchery-reared brook trout were 99-100% of the hatchery-reared brook trout catch. Age-2 feral brook trout composed 32-69% of the feral fish catch, while age-2 fish composed 0-1% of the hatchery-reared catch. Total annual mortality (A) of feral brook trout estimated for combined years ranged from 71% (West Branch Escanaba) to 81% (Iron River). We regressed effort against instantaneous total mortality (Z) in the combined years for the four rivers. Instantaneous mortality was related positively to fishing pressure ($F = 18.87$, significance of $F = 0.05$, $R^2 = 0.90$). The intercept of this relationship should equal the instantaneous rate of natural mortality ($M = 1.15$) or conditional natural mortality (n) = 68% (Ricker 1975). So, fishing mortality (m) of feral fish averaged 8% and ranged from 3% in the

West Branch Escanaba River to 13% in the Iron River. Tagged hatchery-reared fish from electrofishing, creel survey, and volunteer anglers, including fish from outside the study sections, totaled 331 fish. Only 5 of the 331 tag returns were from age-2 fish so mortality from age 1 to age 2 was 98% for hatchery-reared fish.

Growth and Weight-Length Relationships

The mean back-calculated lengths and von Bertalanffy growth functions for feral brook trout are presented in Table 16. Back calculated length-at-age 1 of combined age groups was significantly smaller in the East Branch Escanaba River than in the other rivers and Iron River fish were significantly smaller than West Branch Escanaba and Middle Branch Ontonagon rivers. However, considering only age-1 fish the length-at-age 1 was similar in the East Branch Escanaba and Iron rivers and Iron River fish were smaller than in the Middle Branch Ontonagon River. There were no significant differences among any rivers for ages 2, 3, and 4, and the von Bertalanffy growth functions were not significantly different among rivers. Thus, overall growth was similar in the four rivers. Mean back-calculated lengths-at-age fit the von Bertalanffy growth function very closely as indicated by the high R^2 for each river.

Lengths used to determine weight-length relationships of hatchery-reared brook trout just prior to stocking ranged from 4.6 to 7.6 inches and averaged 6.5 inches, hatchery-reared fish in the rivers ranged from 5.4 to 9.8 (average 7.8), and feral fish ranged from 3.4 to 10.9 inches (average 6.8). The number of fish weighed at each stream each year ranged from 15 to 28, (average 21). Weight-length relationships for feral brook trout in each river, hatchery-reared brook trout in the three stocked rivers combined, and hatchery brook trout in the hatchery are presented in Table 17. There were no significant differences in either slope or intercept (based on overlapping 95% confidence intervals) for either feral brook trout or hatchery-reared brook trout in the hatchery among rivers. However, slope and intercept for hatchery-reared fish in the rivers were greater than for feral fish in the combined rivers and in the Middle Branch Ontonagon River, and the intercept for hatchery-reared fish in the rivers was greater than feral fish in the Iron River, indicating that the hatchery-reared fish were heavier at a given length.

The mean daily post-stocking growth of age-1 hatchery-reared brook trout is presented in Table 18. Daily growth ranged from 0.00840 to 0.01344 inches and averaged 0.01082 inches per day in the East Branch Escanaba, from 0.00840 to 0.01344 (average 0.01082) inches per day in the West Branch Escanaba, and from 0.00840 to 0.01344 (average 0.01082) inches per day in the Middle Branch Ontonagon rivers. Daily growth ranged from 0.01067 to 0.01690 inches and averaged 0.01636 inches per day in the combined rivers. Daily growth was generally significantly better in 1991 and 1992 than in 1990 for the combined rivers.

Physical Parameters and Substrates

The mean physical parameters and percent of substrate types for the study areas of the four rivers are presented in Table 2. The mean width, depth, and discharge indicate that the East Branch Escanaba was a somewhat larger river than the others and the West Branch Escanaba was smaller in terms of average width but was about equal in discharge to the Iron and Middle Branch Ontonagon rivers. The percentages of coarse substrates in the rivers were 53% in the East Branch Escanaba River, 28% in the Iron River, 28% in the Middle Branch Ontonagon River, and 7% in the West Branch Escanaba River. Conversely, the percentages of fine substrates in the rivers were 45% in the East Branch Escanaba River, 69% in the Iron River, 72% in the Middle Branch Ontonagon River, and 93% in the West Branch Escanaba River. Percentages did not always equal 100% due to rounding.

River Temperature

The average river temperature for each day was calculated based on the 12 bi-hourly records. Graphs of the average daily temperatures are shown in Figures 2-5. No graph is shown after November 1989 (Julian day 334) for the Middle Branch Ontonagon River due to a malfunction of the thermograph which was not detected until data were analyzed. Rivers reached their maximum water temperature between 1600 h and 2000 h 74% of the time with 40% of the maximum temperatures at 1800 h (Table 19). Rivers reached their minimum water temperature between 0600 h and 1000 h 82% of the time with 45% of the minimum temperatures at 0800 h. Odd situations caused maximum and minimum daily temperatures to occur at other hours (0200 and 2400 h) when a decrease in temperature occurred over entire days. The highest average daily temperatures never exceeded 24 C in East Branch Escanaba or West Branch Escanaba rivers, never exceeded 22 C on the Iron River, and never exceeded 20 C in the Middle Branch Ontonagon River (Table 19). The highest water temperatures recorded in a two-hour period during the study were: East Branch of the Escanaba, 24.9 C at 1800 hr; West Branch Escanaba, 24.9 C at 2000 hr and Iron River, 25.0 C at 2000 hr. All occurred on July 18, 1991 (Julian day 199). The summer of 1992 was cooler than other years during the study and average daily temperature never exceeded 20.0 C. Winter temperatures fluctuated much more in the Iron and Middle Branch Ontonagon rivers than the other rivers indicating lack of ice cover during most of the winter (Figures 2-5). The average annual water temperatures were cooler in the Middle Branch Ontonagon (7.1 C) and Iron (7.5 C) rivers than in the East Branch Escanaba (7.9 C) and West Branch Escanaba (8.2 C) rivers.

We related the estimated number of feral brook trout per acre and catch per angler hour of adult brook trout to the average river water temperature and physical river parameters (discharge, percent rocky substrate [excluding bedrock], and percent sand) using linear regression. Relationships were stronger for temperature than for physical stream parameters. Estimated number of feral brook trout per acre was inversely related to average annual water temperature ($F = 2.36$; significance of $F = 0.26$; $R^2 = 0.54$). Estimated catch per hour of feral brook trout was also inversely related to average annual water temperature ($F = 3.72$; significance of $F = 0.19$; $R^2 = 0.65$). Higher average water temperature corresponded to lower numbers of feral brook trout per acre and lower catch per angler hour of adult brook trout in the East Branch Escanaba and West Branch Escanaba rivers, and conversely, lower average water temperatures corresponded to higher numbers of feral brook trout per acre and higher catch per angler hour of adult brook trout. For other physical parameters significance of the relationships to fish numbers and catch per angler hour generated values for F from 0.32 to 0.88 and R^2 values from 0.01 to 0.46.

Groundwater Yield Index

Five different soil types occurred within the different study watersheds (Table 1). Of these soil types, glaciofluvial deposits provide the greatest potential for groundwater input followed by coarse textures. The remaining three soil types (organic deposits, medium textures, and till over bedrock) provide essentially no groundwater in a river system. The East Branch Escanaba and West Branch Escanaba river watersheds were composed primarily (71% and 74%) of material in the groups that provide the least amount of groundwater. Conversely, the Middle Branch Ontonagon and Iron river watersheds were composed primarily (98% and 100%) of permeable materials.

We used groundwater yield index to relate the importance of soil permeability and head within a watershed to several brook trout population parameters and to average river water temperatures. Estimated number of feral brook trout per acre was significantly related to the groundwater yield index ($F = 53.94$; significance of $F = 0.02$; $R^2 = 0.96$). Estimated catch per hour of feral brook trout was also positively related to the groundwater yield index ($F = 9.45$; significance of $F = 0.07$; $R^2 = 0.83$) (Figure 6). Groundwater yield index was inversely related to average annual water temperature ($F = 1.17$; significance of $F = 0.39$; $R^2 = 0.37$). Lower groundwater yield indexes in the East Branch Escanaba and West Branch Escanaba rivers corresponded to fewer feral brook trout present per acre, lower catch per hour of feral brook trout, and to higher average water temperatures. Greater groundwater yield indexes in the Middle Branch Ontonagon and Iron rivers corresponded to higher numbers of feral brook trout present per acre, higher catch per angler hour, and lower average water temperature.

Fish Health

Autopsy based fish health parameters for hatchery-reared brook trout prior to stocking, hatchery-reared brook trout after stocking, and feral fish are presented in Table 20. The condition factor (K_{tl}) for hatchery brook trout prior to stocking was significantly higher than for hatchery fish after they had been in the rivers approximately three months, and also higher than for feral fish. Condition of feral brook trout was significantly higher than hatchery-reared brook trout in the rivers. The mean volume of red blood cells (hematocrit) ranged from 38.3 to 40.2% and was not statistically different among the three groups. The means for plasma protein ranged from 4.4 to 5.4 grams per 100 ml in the three groups. Plasma protein levels averaged significantly higher in feral fish than in the other groups. Plasma protein levels in hatchery-reared brook trout prior to stocking and hatchery-reared brook trout after stocking were not significantly different. Percentage of the pyloric caeca covered with fat deposits was significantly higher in hatchery-reared brook trout prior to stocking than in hatchery-reared fish approximately three months after stocking (X^2=59.62, p<0.01) and also higher than in feral brook trout (X^2=38.67, p<0.01). Fat in feral brook trout was not significantly different than fat in hatchery-reared fish after stocking (X^2=3.21, p>0.05). Fin erosion was significantly less pronounced in hatchery-reared fish three months after stocking than in the hatchery (X^2=37.03, p<0.01) and fin erosion in feral fish was significantly less than for hatchery fish in the hatchery (X^2=1,841.12, p<0.01) or for hatchery fish after stocking (X^2=516.33, p<0.01). The percentage of feral brook trout with abnormal gills was significantly higher than for either of the hatchery-reared groups in the hatchery (X^2=12.77, p<0.01) or after stocking (X^2=6.61, p<0.05), and percentage of abnormal gills in hatchery-reared fish after stocking was higher than for hatchery-reared fish prior to stocking (X^2=7.59, p<0.01). Livers of hatchery-reared brook trout prior to stocking had significantly more abnormal ratings than for either hatchery-reared fish after stocking (X^2=36.68, p<0.01) or for feral fish (X^2=93.49, p<0.01), and livers of feral fish had significantly more abnormal ratings than for hatchery-reared fish after stocking (X^2=3.84, p<0.05). The percentage of fish with full gall bladders was lower in hatchery-reared brook trout prior to stocking than feral fish, but chi-square comparison indicated no significant difference (X^2=1.74, p>0.05). The percentage of hatchery and feral fish with full gall bladders was significantly lower than hatchery-reared fish after stocking (X^2=8.21, p<0.01 and X^2=6.90, p<0.05, respectively).

Discussion

Stocking yearling brook trout increased the number of legal-sized brook trout to levels equal to those in the unstocked Iron River in two of the three stocked rivers, but over-winter survival of stocked fish was very low. Year-class strength of feral brook trout, based on YOY estimates, varied 4-8 fold among the study rivers with the highest variation in the Iron River (8 fold) during the five year study. Relative year-class strength was generally not in synchrony between rivers. At the Iron River the weak 1991 year class coincided with an unusual presence of northern pike (observed by the electrofishing crew) in the river which may have preyed heavily on YOY brook trout. This weak 1991 year class was reflected in low numbers of sublegal brook trout in 1992. The 1991 year class was also weak at the West Branch Escanaba River. The 1989 year class was weak at the East Branch Escanaba River which was reflected in low sublegal numbers in 1990. The 1992 year class was the strongest during the 5-year study at the Iron River and East and West branches Escanaba River.

Natural brook trout populations varied in density among our study rivers. The Iron River populations averaged about 4, 8, and 24 times greater density than populations in the Middle Branch Ontonagon (450/acre), East Branch Escanaba (150/acre), and West Branch Escanaba (50/acre) rivers, respectively. The number of feral brook trout per acre in the Iron River (about 1,200) in July-August was greater than reported by Cooper (1951) for average brook trout populations (268) in the Pigeon River, Michigan in September 1949 and 1950. However, estimated numbers of feral brook trout per acre in the Iron River were comparable to those reported by McFadden (1961) for average Lawrence Creek, Wisconsin populations (about 1,400) in September 1953-1957. Gowing and Alexander (1980) reported average fall brook trout populations of 409 fish per acre for 10 northern Lower Peninsula, Michigan rivers.

Stocking hatchery-reared brook trout improved catch per angler hour by 36-53% in the three stocked rivers. As expected in relatively short lived fish, total mortality of feral brook trout in our study rivers was fairly high. Fishing mortality was not excessive, but overwinter mortality of stocked fish was high. Total annual mortality, estimated from the sport fishery, of feral brook trout in our study rivers was similar to brook trout mortality calculated from population estimates in Hunt Creek, Michigan (McFadden et al. 1967). Total annual mortality of feral brook trout for combined years ranged from 71 to 81% in our study rivers. Total annual mortality in Hunt Creek averaged 67% and ranged from 53 to 76% during 14 years from 1949-62. Mortality attributable to fishing averaged 10% for the combined rivers and ranged from 3 to 13%. Fishing mortality was generally proportional to fishing effort in individual rivers.

Stocking of hatchery-reared brook trout enhanced the fisheries in our study rivers in terms of increasing catch per angler hour and increasing catch. Although large variances prevented detection of significant changes due to stocking at the East Branch Escanaba and West Branch Escanaba rivers, the average increase in catch per hour was 79% with 26% of the increase attributable to stocked fish. Average increase in catch was 72% with 39% of the increase attributable to stocked fish. Catch per hour declined 4% and catch declined 23% in the unstocked Iron River. Catch rates in our study rivers were within the range (0.101-0.581) reported by Cooper (1952) for brook, brown, and rainbow trout in the Pigeon River, Michigan and by Alexander et al. (1979) for brown trout in the Au Sable River, Michigan (0.148-0.154).

Return to the creel, in this study, of planted sublegal- and legal-sized fish was greater than in studies planting only sublegal fish but less than in studies planting only legal-sized fish. Our average return to the creel was 4.6%. There have been no formal evaluations in the Upper Peninsula of return to the angler of various sizes of brook trout stocked, but some studies have been made in other areas. Shetter et al. (1964) summarized results of 40 brook trout stocking experiments in Michigan rivers. Six experiments involved 4.0-6.9 inch fish. The average return to the creel was 1.9%. Whereas, the average return to the creel in 18 experiments with fish seven inches and longer was 41.7%. Cooper (1952) reported on the returns of legal-sized (≥7 inches) brook trout stocked in late April-early June in a heavily fished stream in the Lower Peninsula of Michigan. During the first year after stocking 48% were caught but only 0.05% were caught the second year. McCrimmon (1960) found that fall fingerlings (3 to 5 inches long) stocked in two small southern Ontario streams had overwinter survivals of 3 and 21% but none had grown to legal size (≥7 inches) by the opening of trout season.

Due to high cost of the state hatchery program, return to the creel is an important consideration when stocking fish into state waters. The Michigan Fish Stocking Guidelines (Borgeson, 1987) suggest that more pounds of fish should be harvested than are stocked. We estimated that harvested pounds of brook trout, in our 3 study rivers, were 9% of initial pounds planted. Brook trout stocked in the East Branch Escanaba and West Branch Escanaba rivers cost $38 and $19 per harvested fish, respectively. Brook trout stocked in the Middle Branch Ontonagon River were more likely to be harvested and cost $9 per harvested fish (Table 7). Cochrane et al. (1992) estimated that the cost of each captured hatchery-reared brook trout in Wisconsin waters of Lake Michigan was $12.67

compared to our average estimated cost of $16 per harvested fish.

Based on stream discharge and distribution of substrate types the study rivers were ranked from best to worst: East Branch Escanaba, Iron, Middle Branch Ontonagon, and West Branch Escanaba. The East Branch Escanaba ranking is out of line with the population present, the creel survey results, and with the groundwater yield index ranking. The other rivers rank the same as populations present, the creel survey results, and with the groundwater yield index ranking. An obvious shortcoming of trying to use these parameters as an index of a stream's ability to sustain trout populations is that the measurements were taken at one time of the year. Stream discharge can change markedly depending on groundwater input and rainfall. The coarse substrates (cobble and gravel) are important for reproduction of stream salmonines. The fine substrates (sand, silt, and detritus) are generally considered inferior for trout streams because they tend to produce few food items, generally provide poor shelter for trout, and tend to inundate spawning gravels (Alexander and Hansen 1983). River pH was above 7.0 and total alkalinity well above 30 ppm in our study rivers. Total alkalinity greater than 30 ppm was suggested by Merna and Alexander (1983) as an adequate buffering level in areas of acid precipitation. Thus, our study rivers are probably adequately buffered and survival of brook trout would probably not be affected by acid precipitation.

Brook trout population size and quality of angling was closely related to average annual water temperature and to the groundwater yield index. Examination of potential groundwater input into each of the four study streams provides plausible explanations for differences in feral brook trout population sizes, angler catch rates, and return to the creel of hatchery-reared brook trout. Our four study watersheds can be placed into two distinct groups based on groundwater yield index. The East Branch Escanaba and West Branch Escanaba rivers would be in the most unstable group since they have the least potential for groundwater input. Corresponding to this categorization, both rivers contain modest numbers of feral brook trout per acre, lower angler catch per angler hour of brook trout, and fewer stocked brook trout returned to the creel. Middle Branch Ontonagon and Iron rivers would be in the more stable group, having the greatest potential for groundwater input. Appropriately for this categorization, there are greater numbers of adult brook trout per acre, greater angler catch per hour, and in the case of the Middle Branch Ontonagon, more stocked trout returned to the creel.

Water source of a river system relates to the river's physical characteristics, what types of fish may live in that river, age structure of individual fish populations, and that population's recruitment potential. For example, groundwater input into a river provides more stable flows, narrower temperature extremes, greater drought flows, and generally a better fishery (Hendrickson, et al. 1973). Rivers with stable flows have larger-sized, more specialized species, higher recruitment, and more even age distributions, while rivers with less stable flows (influenced more by surface runoff), have smaller-sized fish, lower recruitment and uneven age distributions (Poff and Ward 1989). Rivers receiving a greater percentage of their water from groundwater are generally cooler during summer months and warmer during winter months, and are less likely to be influenced by extreme air temperatures (Benson 1953; Hendrickson et al. 1973). Nelson et al. (1992) only found brook trout in glaciated portions of the Humboldt River drainage where the land type association was sedimentary-glacial or detrital-glacial. Although they did not specify high groundwater influence, they described the stream reaches as well-watered with high percentages of large stream-bottom particles.

Hendrickson et al. (1973) and Harr (1962) verify the permeable nature of glaciofluvial deposits and coarse textures, and the impermeable nature of organic deposits, medium textures, and till over bedrock. Hendrickson et al. (1973) also noted that areas of till over bedrock are characterized by highly variable stream flow and low drought flow. Benson (1953) determined that groundwater seepage was the main limnological factor controlling brook trout populations in the Pigeon River. Benson noted that physical characteristics such as structures and pools positively influence survival and growth, but have no effect on population size of natural trout if spawning habitat is lacking. Despite adequate food and cover in the Pigeon River, where groundwater was lacking brook trout populations were sparse. Latta (1965) found a highly significant positive linear correlation between groundwater levels and numbers of YOY brook trout in the Pigeon River. Benson (1953) and Latta (1969) showed that stream edge temperatures, compared to stream middle temperatures, were more moderate in spring when there was greater groundwater input. Latta (1969) found that brook trout fry populated stream edges moderated by groundwater, and that the moderated temperatures resulted in better survival rates in starvation situations.

High summer water temperature was not a limiting factor for brook trout, but differences in groundwater discharge probably influenced winter temperatures in our study streams. The 7-day upper lethal temperature limit for brook trout was reported to be 24 C (Cherry et al. 1977). This was the temperature at which no mortality occurred during a 7-day period at a given temperature. The few brief times that the water temperature reached 24 C during this study should not have had a lethal effect on brook trout. The Iron River had the greatest number of times that water temperature exceeded 23 C and 24 C, yet also had the largest number of brook trout. The wider fluctuations in average daily winter temperature in the Iron and Middle Branch Ontonagon rivers may be indicative of the influence of higher groundwater discharge than in the East Branch Escanaba and West Branch Escanaba rivers. The former two rivers were ice covered much less than the latter two rivers.

Overwinter survival of planted brook trout has often been reported to be poor (Cooper 1952; Flick and Webster 1964; Hunt 1969; White 1989). Our estimate of survival of hatchery-reared fish from age 1 to age 2 (1.5%) agrees with those studies. For example, Cooper (1952) recovered only two fish in the second year after 4,000 fish were initially stocked. In Lawrence Creek, Wisconsin, Hunt (1969) found averages of 54% and 45% overwinter survival of feral brook trout from age 0 to age 1 and from age 1 to age 2, respectively.

Fish health analysis provided possible explanations for the poor overwinter survival to age 2 of hatchery-reared brook trout. Condition factor, hematocrit, and fat reserves of feral and hatchery fish prior to stocking, were higher than for hatchery fish after stocking and indicates that hatchery brook trout enter their first winter in the wild with less reserve energy. Plasma protein was also higher in feral fish than in either hatchery group. Fin erosion is very common in hatchery-reared brook trout in the Marquette State Fish Hatchery (John Driver, MDNR, personal communication), but was much less 2-3 months after stocking. This indicates that regeneration of fins is occurring and/or mortality was higher for those fish with eroded fins. Gill condition in hatchery-reared fish was rated better than for feral fish, so it is doubtful that gill problems contribute to poor survival of hatchery-reared fish. Livers of most hatchery-reared fish after stocking were rated normal. Gall bladder fullness and coloration in hatchery-reared brook trout was better than feral fish indicating that the hatchery fish were feeding normally. The decline in condition factor, hematocrit, blood plasma protein, and fat levels may be relatively good indicators of the ability of hatchery-reared brook trout to survive winter. However, we recommend that additional studies include sampling of hatchery-reared and feral fish throughout the year to better determine the mechanisms that cause poor survival of hatchery-reared brook trout in the Upper Peninsula. Latta (1969) indicated that territorial behavior likely affects survivability of brook trout, and hatchery-reared fish may be less likely to compete effectively for territories. The inability of hatchery-reared brook trout to compete for territory subjects them to higher predation rates, making them less able to compete for food, and making them more likely to migrate out of the area. Fish health analysis on wild and stocked lake trout in Lake Superior had results similar to ours in that condition factor, blood plasma protein, and fat level were higher in wild than in stocked fish (Slade et al. 1994).

Due to drought conditions, stream trout fishing in northern Wisconsin was curtailed during 1989-91. Fishing was prohibited in 1990 and limited to catch-and-release during 1989 and 1991. Fisheries managers were concerned that many Wisconsin anglers would shift their fishing effort to Michigan streams located near the Wisconsin border. The study areas of the Middle Branch Ontonagon and Iron rivers were within 10 miles of the Michigan-Wisconsin border and had good reputations for brook trout fishing. If many Wisconsin anglers were coming to Michigan where a "catch and keep" fishery was allowed, the percentage of out-of-state anglers should have been greater during 1989-91. We could not detect a significant increase in out-of-state anglers, particularly from Wisconsin, during 1989-1991. Likewise, no large increase in anglers was noticed at trout streams in southern Wisconsin that remained open to normal regulations during 1989-91 (Larry Claggett, personal communication, Wisconsin Department of Natural Resources).

Although we found no evidence that stocking hatchery-reared brook trout had any detrimental effects on feral brook trout, the longer-term effects of stocking fish over feral populations are becoming well documented. For example, Evans et al. (1990) states, "There are three major ways in which stocking of hatchery-reared lake trout may have a detrimental effect upon native populations of lake trout. These are: (1) altering the genetic constitution of the native fish (introgressive hybridization); (2) displacing native fish from spawning sites; and (3) by causing increased exploitation rates on native fish".

When hatchery-reared brook trout are stocked in streams, stresses associated with the hatchery (for example, over-crowding, disease) are exchanged for stresses associated with the wild environment (for example, competition for limited food, increased dangers from predators). Stocks held in hatcheries usually have been selected for characteristics such as good survival, rapid growth, and ease of rearing in the hatchery. Many of the genes that make fish better able to survive in the wild may be lost when fish are selected for hatchery production characteristics.

Recommendations

1. Emphasize stocking in rivers where the groundwater yield index is high, but feral trout populations are low due to other limiting factors. Because summer water temperatures were not limiting on any of the study rivers, return to the creel of hatchery-reared brook trout could be improved by stocking legal-sized fish prior to the opening day of fishing in rivers where overwinter survival is poor. We do not recommend changing regulations at this time, however results from this and other studies should be used to model the populations to specify the impacts of altering regulations.

2. Inventory and rank all Upper Peninsula river basins as to their groundwater yield index and incorporate the information into a Geographic Information Systems (GIS). Inventory and rank trout populations in relation to the groundwater yield index and add to the GIS. Compile District data on trout streams into a computerized database and add to the GIS.

Acknowledgments

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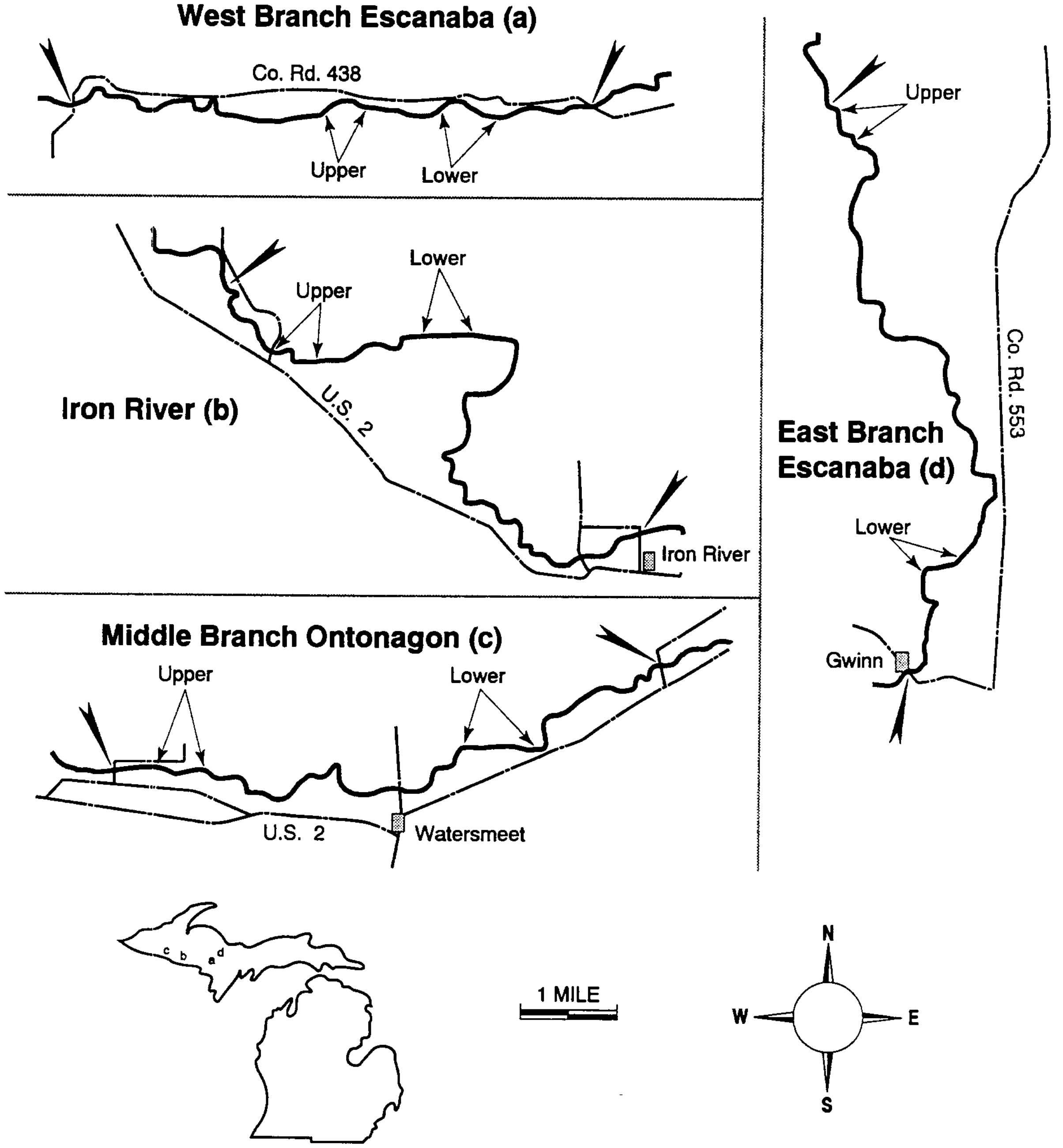

Figure 1.—Maps showing study sections of the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers. Large arrows indicate lower and upper limits of the study sections and small arrows indicate approximate locations of the lower and upper index stations.

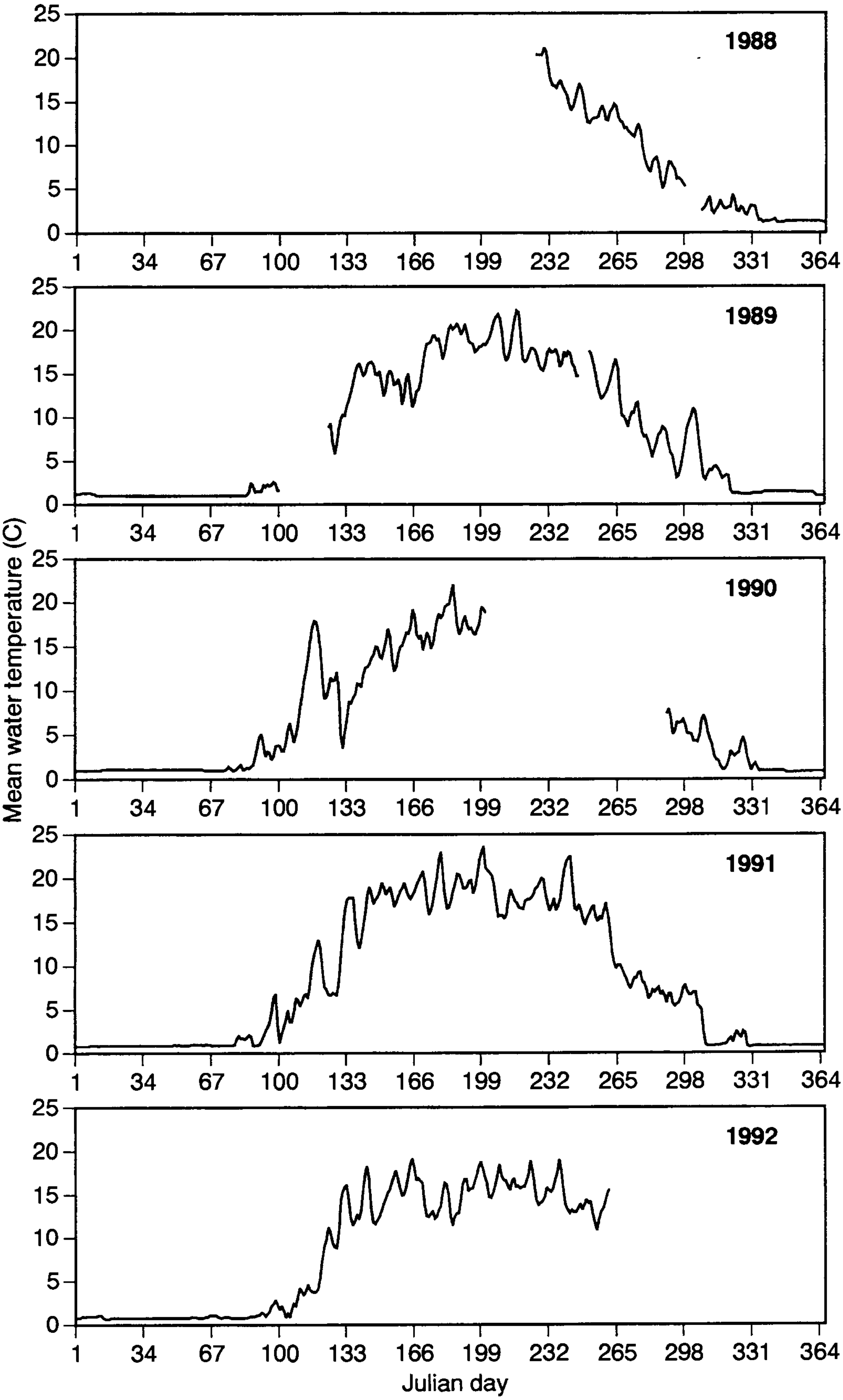

Figure 2.—Mean daily water temperatures (C) of the East Branch Escanaba River, Marquette County, 1988-92.

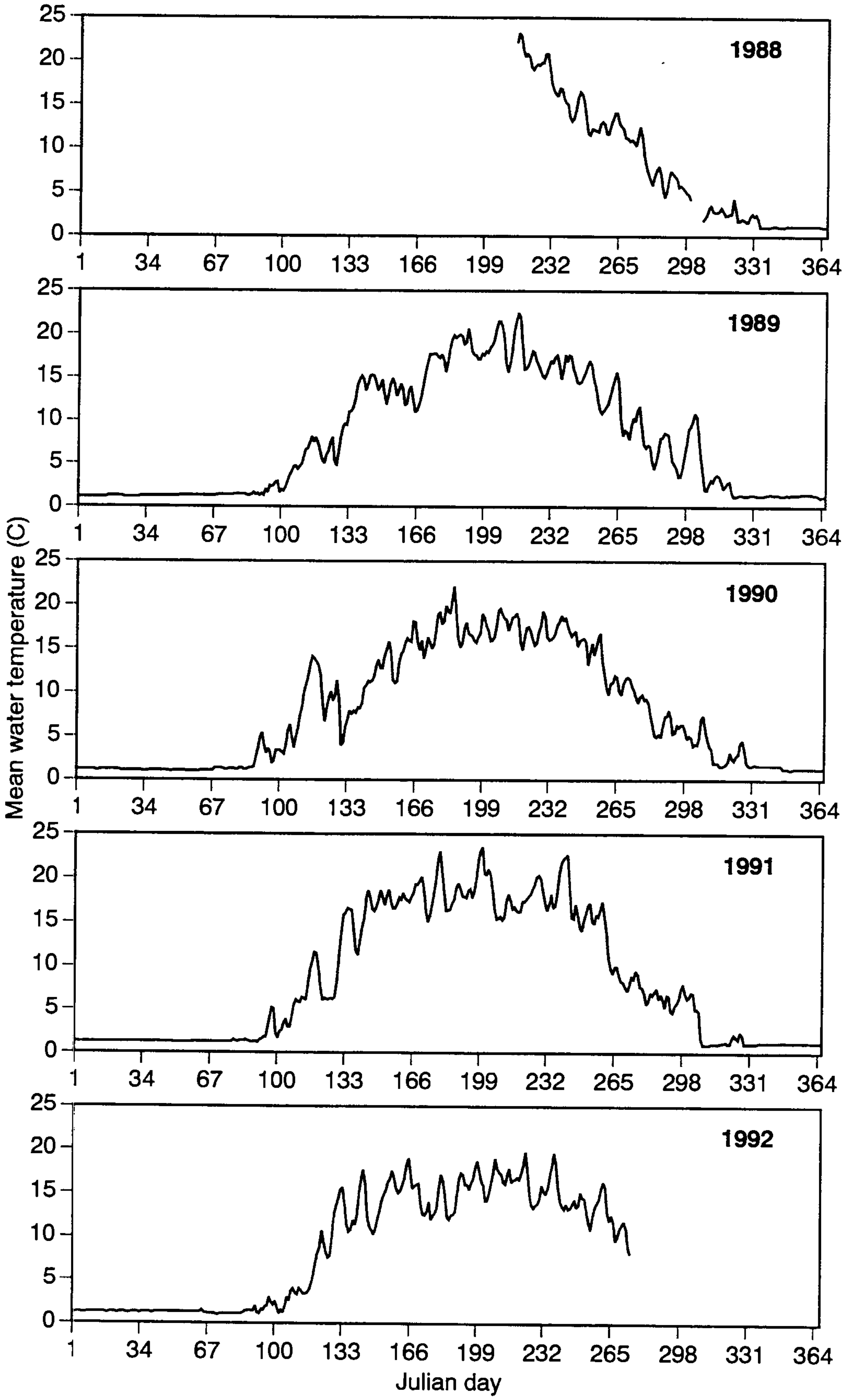

Figure 3.—Mean daily water temperatures (C) of the West Branch Escanaba River, Dickinson County, 1988-92.

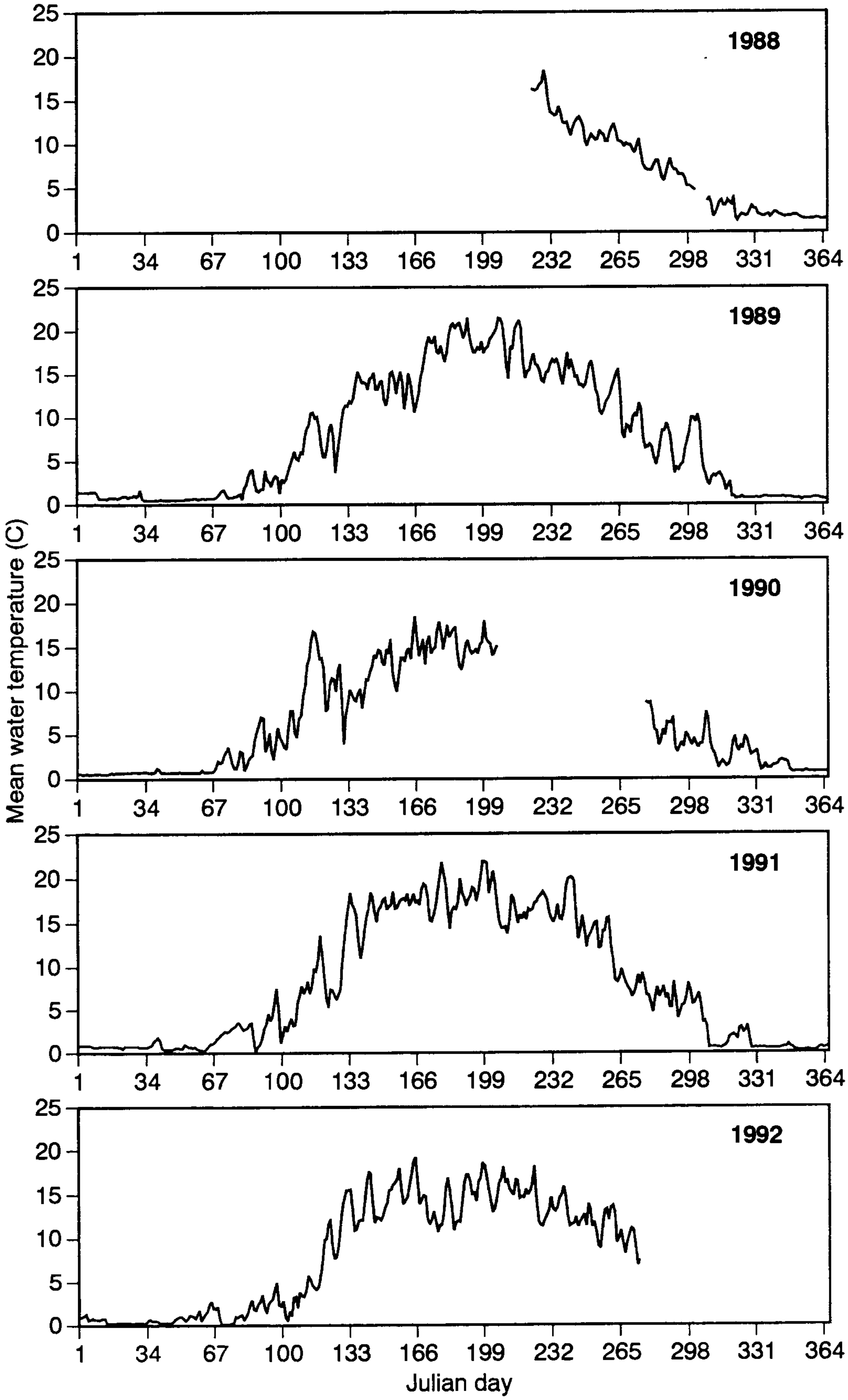

Figure 4.—Mean daily water temperatures (C) of the Iron River, Iron County, 1988-92.

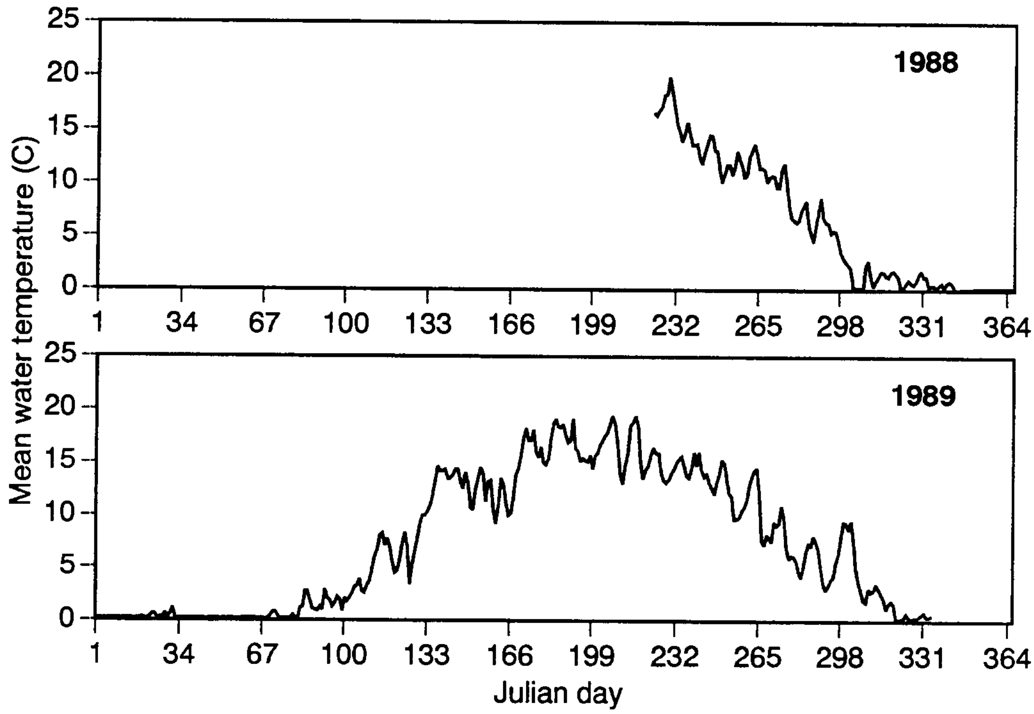

Figure 5.—Mean daily water temperatures (C) of the Middle Branch Ontonagon River, Gogebic County, 1988-89.

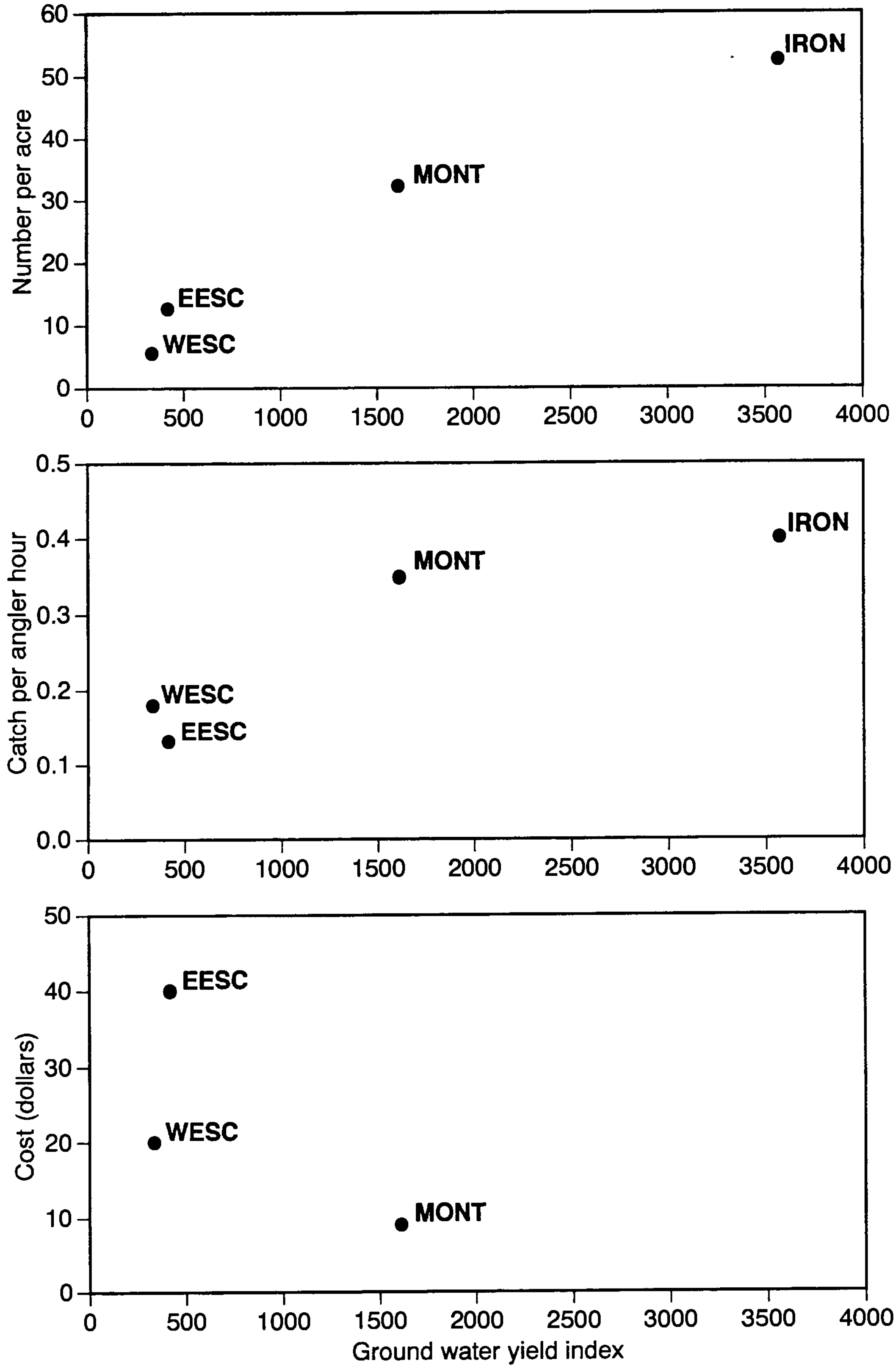

Figure 6.—Adult feral brook trout per acre, catch per hour of feral brook trout, and cost per harvested hatchery brook trout versus ground water yield index in the East (EESC) and West (WESC) Branch Escanaba, Middle Branch Ontonagon (MONT), and Iron (IRON) rivers.

Table 1.—Maximum and minimum elevations above sea level, watershed length, percentage of each soil type, and the estimated groundwater yield index of the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron river watersheds. Permeability value of the soil types are in parentheses.

Parameter	River			
	East Branch Escanaba	West Branch Escanaba	Middle Branch Ontonagon	Iron
Watershed length (mi)	22.08	11.70	13.00	8.80
Maximum elevation (ft)	1,200	1,480	1,772	1,660
Minimum elevation (ft)	1,090	1,112	1,558	1,480
Soil type (%)				
Glaciofluvial deposits (400.0)	20.26	—	18.66	37.50
Coarse textures (30.0)	9.15	26.47	79.10	62.50
Organic deposits (6.0)	—	44.12	2.24	—
Medium textures (0.5)	—	29.41	—	—
Till over bedrock (0.5)	70.59	—	—	—
Groundwater yield index	419	338	1,614	3,574

Table 2.—Mean physical parameters and substrate types (percent) in study sections of the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers.

	River			
Parameter	East Branch Escanaba	West Branch Escanaba	Middle Branch Ontonagon	Iron
Width (ft)	42	27	36	43
Depth (in)	23	20	18	19
Discharge (CFS)	87	45	41	45
Velocity (ft/s)	1.3	1.2	0.8	0.8
Pools				
Size	1.6	2.1	1.9	2.2
Type	1.7	1.9	2.0	2.2
Frequency	1.8	2.3	2.3	2.4
Substrate				
Bedrock	7			
Boulder	3	<1	2	3
Cobble	12	1	4	4
Pebble	16	1	6	8
Granular	15	4	16	13
Coarse sand	8	30	23	16
Fine sand	23	50	34	29
Silt	13	6	14	23
Detritus	<1	7	<1	<1

Table 3.—Mean physical parameters and substrate types (percent) in index stations of the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers.

	River							
	East Branch Escanaba		West Branch Escanaba		Middle Branch Ontonagon		Iron	
Parameter	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Width (ft)	38	42	29	28	43	32	38	47
Depth (in)	21	14	18	20	27	21	17	19
Velocity (ft/s)	1.3	1.4	1.3	1.0	1.1	0.7	0.8	[a]
Pools								
Size	1.5	1.5	2.0	2.4	1.4	1.4	2.5	2.1
Type	1.8	1.8	1.7	1.9	1.4	1.8	2.5	2.0
Frequency	2.0	2.0	2.5	2.4	1.7	2.4	2.9	2.9
Substrate								
Bedrock								
Boulder		8	1				2	1
Cobble	5	33	2	2			5	
Pebble	27	13	1	1	6	2	14	3
Granular	24	18	1	5	26	11	21	9
Coarse sand	1		48	24	25	16	22	9
Fine sand	38		48	35	37	63	21	57
Silt	5			16	7	9	14	21
Detritus				11				

[a] Velocity was not measured.

Table 4.—Planting dates, number, mean length (in), standard deviation (SD), range, percent legal-size (≥7 in), and total estimated pounds of brook trout stocked in the East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, 1990-92.

	Number		Length (in)			Percent
River and date planted	Clipped	Tagged	Mean	SD	Range	≥7.0 in
East Branch Escanaba						
May 4, 1990	5,650	1,850	6.74	0.63	4.5-8.8	39
Apr 29, 1991	—	7,500	6.40	0.41	4.6-8.5	11
Apr 28, 1992	—	7,500	6.42	0.47	5.9-8.6	9
Pounds	2,349					
West Branch Escanaba						
May 2, 1990	2,250	750	6.44	0.75	3.9-8.3	25
May 3, 1991	—	3,000	6.48	0.45	5.7-9.2	14
Apr 28, 1992	—	3,000	6.56	0.46	6.0-8.8	17
Pounds	925					
Middle Branch Ontonagon						
May 17, 1990	5,200	1,800	6.88	0.59	4.9-8.6	47
May 2, 1991	—	7,000	6.44	0.44	4.9-9.4	13
Apr 27, 1992	—	7,000	6.50	0.44	6.0-8.6	15
Pounds	2,295					
Total pounds stocked	5,569					

Table 5.—Estimated number of brook trout per acre (± 2 SE) in combined index stations of the stocked East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, and the unstocked Iron river study sections, July-August 1988-92. The 1990-92 estimates include hatchery-reared and feral brook trout combined.

		Estimated number per acre ± 2 SE		
River and area	Year	YOY[a]	Sublegal[b]	Legal[c]
East Branch Escanaba				
3.95 acres	1988	117±81	24±13	6±6
	1989	37±30	27±10	5±2
	1990	94±23	16±10	21±23
	1991	116±25	37±18	33±27
	1992	194±33	29±11	48±39
	Mean	112±20		
West Branch Escanaba				
3.55 acres	1988	36±28	3±3	2±2
	1989	44±16	1±0	2±1
	1990	48±12	7±3	8±4
	1991	16±5	2±1	18±9
	1992	66±15	3±1	17±7
	Mean	42±8		
Middle Branch Ontonagon				
5.27 acres	1988	130±87	124±23	24±6
	1989	379±82	42±10	20±5
	1990	649±65	76±13	24±5
	1991	251±69	158±19	66±11
	1992	264±65	60±16	56±18
	Mean	335±33		
Iron				
5.44 acres	1988	602±143	240±30	71±12
	1989	1,156±231	222±30	40±8
	1990	971±119	315±30	52±11
	1991	198±58	375±35	67±10
	1992	1,615±251	80±14	32±8
	Mean	908±79		

[a] YOY (young-of-year) were all feral fish.
[b] YOY excluded.
[c] Total length ≥7.0 inches.

Table 6.—Estimated average number of brook trout per acre (± 2 SE) during pre-stocking (1988-89) and stocking (1990-92) years in the stocked East Branch Escanaba, West Branch Escanaba, and Middle Branch Ontonagon rivers, and the unstocked Iron River.

		Estimated average number per acre ± 2 SE		
River and years	Origin	YOY	Sublegal[a]	Legal[b]
East Branch Escanaba				
1988-89	Feral	77±43	26±8	6±3
1990-92	Feral	135±16		17±11
	Hatchery			17±13
	Feral and hatchery total	135±16	27±8	34±18
West Branch Escanaba				
1988-89	Feral	44±16	2±2	2±1
1990-92	Feral	43±7		8±3
	Hatchery			7±3
	Feral and hatchery total	43±7	4±1	15±4
Middle Branch Ontonagon				
1988-89	Feral	255±60	83±13	22±4
1990-92	Feral	388±38		39±7
	Hatchery			13±2
	Feral and hatchery total	388±38	98±9	52±7
Iron				
1988-89	Feral	879±136	231±21	56±7
1990-92	Feral	928±95	257±16	50±7

[a] Does not include YOY (young-of-year)
[b] Total length ≥7.0 inches

Table 7.—Number of tagged brook trout seen by creel survey clerks in the study areas and voluntary tag returns from inside and outside the survey areas, estimated harvest of tagged fish, estimated percent harvest, and estimated cost per harvested fish.

		River			
Year	Parameter	East Branch Escanaba	West Branch Escanaba	Middle Branch Ontonagon	Total
1990	Number planted	1,850	750	1,800	4,400
	Caught in study area	4	5[a]	3	12
	Estimated catch	34	5[a]	52	91
	Caught outside study area	9	4	10	23
	Estimated catch	17	7	18	42
	Percent caught	2.8	1.6	3.9	3.0
1991	Number planted	7,500	3,000	7,000	17,500
	Caught in study area	7[a]	17	85	109
	Estimated catch	7[a]	97	682	786
	Caught outside study area	6	11	13	30
	Estimated catch	11	20	24	55
	Percent caught	0.2	3.9	10.0	4.8
1992	Number planted	7,500	3,000	7,000	17,500
	Caught in study area	33	27	80	140
	Estimated catch	231	101	452	784
	Caught outside study area	5	8	3	16
	Estimated catch	9	15	6	30
	Percent caught	3.2	3.9	6.5	4.6
Total	Number planted	16,850	6,750	15,800	39,400
	Caught in study area	44	49	168	261
	Estimated catch	279	208	1,186	1,673
	Caught outside study area	20	23	26	69
	Estimated catch	37	42	48	128
	Percent caught	1.9	3.7	7.8	4.6
	Estimated pounds caught	80	70	364	514
	Percent of pounds stocked	3.4	7.6	15.9	9.2
	Cost per fish caught	$40	$20	$9	$16

[a] No estimate could be calculated from the creel survey but these tags were reported by volunteer anglers.

Table 8.—Estimated angler hours (± 2 SE), number legal-sized[a] brook trout per angler hour (CPH), and total number of legal-sized brook trout caught from study sections of rivers during 1988-92.

Year and parameter	E. Br. Escanaba		W. Br. Escanaba		M. Br. Ontonagon		Iron
	Feral	Hatchery	Feral	Hatchery	Feral	Hatchery	Feral
1988							
Hours	923±241		539±100		1,883±279		3,134±353
CPH	0.166±0.168	—	0.020±0.027	—	0.408±0.170	—	0.564±0.164
Catch	153±150	—	11±15	—	768±300	—	1,768±474
1989							
Hours	1,389±282		1,039±197		1,638±285		3,258±346
CPH	0.099±0.068	—	0.261±0.129	—	0.189±0.127	—	0.258±0.083
Catch	138±90	—	271±124	—	310±200	—	842±254
1990							
Hours	1,261±287		400±105		1,104±172		2,309±236
CPH	0.071±0.043	0.083±0.076	0.220±0.215	0.000	0.279±0.166	0.053±0.079	0.321±0.109
Catch	89±61	105±92	88±83		308±192	58±87	740±240
1991							
Hours	1,163±246		993±202		1,665±262		2,568±326
CPH	0.260±0.242	0.000	0.154±0.075	0.097±0.070	0.264±0.089	0.433±0.191	0.549±0.178
Catch	302±275		153±87	96±67	440±175	721±296	1,409±420
1992							
Hours	1,733±255		597±153		1,694±198		2,750±259
CPH	0.096±0.053	0.138±0.086	0.199±0.098	0.171±0.130	0.566±0.161	0.233±0.096	0.309±0.108
Catch	166±159	240±145	119±56	102±73	958±313	394±157	849±285
1988-89 Mean							
Hours	1,156±185		789±111		1,760±199		3,196±247
CPH	0.126±0.078	—	0.179±0.083	—	0.306±0.108	—	0.408±0.090
Catch	146±87	—	141±63	—	539±180	—	1,305±269
1990-92 Mean							
Hours	1,386±152		663±91		1,488±123		2,542±160
CPH	0.134±0.079	0.083±0.042	0.181±0.071	0.100±0.052	0.382±0.097	0.263±0.079	0.393±0.078
Catch	186±108	115±57	120±45	66±33	569±136	390±121	999±187
1990-92 combined hatchery and feral means							
CPH	0.217±0.091		0.280±0.091		0.645±0.034		0.393±0.078
Catch	301±122		186±55		959±182		999±187

[a] Legal-size was ≥7 inches.

Table 9.—Number (Num) and percentage (%) of interviewed anglers that caught 0-10 brook trout during an angling trip during 1988-92.

Number of fish	East Branch Escanaba		West Branch Escanaba		Middle Branch Ontonagon		Iron		All		Total fish[a]
	Num	%	Num	%	Num	%	Num	%	Num	%	
0	469	83.30	194	69.29	366	62.46	816	70.59	1,845	71.37	
1	62	11.01	38	13.57	82	13.99	134	11.59	316	12.22	316
2	20	3.55	23	8.21	53	9.04	62	5.36	158	6.11	316
3	5	0.89	14	5.00	34	5.80	35	3.03	88	3.40	264
4	3	0.53	5	1.79	14	2.39	29	2.51	51	1.97	204
5	2	0.36	3	1.07	13	2.22	35	3.03	53	2.05	265
6	0	0.00	2	0.71	8	1.37	20	1.73	30	1.16	180
7	0	0.00	0	0.00	3	0.51	7	0.61	10	0.39	70
8	1	0.18	0	0.00	2	0.34	4	0.35	7	0.27	56
9	1	0.18	0	0.00	4	0.68	3	0.26	8	0.31	72
10	0	0.00	1	0.36	7	1.19	11	0.95	19	0.74	190
Total	563	100	280	100	586	100	1,156	100	2,585	100	1,933

[a] Number of anglers times catch.

Table 10.—Distribution of angler effort and catch in the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers, 1988-92.

	River				
Period	East Br. Escanaba	West Br. Escanaba	Middle Br. Ontonagon	Iron	Mean
Percent of angler effort					
First week	19	8	13	22	17
May	24	24	23	30	27
June	16	25	23	19	20
July	18	19	17	15	16
August	15	11	13	10	12
September	8	13	11	5	8
Total	100	100	100	100	100
Percent of angler catch					
First week	15	2	5	32	19
May	23	18	11	32	23
June	16	30	39	11	22
July	21	23	19	8	14
August	14	11	16	8	11
September	10	15	9	10	10
Total	100	100	100	100	100

Table 11.—Number and percent by residence[a] of anglers interviewed during creel surveys of East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers, 1988-92.

River and year	Number interviewed	Percent		
		Local resident	Non-local resident	Out-of-state
East Branch Escanaba				
1988	29	93	3	3
1989	131	85	5	10
1990	121	87	7	7
1991	96	82	6	11
1992	150	90	3	7
Total	527	87	5	8
West Branch Escanaba				
1988	9	89	11	—
1989	60	85	10	5
1990	46	80	11	9
1991	84	64	10	26
1992	61	69	16	15
Total	260	74	11	15
Middle Branch Ontonagon				
1988	92	42	11	47
1989	97	54	9	37
1990	64	28	11	61
1991	150	33	11	56
1992	170	25	9	66
Total	573	34	12	55
Iron				
1988	116	57	7	36
1989	271	72	4	24
1990	190	70	9	21
1991	160	71	7	22
1992	282	77	9	14
Total	1,019	71	7	22

[a] Local residents lived within the county or an adjacent county to where the creel surveyed section was located; non-local residents resided elsewhere in Michigan.

Table 12.—Age and length (in) distributions of hatchery-reared and feral brook trout and total annual mortality (A) of feral brook trout in the catch of anglers surveyed in the creel census at the East Branch Escanaba River, 1988-92.

	Hatchery		Feral		Combined	
Distribution	Number	Percent	Number	Percent	Number	Percent
Age						
1	17	100.0	6	9.1	23	27.7
2	—	—	44	66.7	44	53.0
3	—	—	14	21.2	14	16.9
4	—	—	2	3.0	2	2.4
Total	17	100.0	66	100.0	83	100.0
Mean age	1.00		2.18 A = 77%		1.94	
Length						
6	1	2.2	—	—	1	0.7
7	31	67.4	24	24.5	55	38.2
8	11	23.9	18	18.4	29	20.1
9	2	4.3	26	26.5	28	19.4
10	—	—	13	13.3	13	9.0
11	1	2.2	12	12.2	13	9.0
12	—	—	5	5.1	5	3.5
13	—	—	—	—	—	—
14	—	—	—	—	—	—
15	—	—	—	—	—	—
Total	46	100.0	98	100.0	144	100.0
Mean length	7.8		9.3		9.1	

Table 13.—Age and length (in) distributions of hatchery-reared and feral brook trout and total annual mortality (A) of feral brook trout in the catch of anglers surveyed in the creel census at the West Branch Escanaba River, 1988-92.

Distribution	Hatchery		Feral		Combined	
	Number	Percent	Number	Percent	Number	Percent
Age						
1	45	100.0	5	4.1	50	29.9
2	—	—	72	59.0	72	43.1
3	—	—	42	34.4	42	25.1
4	—	—	3	2.5	3	1.8
Total	45	100.0	122	100.0	167	100.0
Mean age	1.00		2.35		1.99	
			A = 71%			
Length						
6	—	—	—	—	—	—
7	19	42.2	21	16.3	40	22.9
8	17	37.8	14	10.8	31	17.7
9	6	13.3	31	24.0	37	21.1
10	2	4.4	33	25.6	35	20.0
11	1	2.2	22	16.3	23	13.1
12	—	—	6	4.7	6	3.4
13	—	—	2	1.6	2	1.1
14	—	—	1	—	1	0.6
15	—	—	—	—	—	—
Total	45	100.0	130	100.0	175	100.0
Mean length	8.1		9.7		9.3	

Table 14.—Age and length (in) distributions of hatchery-reared and feral brook trout and total annual mortality (A) of feral brook trout in the catch of anglers surveyed in the creel census at the Middle Branch Ontonagon River 1988-92.

	Hatchery		Feral		Combined	
Distribution	Number	Percent	Number	Percent	Number	Percent
Age						
1	164	98.8	46	15.4	210	45.2
2	2	1.2	185	31.9	187	40.2
3	—	—	57	19.1	57	12.3
4	—	—	11	3.7	11	2.4
Total	166	100.0	299	100.0	465	100.0
Mean age	1.02		2.11		1.72	
			A = 76%			
Length						
6	1	0.6	5	1.2	6	1.0
7	86	51.5	77	18.5	163	27.9
8	52	31.1	124	29.7	176	30.1
9	24	14.4	87	20.9	113	19.3
10	2	1.2	63	15.1	65	11.1
11	1	0.6	35	8.4	36	6.2
12	1	0.6	13	3.1	14	2.4
13	—	—	7	1.7	7	1.2
14	—	—	5	1.2	3	0.5
15	—	—	1	0.2	1	0.2
Total	167	100.0	417	100.0	584	100.0
Mean length	8.1		9.3		8.8	

Table 15.—Age and length (in) distributions and total annual mortality (A) of feral brook trout in the catch of anglers surveyed in the creel census at the Iron River, 1988-92.

Distribution	Feral	
	Number	Percent
Age		
1	29	11.6
2	173	68.9
3	45	17.9
4	4	1.6
Total	251	100.0
Mean age	2.10	
	A = 81%	
Length		
6	16	1.6
7	314	31.8
8	331	33.6
9	187	19.0
10	79	8.0
11	31	3.1
12	16	1.6
13	9	0.9
14	3	0.3
15	—	—
Total	986	100.0
Mean length	8.6	

Table 16.—Back calculated total length-at-age ± 2 SE (in) and von Bertalanffy growth function parameters (VBGF) of feral brook trout in the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron rivers, 1988-92.

River and Age	Number	Age 1	Age 2	Age 3	Age 4
East Branch Escanaba					
1	152	3.96±0.13			
2	87	4.31±0.16	6.79±0.28		
3	18	4.50±0.25	7.00±0.58	9.30±0.59	
4	2	3.70±0.85	6.37±0.68	8.65±0.04	10.44±0.71
All	259	4.11±0.10	6.82±0.25	9.24±0.54	10.44±0.71
West Branch Escanaba					
1	48	4.46±0.23			
2	95	4.74±0.17	7.26±0.27		
3	46	4.52±0.16	6.73±0.27	9.25±0.33	
4	3	4.37±0.25	6.21±0.44	9.24±1.78	11.31±1.50
All	192	4.61±0.11	7.07±0.20	9.25±0.32	11.31±1.50
Middle Branch Ontonagon					
1	379	4.39±0.09			
2	344	4.62±0.08	6.85±1.16		
3	77	4.64±0.18	6.97±0.26	9.18±0.31	
4	17	4.61±0.61	6.47±0.57	9.45±0.69	11.42±0.69
All	817	4.52±0.05	6.87±0.10	9.23±0.27	11.42±0.69
Iron					
1	385	4.17±0.08			
2	371	4.58±0.08	6.81±0.11		
3	77	4.52±0.17	6.18±0.07	9.07±0.31	
4	6	4.57±0.71	6.83±0.87	8.56±1.42	11.74±1.16
All	839	4.38±0.06	6.81±0.10	9.03±0.30	11.74±1.16
von Bertalanffy growth function parameters					
East Branch Escanaba		K = 0.3381	$L\infty = 14.2$	$t_0 = -0.0001$	$R^2 = 0.99$
West Branch Escanaba		K = 0.3083	$L\infty = 15.6$	$t_0 = -0.0262$	$R^2 = 1.00$
Middle Branch Ontonagon		K = 0.2633	$L\infty = 17.2$	$t_0 = -0.0332$	$R^2 = 1.00$
Iron		K = 0.2002	$L\infty = 20.7$	$t_0 = -0.0458$	$R^2 = 0.99$

Table 17.—Weight (lb)-length (in) relationships ± 95% confidence intervals for hatchery-reared (1990-92) and feral (1988-92) brook trout.

River	Origin	*N*	Intercept (a)	Slope (b)	R^2
Hatchery	Hatchery	58	-3.71±0.19	3.35±0.23	0.94
East Branch Escanaba	Feral	77	-3.59±0.17	3.14±0.21	0.92
West Branch Escanaba[a]	Feral	43	-3.66±0.16	3.24±0.19	0.97
Middle Branch Ontonagon	Feral	85	-3.57±0.09	3.10±0.11	0.98
Iron	Feral	100	-3.58±0.08	3.15±0.19	0.98
All rivers	Hatchery	73	-4.00±0.29	3.59±0.32	0.88
All rivers	Feral	305	-3.62±0.06	3.18±0.07	0.97
All hatchery and feral		436	-3.58±0.05	3.14±0.06	0.96

[a] No brook trout were weighed in 1988 and 1989.

Table 18.—Estimated daily growth (in) and 2 SE from stocking date to recapture date of hatchery-reared brook trout in the East Branch Escanaba, West Branch Escanaba,- and Middle Branch Ontonagon rivers. Recaptures were made during population estimates and during creel surveys.

River and year	*N*	Mean growth	2 SE
East Branch Escanaba			
1990	8	0.01153	0.00381
1991	21	0.00840	0.00142
1992	88	0.01344	0.00121
Total	137	0.01082	0.00111
West Branch Escanaba			
1990	1	0.00490	—
1991	40	0.02310	0.00180
1992	42	0.01671	0.00194
Total	83	0.01965	0.00146
Middle Branch Ontonagon			
1990	3	0.01033	0.00082
1991	164	0.01534	0.00080
1992	113	0.01937	0.00106
Total	280	0.01692	0.00667
Combined rivers			
1990	12	0.01067	0.00213
1991	225	0.01607	0.00085
1992	243	0.01690	0.00075
Total	480	0.01636	0.00056

Table 19.—Number of days that average daily water temperature exceeded 20.0-20.9, 21.0-21.9, 22.0-22.9, and 23.0-23.9 C and the percentage of time that maximum and minimum water temperatures occurred during May-September, in the East Branch Escanaba, West Branch Escanaba, and Iron rivers during 1988-91. Average daily temperature never exceeded 20 C in the Ontonagon River in 1988 or 1989.

	Temperature range (C)			
River and year	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9
East Branch Escanaba				
1988	5	1		
1989	8	5	2	
1990	1		1	
1991	11	3	4	3
1992				
West Branch Escanaba				
1988	5	1	2	1
1989	4	4	2	
1990	1		1	
1991	8	2	5	3
1992				
Iron				
1988				
1989	10	5		
1990				
1991	8	4		
1992				

Two hour period and percent (N=2,506)

0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200	2400
					Maximum						
21	0	0	0	0	0	1	13	40	21	4	0
					Minimum						
2	1	8	45	29	4	0	0	0	0	0	10

Table 20.—Autopsy based fish health parameters (condition factor, hematocrit, and plasma protein are means ± 95% C. I.) for hatchery-reared brook trout prior to stocking, hatchery-reared brook trout in July after stocking, and feral fish in study rivers in July, (1990-92 for hatchery fish and 1988-92 for feral brook trout).

Parameter and rank		Source, location, and number Hatchery/hatchery (*N*=58)	 Hatchery/river (*N*=75)	 Feral/river (*N*=306)
Condition (K_d)		1.05±0.01	0.89±0.01	0.94±0.01
Hematocrit (% total blood volume)		40.16±1.14	38.91±1.14	38.31±1.14
Plasma protein (g per 100 mL)		4.63±0.22	4.39±0.22	5.39±0.22
Fat (pyloric caeca)				
None		0	3	3
	Caeca >0-50% covered	0	6	16
	Caeca 50% covered	0	33	107
	Caeca >50% covered	58	32	160
	Caeca covered	0	1	20
Eroded Fins	0%	8	27	301
	>0-0.33%	27	34	5
	0.33-0.67%	17	14	0
	> 0.67%	6	0	0
Gills	Normal	56	67	235
	Abnormal	2	8	71
Eyes	Normal	55	70	292
	Abnormal	3	5	14
Kidney	Normal	57	73	297
	Abnormal	1	2	9
Liver	Normal	36	72	272
	Abnormal	22	3	34
Gall bladder	Empty/yellow	7	2	4
	Full/yellow	47	50	247
	Full/lt. green	4	17	41
	Full/dark green	0	6	12

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Appendix 1.—Means and 95% confidence intervals (in parentheses) of physical parameters[a] of the East Branch of the Escanaba River study area in 0.5-mile sections progressing upstream. Pool classifications were made per Lagler (1952), and substrates per Welch (1948).

			Pools			Substrate							
No	Wi	De	Siz	Typ	Fre	Br	Bo	Co	Pe	Gr	Sc	Sf	Ls
1	44	27	2.3	2.4	2.3		8	21	17	28	23	4	
	(3)	(2)	(0.2)	(0.2)	(0.2)		(4)	(5)	(2)	(4)	(5)	(2)	
2	49	31	2.0	1.9	2.3		4	14	20	18	8	5	
	(9)	(4)	(0.2)	(0.2)	(0.2)		(1)	(3)	(4)	(3)	(2)	(2)	
3	39	34	1.4	1.5	1.6		2	3	14	10	4	23	8
	(5)	(4)	(0.2)	(0.2)	(0.2)		(1)	(1)	(5)	(4)	(2)	(6)	(3)
4	38	21	1.4	1.7	1.9			6	24	26	1	39	5
	(3)	(2)	(0.2)	(0.2)	(0.2)			(2)	(2)	(2)	(1)	(3)	(2)
5	33	18	1.4	1.6	1.9			14	23	20	1	41	
	(2)	(2)	(0.2)	(0.2)	(0.2)			(2)	(3)	(2)	(1)	(4)	
6	36	22	1.8	1.9	2.1		1	9	27	16		38	1
	(3)	(3)	(0.2)	(0.2)	(0.2)		(0)	(3)	(4)	(2)		(7)	(1)
7	42	23	1.9	2.1	2.4		1	6	16	21	5	26	1
	(5)	(4)	(0.2)	(0.2)	(0.2)		(1)	(2)	(3)	(3)	(2)	(4)	(1)
8	43	39	1.1	1.3	1.2			5	8	8	8	25	35
	(3)	(4)	(0.1)	(0.1)	(0.1)			(2)	(3)	(3)	(3)	(7)	(11)
9	42	30	2.2	2.1	2.1		4	17	12	15	12	7	9
	(4)	(4)	(0.2)	(0.2)	(0.2)		(1)	(5)	(3)	(4)	(4)	(4)	(6)
10	44	46	1.3	1.4	1.4			1	1	1	4	10	8
	(5)	(3)	(0.2)	(0.2)	(0.2)			(1)	(1)	(1)	(3)	(5)	(4)
11	39	23	1.4	1.6	2.3	1	4	11	27	12	1	31	
	(10)	(4)	(0.2)	(0.2)	(0.2)	(1)	(2)	(3)	(6)	(3)	(1)	(7)	
12	45	40	1.4	1.3	1.5		2	9	2	4	7	7	38
	(3)	(4)	(0.2)	(0.1)	(0.2)		(1)	(4)	(1)	(1)	(3)	(3)	(11)
13	43	32	1.6	1.6	1.5	12	10	13	9	9	7	2	
	(3)	(5)	(0.2)	(0.2)	(0.2)	(8)	(3)	(4)	(2)	(3)	(3)	(1)	
14	46	42	1.5	1.5	1.8	11	3	6	9	8	15	11	13
	(10)	(4)	(0.2)	(0.2)	(0.2)	(7)	(1)	(3)	(4)	(3)	(4)	(4)	(7)
15	48	42	1.4	1.4	1.4	31	3	4	1	1	1	14	32
	(8)	(4)	(0.2)	(0.2)	(0.2)	(11)	(2)	(2)	(1)	(1)	(1)	(7)	(10)
16	44	39	1.5	1.6	1.8	36	4	11	6	4	4	13	3
	(10)	(5)	(0.2)	(0.2)	(0.2)	(11)	(2)	(4)	(2)	(2)	(2)	(7)	(1)
17[b]	37	37	1.7	1.4	1.7	6	3	12	5	8	10	19	37
	(4)	(5)	(0.2)	(0.2)	(0.2)	(6)	(1)	(4)	(2)	(2)	(3)	(5)	(11)

[a] Abbreviations and units: No=section number, Wi=width (ft), De=depth (in), Vel=velocity (ft/sec), Siz=size, Typ=type, Fre=frequency, Br=bedrock, Bo=boulder, Co=cobble, Pe=pebble, Gr=granular, Sc=coarse sand, Sf=fine sand, Ls=silt, Dt=detritus.
[b] Section is 0.47 miles long.

Appendix 2.—Means and 95% confidence intervals (in parentheses) of physical parameters[a] of the West Branch of the Escanaba River study area in 0.5-mile sections progressing upstream. Pool classifications were made per Lagler (1952), and substrates per Welch (1948).

			Pools			Substrate							
No	Wi	De	Siz	Typ	Fre	Bo	Co	Pe	Gr	Sc	Sf	Ls	Dt
1	25	16	2.3	2.1	2.6					1	99		
	(2)	(3)	(0.1)	(0.2)	(0.2)					(0)	(0)		
2	22	18	2.0	1.9	2.6					1	99		
	(2)	(2)	(0.2)	(0.2)	(0.2)					(0)	(0)		
3	25	21	1.6	1.8	1.9					50	50		
	(1)	(2)	(0.1)	(0.2)	(0.2)					(0)	(0)		
4	23	23	1.3	1.4	1.3					50	49		1
	(1)	(3)	(0.1)	(0.1)	(0.1)					(0)	(1)		(1)
5	26	21	1.3	1.6	1.9					50	50		
	(2)	(3)	(0.2)	(0.2)	(0.2)					(0)	(0)		
6	30	18	2.1	1.8	2.7	1	2	1	2	47	47		
	(3)	(2)	(0.2)	(0.2)	(0.1)	(1)	(1)	(1)	(1)	(1)	(1)		
7	30	20	2.0	1.8	2.3	1	5	6	9	42	38		
	(2)	(3)	(0.2)	(0.2)	(0.2)	(1)	(2)	(2)	(2)	(3)	(3)		
8	26	20	2.3	2.1	2.4				3	37	44	12	4
	(1)	(3)	(0.2)	(0.2)	(0.2)				(1)	(4)	(2)	(3)	(2)
9	25	21	2.6	2.1	2.5			1	6	29	35	16	13
	(3)	(2)	(0.1)	(0.1)	(0.2)			(1)	(1)	(2)	(3)	(2)	(4)
10	30	21	2.4	1.9	2.4		2		7	19	28	15	24
	(3)	(3)	(0.1)	(0.2)	(0.1)		(2)		(2)	(3)	(3)	(2)	(5)
11	28	22	2.6	2.1	2.6				11	15	31	11	33
	(1)	(3)	(0.1)	(0.2)	(0.1)				(4)	(2)	(3)	(3)	(5)
12	30	32	2.3	1.8	2.5	1	8		9	18	35	18	4
	(3)	(5)	(0.2)	(0.2)	(0.2)	(0)	(4)		(3)	(3)	(5)	(2)	(1)

Approximately 3.9 additional miles not examined.

[a] Abbreviations and units: No=section number, Wi=width (ft), De=depth (in), Vel=velocity (ft/sec), Siz=size, Typ=type, Fre=frequency, Br=bedrock, Bo=boulder, Co=cobble, Pe=pebble, Gr=granular, Sc=coarse sand, Sf=fine sand, Ls=silt, Dt=detritus.

[b] Section is 0.47 miles long.

Appendix 3.—Means and 95% confidence intervals (in parentheses) of physical parameters[a] of the Middle Branch of the Ontonagon River study area in 1/2-mile sections progressing upstream. Pool classifications were made per Lagler (1952), and substrates per Welch (1948).

			Pools			Substrate						
No	Wi	De	Siz	Typ	Fre	Bo	Co	Pe	Gr	Sc	Sf	Ls
1	41	27	2.1	2.0	2.3	8	12	13	18	16	31	1
	(5)	(4)	(0.2)	(0.2)	(0.2)	(4)	(3)	(4)	(5)	(6)	(8)	(1)
2	48	21	2.1	2.4	2.6	11	15	10	14	16	14	19
	(6)	(3)	(0.2)	(0.2)	(0.2)	(4)	(4)	(2)	(2)	(3)	(3)	(6)
3	44	22	1.9	2.0	2.5		3	5	11	31	27	23
	(3)	(3)	(0.2)	(0.2)	(0.2)		(1)	(2)	(2)	(2)	(1)	(2)
4	37	28	1.6	1.7	1.9			1	24	23	41	4
	(3)	(3)	(0.2)	(0.2)	(0.2)			(1)	(4)	(3)	(5)	(2)
5	44	25	1.8	1.8	1.9			6	34	23	31	8
	(4)	(2)	(0.2)	(0.2)	(0.2)			(2)	(4)	(3)	(4)	(2)
6	39	27	1.7	1.8	2.4			1	29	34	34	2
	(3)	(2)	(0.3)	(0.2)	(0.2)			(1)	(3)	(2)	(4)	(1)
7	40	15	2.9	2.9	2.9	1	6	16	31	24	16	7
	(4)	(2)	(0.1)	(0.1)	(0.1)	(0)	(1)	(2)	(2)	(2)	(2)	(2)
8	35	15	2.1	2.2	2.8	8	17	19	21	16	11	8
	(3)	(2)	(0.2)	(0.2)	(0.1)	(1)	(2)	(2)	(1)	(2)	(2)	(2)
9	34	18	1.6	2.1	1.9	3	9	10	14	18	24	22
	(3)	(2)	(0.2)	(0.2)	(0.2)	(1)	(2)	(2)	(2)	(1)	(3)	(3)
10	33	20	1.4	1.8	2.3		5	6	12	24	27	26
	(3)	(2)	(0.2)	(0.2)	(0.2)		(2)	(1)	(2)	(2)	(1)	(2)
11	33	18	2.2	2.2	2.3	1	1	5	15	27	27	24
	(3)	(3)	(0.2)	(0.2)	(0.2)	(1)	(1)	(1)	(2)	(1)	(2)	(2)
12	31	20	1.8	1.9	2.3	1	1	2	6	26	31	28
	(6)	(4)	(0.2)	(0.2)	(0.2)	(1)	(1)	(1)	(2)	(2)	(3)	(3)
13	27	13	1.7	1.6	2.3					28	38	28
	(6)	(2)	(0.2)	(0.2)	(0.2)					(2)	(2)	(2)
14	29	18	1.6	1.8	2.1				3	34	42	21
	(3)	(4)	(0.2)	(0.2)	(0.2)				(1)	(4)	(4)	(3)
15	33	18	2.0	2.1	2.8		1	4	18	24	44	9
	(3)	(2)	(0.2)	(0.2)	(0.1)		(1)	(2)	(2)	(3)	(5)	(1)
16	31	20	1.6	1.9	2.3			2	8	9	69	11
	(3)	(2)	(0.2)	(0.2)	(0.2)			(1)	(3)	(2)	(3)	(1)
17	30	22	1.9	1.9	2.3				12	13	68	8
	(3)	(2)	(0.2)	(0.2)	(0.2)				(3)	(2)	(3)	(2)

[a] Abbreviations and units: No=section number, Wi=width (ft), De=depth (in), Vel=velocity (ft/sec), Siz=size, Typ=type, Fre=frequency, Br=bedrock, Bo=boulder, Co=cobble, Pe=pebble, Gr=granular, Sc=coarse sand, Sf=fine sand, Ls=silt, Dt=detritus.

Appendix 4.—Means and 95% confidence intervals (in parentheses) of physical parameters[a] of the Iron River study area in 0.5-mile sections progressing upstream. Pool classifications were made per Lagler (1952), and substrates per Welch (1948).

No	Wi	De	Pools			Substrate							
			Siz	Typ	Fre	Bo	Co	Pe	Gr	Sc	Sf	Ls	Dt
1	35 (5)	34 (4)	1.1 (0.1)	1.2 (0.1)	1.3 (0.1)	1 (1)	2 (1)	1 (1)	2 (1)	3 (2)	18 (5)	73 (7)	1 (0)
2	36 (5)	38 (4)	2.0 (0.3)	2.0 (0.3)	2.0 (0.3)	3 (1)	2 (1)	4 (2)	7 (2)	9 (3)	33 (6)	36 (10)	
3	42 (3)	18 (2)	2.3 (0.2)	2.3 (0.2)	2.6 (0.2)	1 (1)	11 (2)	28 (7)	11 (3)	11 (2)	34 (8)	5 (2)	
4	40 (4)	18 (3)	2.5 (0.2)	2.5 (0.2)	2.8 (0.1)		8 (3)	14 (2)	26 (2)	29 (2)	13 (2)	8 (2)	
5	42 (3)	21 (2)	1.8 (0.1)	1.8 (0.2)	1.8 (0.2)			3 (1)	15 (2)	29 (2)	29 (1)	24 (2)	
6	46 (5)	18 (2)	2.4 (0.2)	2.1 (0.2)	2.4 (0.2)		7 (1)	16 (2)	27 (2)	23 (1)	16 (2)	12 (1)	
7	40 (3)	15 (2)	2.3 (0.2)	2.4 (0.1)	2.7 (0.1)		5 (1)	13 (2)	25 (2)	24 (1)	19 (2)	13 (1)	
8	36 (6)	22 (4)	1.5 (0.2)	1.8 (0.2)	1.8 (0.2)		4 (2)	4 (2)	8 (2)	29 (2)	26 (2)	23 (3)	
9	41 (6)	17 (3)	2.1 (0.2)	2.4 (0.2)	2.3 (0.2)	1 (1)	9 (3)	16 (4)	15 (3)	25 (3)	19 (3)	15 (4)	
10	52 (8)	24 (3)	1.2 (0.1)	1.6 (0.2)	1.2 (0.1)		3 (1)	2 (1)	7 (2)	19 (3)	30 (3)	39 (5)	
11	43 (3)	17 (2)	2.6 (0.2)	2.6 (0.2)	2.8 (0.1)	2 (1)	6 (2)	9 (2)	25 (3)	23 (2)	18 (2)	9 (2)	
12	38 (6)	17 (2)	2.6 (0.2)	2.5 (0.2)	2.9 (0.1)	1 (0)	5 (1)	10 (2)	14 (3)	14 (3)	64 (6)	14 (2)	
13	37 (16)	26 (6)	3.0 (0.0)	3.0 (0.0)	3.0 (0.0)	32 (10)	7 (3)	9 (3)	10 (3)	4 (2)	10 (6)	3 (1)	
14	44 (6)	20 (3)	2.4 (0.2)	1.9 (0.2)	2.9 (0.1)	6 (2)	1 (1)		1 (1)	3 (2)	55 (3)	34 (2)	
15	44 (4)	20 (2)	1.9 (0.2)	1.9 (0.2)	2.9 (0.1)	2 (1)		3 (1)	11 (3)	8 (3)	58 (3)	19 (3)	
16	52 (15)	39 (5)	2.8 (0.1)	2.6 (0.2)	3.0 (0.0)	1 (1)		1 (1)	5 (3)	3 (2)	26 (7)	65 (10)	1 (0)
17[b]	32 (7)	13 (1)	2.7 (0.2)	2.6 (0.3)	2.9 (0.4)	1 (1)	3 (2)	8 (4)	14 (7)	14 (6)	52 (12)	8 (4)	

[a] Abbreviations and units: No=section number, Wi=width (ft), De=depth (in), Vel=velocity (ft/sec), Siz=size, Typ=type, Fre=frequency, Br=bedrock, Bo=boulder, Co=cobble, Pe=pebble, Gr=granular, Sc=coarse sand, Sf=fine sand, Ls=silt, Dt=detritus.
[b] Section is 0.625 miles long.

Appendix 5.—Estimated number of brook trout per acre (± 2 SE) in lower and upper index stations of the East Branch Escanaba, West Branch Escanaba, Middle Branch Ontonagon, and Iron River study sections, July-August 1988-92. The 1990-92 estimates include hatchery-reared and feral brook trout combined.

River, section, area, length, and location[a]	Year	Estimated number per acre ± 2 SE		
		YOY	Sublegal[b]	Legal[c]
East Branch Escanaba				
Lower	1988	178±198	22±14	4±5
2.91 acres	1989	46±42	16±10	3±2
0.65 miles	1990	94±29	8±5	27±32
45-25-18	1991	76±21	32±14	20±18
	1992	159±36	21±11	63±53
Upper	1988	104±81	34±36	13±17
1.04 acres	1989	14±6	56±28	10±7
0.23 miles	1990	91±33	37±36	5±0
45-25-20	1991	225±75	52±55	67±88
	1992	292±75	50±30	8±6
Total	1988	117±81	24±13	6±6
3.95 acres	1989	37±30	27±10[d]	5±2
	1990	94±23	16±10	21±23
	1991	116±25[d]	37±18	33±27
	1992	194±33[d]	29±11	48±39
West Branch Escanaba				
Lower	1988	—[e]	—[e]	—[e]
1.72 acres	1989	33±23	—[f]	—[f]
0.50 miles	1990	56±17	8±5	8±4
44-27-27	1991	6±4	1±0	17±16
	1992	49±11	2±1	16±7
Upper	1988	36±28	3±0	2±2
1.82 acres	1989	55±24	1±0	2±1
0.50 miles	1990	41±16	6±4	8±6
44-27-28	1991	25±5	3±1	19±10
	1992	82±28	3±2	18±12
Total	1988	36±28[g]	3±3[g]	2±2[g]
3.55 acres	1989	44±16	1±0[g]	2±1[g]
	1990	48±12	7±3	8±4
	1991	16±5[d]	2±1[d]	18±9
	1992	66±15	3±1	17±7

Appendix 5.—Continued.

River, section, area, length, and location[a]	Year	Estimated number per acre ± 2 SE		
		YOY	Sublegal[b]	Legal[c]
Middle Branch Ontonagon				
Lower	1988	232±198	66±28	10±3
3.29 acres	1989	358±110	40±13	15±6
0.62 miles	1990	395±66	48±13	18±7
45-39-23	1991	230±103	81±20	33±13
	1992	210±97	36±14	39±26
Upper	1988	38±16	222±40	46±16
1.98 acres	1989	413±117	44±14	28±5
0.62 miles	1990	1,071±144	121±26	33±9
45-39-19	1991	286±70	285±40	121±22
	1992	354±68	101±36	83±25
Total	1988	130±87	124±23[d]	24±6[d]
5.27 acres	1989	379±82	42±10	20±5[d]
	1990	649±65[d]	76±13[d]	24±5
	1991	251±69	158±19[d]	66±11[d]
	1992	264±65	60±16[d]	56±18
Iron				
Lower	1988	367±111	138±26	74±17
2.47 acres	1989	695±128	134±24	38±11
0.50 miles	1990	874±159	276±38	52±20
43-35-16	1991	31±20	308±44	65±14
	1992	1,204±258	37±9	36±16
Upper	1988	695±191	324±54	68±18
2.96 acres	1989	1,540±417	296±52	41±11
0.50 miles	1990	1,052±176	357±47	52±12
43-35-17, 18	1991	336±107	431±55	69±14
	1992	1,957±415	116±26	28±8
Total	1988	602±143[d]	240±30[d]	71±12
5.44 acres	1989	1,156±231[d]	222±30[d]	40±8
	1990	971±119	315±30	52±11
	1991	198±58[d]	375±35[d]	67±10
	1992	1,615±251[d]	80±14[d]	32±8

[a] Township north, range west, and section.
[b] YOY (young-of-the-year) excluded.
[c] Total length ≥7.0 inches.
[d] Number per acre in lower and upper sections are significantly different.
[e] No estimate was made.
[f] Only one brook trout older than YOY was caught.
[g] Upper Section only