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Evaluation of Catch-and-Release Fishing Regulations for Smallmouth Bass on the Huron River, Michigan

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Abstract–Catch-and-release fishing regulations for smallmouth bass *Micropterus dolomieu* were established on 5-mi of Michigan's Huron River. An adjacent 5-mi stretch of river served as a control. Minimum size limit on smallmouth bass during before period (1985-88) and in control section during both before and after period (1990-93) was 12 in. No special terminal tackle restrictions were involved, anglers could use natural or artificial bait. We evaluated catch-and-release fishing regulations with regard to angling pressure, catch, and catch rates; bass population indices of abundance and survival. Angler harvest rates and population dynamics of rock bass *Ambloplites rupestris* were also evaluated.

Anglers released 67% of legal-size bass in our control section, during before period, and 75% during after period. In the treatment section, anglers released 53% of legal-size bass during before period and 95% of bass ≥12 in during after period (catch-and-release).

In the control section, significant differences (P_{α}=0.10) were not detected in angling pressure (mean annual estimated hours) between time periods. Shore anglers catch and catch-per-hour (CPH) of caught-and-released smallmouth bass <12 in and estimated harvest of smallmouth bass ≥12 in were significantly greater during after period.

In the treatment section, mean annual shore angler effort was significantly less during after period than during before period. Shore angler estimated catch and CPH of smallmouth <12 in released and smallmouth ≥12 in released was significantly greater during after period. Wading angler harvest and CPH of smallmouth bass ≥12 in was significantly less during after period. However, wading angler catch and CPH of smallmouth bass ≥12 in released were significantly greater during after period.

Indices of smallmouth bass abundance did not change significantly in control section. In treatment section, indices of smallmouth bass 6.0-11.9 in decreased significantly during after period. However, indices of smallmouth bass ≥12 in increased significantly as did age-4 and -5 bass. Smallmouth bass survival from age 3 to 4 was significantly less in control section during after period. In treatment section, smallmouth bass survival from age 1 to 2 was significantly less. Survival of larger bass, more directly affected by catch-and-release regulations, improved in treatment section during after period. Survival from age 2 to 3, age 3 to 4, and age 4 to 5 was significantly better.

Anglers sought rock bass less often during after period in both sections. Rock bass harvest and CPH by wading anglers in control section were significantly less (P_{α}=0.10) during after period. In treatment section, rock bass harvest and CPH by shore and wading anglers were significantly less during after period. Abundance indices of ≥6-in rock bass and age-5 rock bass

were significantly greater in control section during after period. In treatment section, indices were significantly greater for rock bass 4.0-5.9 in and, ages 4 and 5 increased during after period. Survival from age 1 to 2 and age 4 to 5 declined significantly in control section. Survival from age 2 to 3 was significantly greater in treatment section. Control section rock bass ages 1, 3 and, 4 were significantly smaller during after period. Ages 1 and 2 were significantly smaller during after period in treatment section. Rock bass in treatment section were significantly larger than rock bass in control section during each time period.

Introduction

Information addressing effects of catch-and-release angling are readily found in the literature (Barnhart 1989, Clapp and Clark 1989, Gigliotti 1989, Schneider, et. al. 1989, Milon 1991, Clark and Alexander 1992). However, much of the literature on catch-and-release angling concerns largemouth bass and various species of trout.

Possible catch-and-release effects are frequently evaluated with emphasis placed on hooking mortality, angling catch rates and changes in standing stock. For example, Clapp and Clark (1989) found that mortality of smallmouth bass *Micropterus dolomieu* was significantly greater for caught-and-released fish when live bait was used than for fish which were never caught. Similarly, hooking mortality has been shown to be greater for trout caught with worm-baited hooks than for artificial flies or lures (Shetter and Allison 1955, and Pauley and Thomas 1993).

Angler catch rates for trout, largemouth bass and northern pike (*Esox lucius*) may be increased if anglers release 10% or more of their catch rather than harvest all fish permitted by fishing regulations (Clark 1982). Catch rates may be improved by increasing numbers of fish or by increasing numbers of catchable fish. Since catchability of individual largemouth and smallmouth bass may be quite different (Hackney and Linkous 1978, Burkett et al 1986, Clapp and Clark 1989), allowing the more catchable fish to remain in a population can potentially increase angler catch per hour.

Increases in standing stock of smallmouth bass, particularly spawning size, have occurred when minimum size limits were changed from liberal regulations, such as no minimum size limit, to more restrictive size limits. For example, densities of age 3+ smallmouth bass increased in a Wisconsin lake when the minimum size limit was increased from no minimum size limit to an 8-in minimum size limit (Serns 1984). When regulations on a smallmouth bass fishery were changed to a 12-in minimum size limit from no minimum size limit, a substantial increase in counts of spawning nests occurred in a Virginia river (Surber 1969). A two-fold increase in standing stock (pounds per acre) was attained for smallmouth bass in a Missouri river when regulations were changed from no minimum size limit to catch and release (Fajen 1975).

We selected 10 miles of the Huron River located in Southeastern Michigan to evaluate catch-and-release fishing regulations on a self-sustaining population of smallmouth bass. A 12-in minimum size limit was in effect during the 4-year before period. We also examined angler harvest and population dynamics of rock bass *Ambloplites rupestris*.

Study Area

The Huron River, located in southeastern Michigan, drains 900 square mi and flows 136 mi over 19 dams from its headwaters in Big Lake before emptying into Lake Erie at Pte. Mouillee (Hay-Chemielewski et al 1995). We selected a free flowing 10 mi stretch of river as our study area, located in Michigan's Washtenaw County, approximately 71 mi upstream of Lake Erie (Figure 1). Mean flow at the USGS Ann Arbor gage site, located downstream from our study area, was 530 f^3/s for the period 1985 to 1992. However flows of 18 f^3/s were recorded during summer 1988.

We divided the study area into two approximately equal control and treatment sections. Our control section occupied the upper 5 mi of river originating at Bell Road and extending downstream to Mast Road in the village of Dexter. Flook dam (Portage Lake) is approximately 1 mi above Bell Road and one major tributary, Mill Creek, enters the lower portion of the control section. Flook dam serves as a lake level control structure and introduces epilimnetic water to the river. Our treatment section was from Mast Road downstream to Delhi Road.

Both control and treatment sections have popular park, picnic areas along their banks, and most of the land adjacent to the Huron River within our experimental area is public property owned by the Huron Clinton Metropolitan Authority. Additional description of this area of the Huron River may be found in Bovee et. al. (1994). Cooper (1954) listed smallmouth bass and rock bass as two of the more abundant game fish in this area of the Huron River.

Our study stretch of river was divided into 6 contiguous catch survey subsections, 3 subsections located in the control section and 3 subsections in the treatment section, Figure 1. Anglers may gain access to any of the subsections by canoeing, hiking or wading. Anglers access Bell Road (subsection 1) at the Bell Road bridge, Group Camp and by wading upstream from Hudson-Mills Metropark. Hudson-Mills (subsection 2) is bordered by Hudson-Mills Metropark thus providing relatively easy river access. Maloney's (subsection 3) is more difficult for the general public to access due to private property restrictions. They must wade, hike or canoe downstream from Hudson-Mills Metropark or upstream from Mast Road Bridge. Anglers fishing Mast Road (subsection 4) may wade or hike downstream from Mast Road Bridge or upstream from Dexter-Huron Metropark. Dexter-Huron (subsection 5) is bordered by Dexter-Huron Metropark and this area of the river is easily accessed. Zeeb Road (subsection 6) may be accessed by wading or hiking downstream from Dexter-Huron Metropark, at the Zeeb Road Bridge or at the Upper Delhi Metropark.

Control and treatment sections each contained three fish population sampling stations (Figure 1, Table 1). Population sampling stations were not continuous; these stations were selected to represent pool and riffle habitats in proportion to their occurrence in the overall study area. Bell Road (no. 1) and Dexter-Huron Park (no. 5) contain fast riffles with rock substrate. These 2 sampling stations were each 0.25 mi in length, which is essentially the entire length of the riffle. The remaining 4 stations were each 0.5 mi long. Group Camp (no. 2) and Mast Road (no. 4) each contained deep (4 ft) slow moving water with pools and log-jams as fish cover. Maloney's (no. 3) and Zeeb Road (no. 6) each contained combinations of riffle and sand pools.

Methods

Study periods

Before period was from 1985 through 1988. Minimum size limit on smallmouth bass was 12 in with a 5 fish limit. Beginning in 1989, catch-and-release fishing regulations went into effect for the treatment section. After period was from 1990 through 1993. During after period, catch-and-release fishing regulations remained in effect in the treatment section while the 12 in, 5 fish bag limit remained in effect in the control section. No special bait or terminal tackle restrictions were adopted. The first year of catch and release fishing (1989) is considered a transition period and, therefore, not reflected in this analysis.

Catch Survey

Catch surveys were initiated each year beginning with the first day of bass season, Saturday of Memorial Day weekend, and continuing through Monday of Labor Day weekend. Creel survey methods similar to those described by Ryckman (1981) and, Ryckman and Lockwood (1985) were used throughout the study.

Estimates were stratified, for each month, by 3 angling modes (boat angling, wading angling, shore angling), 2 day types (week days, weekend days including holidays) and 6 river subsections (Figure 1). Both weekend days, plus any holiday, and three randomly selected week days, two if a holiday occurred, were sampled during each week. The only recognized holidays were Memorial Day, Fourth of July and Labor Day. One of 2 shifts was randomly selected each scheduled day to sample daylight angling hours. The early shift was from 6 a.m. to 3 p.m. and the late was from 1 p.m. to 10 p.m. Two counts of anglers were made each sampling day. Only one section (control or treatment) was counted on a sampling day and counts were made at least 3 h apart. Interviews, however, were collected at each of 6 subsections on sampling days. Two creel clerks were used during each season: one canoed the river to count and interview anglers, the second interviewed anglers and transported the canoe and the first creel clerk.

Counts for each month were averaged within and then across sampling days for each angling mode, day type, and subsection. Variance of counts was calculated as for any set of independent observations. Counts were converted to angling hours by multiplying the mean count (for a mode, day-type, subsection) by the available angling hours. The variance (V) of a product of a constant and variable is given by Freese (1962) as

$$V(AH) = (V_c)\ (AAH^2)$$

where,

AH = angling hours
V_c = variance of counts (variable)
AAH = available angling hours (constant)

Available angling hours were determined by multiplying 16 h (daily available angling hours) by days within a time period. Daily available angling hours (16 h) correspond to park hours at each Metropark within the study area and available daylight in time period sampled. Angling occurring outside of the range in shift hours was not sampled.

Angler interviews were also recorded by angling mode, day type, and subsection. Total harvest by species and length of fishing trip were recorded for each angling party. In addition, caught-and-released legal smallmouth bass, ≥12 in, and caught-and-released sublegal smallmouth bass, <12 in, were recorded. Beginning in spring 1993, the statewide minimum size limit of smallmouth bass was increased to 14 in. To compensate, we asked anglers the size of smallmouth bass caught-and-released and, whether or not they would have kept 12-14 in fish had the minimum size limit remained at 12 in. Estimated catch of these "would-have-kept" fish was computed separate from other released smallmouth bass and harvested smallmouth bass and were considered "harvested" when estimating the 1993 harvest.

Catch rates were calculated as

$$CPH = \frac{\sum catch}{\sum hours}$$

where,

CPH = catch per hour

for each species, mode, day type, and subsection (Malvestuto 1989 and Hayne 1991). Variance of catch per hour was calculated for j angling parties according to Cochran (1977) as

$$V(CPH) = \frac{1}{\sqrt{n}X_b}\sqrt{\frac{\sum^j y^2 - 2CPH\sum^j yx + CPH^2\sum^j x^2}{n-1}}$$

where,

n = number of parties interviewed
X_b = mean hours fished per interview
y = total fish caught

CPH = catch per hour
x = total hours fished
j = angling parties interviewed

Seasonal catch and pressure estimates for subsections were combined by treatment group (subsections 1-3 control; subsections 4-6 treatment). Annual treatment group estimates were averaged by time period (before 1985-88; after 1990-93) giving 4 estimates for each angling mode. For example, estimated angling pressure by shore anglers was determined for the control section during before period and after period, and for the treatment section during before period and after period. Averaging of count and catch data in this fashion tends to normalized data which otherwise may have been skew (Snedecor and Cochran 1991).

Abundance sampling

Fish population sampling stations were selected, in each treatment section, in an attempt to pair stations between treatment sections and to represent habitat types in whole sections in proportion to their occurrence. Similar physical characteristics existed between: Bell Road (no. 1) and Dexter-Huron (no. 5); Group Camp (no. 2) and Mast Road (no. 4); and Maloney's (no. 3) and Zeeb Road (no. 6).

Length and area of each sampling station were determined using the deflection-angle traverse method (Orth 1989). Total length of each sampling station was measured to 0.1 foot and marked to ensure comparative sampling of individual sites between years. Cross section measurements were taken every 60 feet, on a given side of the river, and measured to 0.1 foot.

Smallmouth bass and rock bass were collected with a T & J Generator (Model 1736 DCV) 320 V (no load) 1750 W 3-phase AC generator rectified for DC output. Further description of this generator, and equipment similar to ours, is contained in Novotny and Priegel (1971). The generator, control box, and 12 V battery were transported in a small wooden boat following the design of Myers (1951). Anodes were copper water pipe measuring 1 in in diameter, approximately 12 in in total length and were attached to ends of fiberglass hand held probes. Each probe was equipped with a 12 V safety switch which operated a DC relay in the control box. Individual operators were thus able to turn electricity on or off at their probe. Cathode, attached to the bottom of the boat, measured 7.25 in wide by 81.00 in long. Reynolds (1989) reports that an effective electrical field for capturing fish occurs when voltage gradient is between 0.1 and 1.0 V/cm. Measurement of the voltage gradient within the electrical field of one of our anodes showed that we had an effective electrical field 98 in in diameter.

Electrofishing crew consisted of 5 members: two crew members shocked and collected fish with hand held scap nets; one pulled the boat, operated the generator and control box, and served as safety supervisor for the crew; one, receiving fish from the two members actively shocking fish, measured, scale sampled and fin clipped fish; the fifth member served as data recorder.

Sampling was done each fall between September 15 and October 31, a time period when canoe traffic on the river was virtually non-existent and water temperatures were generally between 10°C and 21°C. Only smallmouth bass and rock bass were captured. Fish were marked by a top caudal fin clip on the marking run and a bottom caudal fin clip on the recapture run. Scale sampled fish were measured (total length) to the nearest 0.1 in, all others were measured to inch group. Since all fish were measured, scale sampled - when appropriate, fin clipped and immediately returned to the river after capture, no fish were held in tubs or similar containers.

From 1985 to 1988 marking runs at all 6 sampling stations were completed prior to recapture runs. However, recapture rates for both species were extremely low (smallmouth bass were 14.7% and rock bass were 8.3%). To improve recapture rates, recapture runs were made the day after marking runs at each station from 1990 to 1993. Recapture rates improved only modestly (smallmouth bass were 21.0% and rock bass were 21.4%). These recapture rates were well below those reported by Clark and Alexander (1992) for trout species, 30% to 60%. We observed very little mortality of first-run fish, but we suspect movement of larger fish and the difficulty of seeing smaller fish were the primary reasons for low recapture rates. Because population sampling stations were open ended, that is blocking nets were not used, fish could move in and out of our stations. Also, larger bass were mobile and elusive within stations. Fish <3 in long were difficult to see and capture.

Subsequently, numbers of smallmouth bass and rock bass collected on marking runs were used as an index of population size (Lyons and Kanehl 1993). This is essentially measuring abundance as catch per unit of effort (CPUE), where the effort is one pass by the electrofishing crew. Criteria for use of CPUE sampling, as suggested by Lyons and Kanehl (1993), coincided with our sampling methods: crew composition was similar each year (one or more of the authors was always present in the crew while electrofishing), techniques and equipment used to capture fish were consistent; and individual site size, location and relative time of sampling was unchanged.

Annual abundance (CPUE) of smallmouth bass and rock bass, by age or size group, was summed over population sampling stations within each treatment section; CPUE per acre calculated; and then averaged by time period (before or after).

Age and Growth

Scale samples from up to 30 fish per inch group of each species were collected annually from each population sampling station. Individual fish were measured to 0.1 in. Scale samples from individual fish were removed from the area located beneath the spiny anterior portion of the dorsal fin, below the lateral line (Laarman et al 1981). Impressions of scales were made on acetate slides and examined on a Realist model 3352 microform reader. Annuli were identified according to criteria given by Laarman et al (1981).

Mean length at age for both species was calculated using the methods described by Clark and Alexander (1992) except that CPUE was used in place of estimated population. Yearly lengths at age from individual population sampling stations were combined and averaged by treatment section and time period.

Survival

We assumed that CPUE was indicative of populations of smallmouth bass and rock bass and, that differences in relative numbers of a year class from one year to the next were directly related to annual survival of that year class. Smallmouth bass survival was calculated, by year and population sampling station for age groups 0-5. Rock bass survival of was done similarly, except that age-0 fish were excluded. Mean survival rates, by age group, were averaged between population sampling stations within each treatment section and time period.

Smallmouth bass redd counts

During spring 1992 the entire 10-mi research section of the Huron River was examined, by canoe, for smallmouth bass spawning activity. Each side of the river was surveyed by a canoe containing 2 individuals. One person in the stern propelled and controlled the canoe; the second individual in the bow counted spawning redds. Two canoes were utilized during each run, paralleling each other for full cover of both shorelines, and counts were made 7 times during May.

Water temperatures

A Ryan model J chart-recording thermograph was placed in the Huron River immediately below the Zeeb Road Bridge (upper end of Zeeb Road population sampling station 6) in May 1987. Temperatures were read from the chart at 2 h intervals and recorded to the nearest 0.1°C each May from 1987 to 1989. In May of 1991 this unit was replaced with a Ryan model RTM-2 (electronic digital recording) and, in that same year, a second RTM-2 was installed at the Group Camp site (population sampling station 2). A third RTM-2 was installed below Mast Road Bridge (population sampling station 4) in May 1992. All three RTM-2 thermographs recorded temperatures at 1-h intervals to the nearest 0.1°C. Comparable temperatures were obtained for May 22 - July 3 and July 16 - September 11 for Zeeb Road and Group Camp in 1991. Temperature data, for these same summer periods, were collected for all three sites in 1992 and 1993.

Statistical significance

Analysis of variance was used to calculate variances for growth, abundance indices and survival of each species. We calculated 90% confidence intervals and means were considered statistically significant when confidence intervals did not overlap.

Results and Discussion

Catch Survey

Compliance with fishing regulations.— Crucial to any evaluation of fishing regulations is compliance by anglers. Anglers released 67% of the legal-size smallmouth bass they caught in the control section during before period. A somewhat greater proportion, 75%, were released in after period. Anglers in the treatment section released a smaller proportion of their catch during before period, 53%, than during after period, 95%.

During the 1992 catch survey season we surveyed anglers to determine their knowledge of fishing regulations in both sections (control and treatment) of the Huron River. Anglers were interviewed at various sites within our 10 mi research section and their response to our survey question, "Are you allowed to keep smallmouth bass or largemouth bass from this area of the Huron River?", indicated that they did understand current bass fishing regulations, Table 2. A majority of anglers in the control section, 68%±9%, knew they were allowed to harvest bass. Likewise, a majority of anglers in the treatment section, 88%±8%, knew they were required to release all bass. Our results follow those of Kokel (1991) and Paragamian (1984). Kokel (1991) noted that 85% of interviewed anglers complied with a 11-14 in slotted size limit for black bass (*Micropterus spp.*) in the James River, Virginia. Also, anglers that were aware of the slotted size limit were much more likely to abide by it. Paragamian (1984) reported that 86% of anglers that captured sublegal smallmouth bass from Iowa streams complied with the 12 in minimum size limit.

Fishing Effort.— For control section from Bell to Mast Road, estimated mean annual angling effort (hours) was not significantly different between treatment periods by any of 3 angling modes, Table 3.

For treatment section from Mast-to-Delhi Road, estimated mean annual angling effort of shore anglers was greater during before period, 1,658±217, than during after period, 1,234±204, Table 4. Angling pressure of boat or wading anglers was not different between time periods in the treatment section.

Estimated effort by boat anglers and wading anglers was not significantly different between sections for any of the treatment periods. However, estimated effort by shore anglers was significantly lower in the treatment section during after period than in the control section during either time periods (Tables 3 and 4).

Catch of smallmouth bass.— Estimated mean annual catch and CPH of smallmouth bass <12 in by shore anglers was significantly greater during after period in the Bell-to-Mast section (Table 3). Catch of smallmouth bass <12 in was 345±114 during before period and 778±213 during after period; and CPH was 0.172±0.060 and 0.359±0.107 during respective periods. Shore anglers also harvested more smallmouth bass ≥12 in, 31±20, during after period than during before period, 3±3. Wading anglers catch and CPH of smallmouth bass ≥12 in released was greater during after time period. Wading anglers caught 344±128 during after period and 137±51 during before period. Their catch rate during after period was 0.136±0.053 and 0.056±0.022 during before period.

Estimated catch and CPH of smallmouth bass <12 in released by shore anglers was significantly greater during after period in the Mast-to-Delhi section (Table 4). Shore anglers caught and released 769±213 smallmouth bass <12 in during before period and 1,308±423 during after period; and CPH was 0.464±0.142 and 1.060±0.384 during respective periods. Likewise, estimated catch and CPH of bass ≥12 in released by shore anglers was significantly greater during after period. Catch was 48±29 during before period and 190±77 during after period; CPH was 0.029±0.018 and 0.154±0.081 during respective periods. CPH for smallmouth bass ≥12 in released by shore anglers in treatment section, during after period was also significantly greater than either time period in control section. Harvest and CPH of smallmouth bass ≥12 in by wading anglers was significantly less during after period. Wading anglers caught 74±35 during before period and 8±11 during after period; and CPH was 0.032±0.016 and 0.004±0.005 during respective periods. However, catch and CPH of smallmouth bass ≥12 in released by wading anglers was significantly greater during after period. These anglers caught 134±50 during before period and 662±250 during after period; CPH was 0.058±0.023 and 0.289±0.115 during respective periods.

Catch of rock bass.— Harvest and CPH of rock bass, by wading anglers, were significantly less during after period in the Bell-to-Mast section (Table 5). Harvest in before period was 358±163, and 86±67 in after period. CPH in the respective periods was 0.146±0.069 and 0.034±0.027.

Estimated harvest of rock bass by shore anglers was significantly less during after period, 12±15, than during before period, 80±34, in the Mast-to-Delhi section (Table 6). CPH was also significantly less between these respective periods at 0.010±0.012 and 0.048±0.022. Harvest and CPH by wading anglers were significantly less during after period, 14±13 and 0.006±0.006, than during before period, 174±84 and 0.075±0.037.

Species targeted.— Targeted effort by boat anglers for various species remained statistically equivalent between treatment periods in the Bell-to-Mast section (Table 7). Approximately 50% of targeted effort was for smallmouth bass. No shore anglers reported targeting for rock bass during after period, while 5.57%±1.13% of anglers surveyed during before period targeted for rock bass. Significantly more shore anglers indicated they were targeting "anything" during after period, 66.67%±2.81%, than during before period, 59.78%±2.42%. Significantly more wading anglers targeted smallmouth bass during after period, 76.09%±3.12%, than during before period, 55.68%±2.82%. A significantly smaller proportion of wading anglers reported fishing for "other species" during after period, 4.54%±1.52%, than during before period, 8.12%±1.55%. No wading anglers reported targeting rock bass during after period, while 2.63%±0.91% of anglers surveyed during before period targeted rock bass. Percentage of wading anglers targeting "anything" was 33.57%±2.69% during before period and 19.37%±2.89% during after period.

Similar to the control section, targeted effort by boat anglers was consistent between time periods and approximately 50% of boat anglers targeted smallmouth bass in the Mast-to-Delhi section (Table 7). Significantly more shore anglers indicated they were targeting smallmouth bass during after period, 50.53%±4.22%, than during before period, 33.70%±2.90%. No shore anglers surveyed during after period targeted rock bass, while 1.95%±0.85% of surveyed anglers targeted rock bass during before period. Likewise, significantly fewer shore anglers targeted "other species" during after period, 2.10%±1.21%, than during before period, 11.14%±1.93%. Percentage of wading anglers targeting smallmouth bass was 61.42%±3.15% during before period and 83.33%±2.61% during after period. No surveyed wading anglers targeted rock bass during after period, while 2.31%±0.97% of anglers targeted rock bass during before period. Percentage of wading anglers targeting "other species" was 9.57%±1.90% during before period and 4.17%±1.40% during after period. Percentage of wading anglers targeting "anything" declined from 26.70±%2.86% during before period to 12.50%±2.32% during after period.

Bait used

Live bait usage by anglers declined while artificial bait usage increased from before to after periods in the Bell-to-Mast section (Table 8). Percentage of anglers using worms declined significantly from before period, 60.97%±2.02%, to after period, 48.73%±2.57%. Percentage of anglers using crayfish also declined from 6.94%±1.06%, during before period, to 2.63%±0.82%, during after period. Percentage of anglers using artificial bait increased from 18.66%±1.62%, during before period, to 27.19%±2.28%, during after period, and percentage of anglers fly fishing also increased from 5.73%±0.97%, during before period, to 12.48%±1.70%, during after period.

In the Mast-to-Delhi section, similar to the Bell-to-Mast section, live bait usage by anglers declined while artificial bait usage increased from before to after periods (Table 8). Percentage of anglers using worms decline significantly from 45.48%±2.55% during before period to 38.34%±2.94% during after period. Percentage of anglers using crayfish as bait declined significantly from 11.76%±1.65% during before period, to 4.86%±1.30% during after period. Also, percentage of anglers using hellgrammites as bait declined significantly from 8.07%±1.39% during before period, to 3.91%±1.17% during after period. A significantly greater percentage of anglers used artificial bait during after period, 32.25%±2.83% than during before period, 25.75%±2.24%. Percentage of anglers fly fishing also increased significantly from 5.83%±1.20% during before period, to 17.81%±2.32% during after period.

Increased use of artificial bait and targeting of smallmouth bass during after period may have enhanced the fishery and increased catch rates. Numerous studies have shown that survival of fish captured with artificial lures is greater than those captured with live bait (Shetter and Allison 1955; Clapp and Clark 1989; and Pauley and Thomas 1993). Plumb et al (1988) reported that survival of largemouth bass, retained in livewells, released within 30 min of capture was 90.8%. Since the Huron River smallmouth bass fishery is composed primarily of shore and wading anglers, any fish returned to the river would have been done so almost immediately. Use of artificial lures plus immediate release would both contribute to survival.

Angler residence.— In the Bell-to-Mast section, Wayne County anglers represented 61.15%±1.79% of anglers interviewed during before period and 50.65%±2.22% during after period (Table 9). Washtenaw County anglers represented 25.62%±1.59% during before period and 31.33%±2.06% during after period. Anglers traveling from other counties or states represented 13.23%±1.24% during before period and 18.02%±1.70% during after period.

In the Mast-to-Delhi section, Wayne County anglers represented 46.16%±2.17% of anglers interviewed during before period and 34.35%±2.45% during after period (Table 9). Washtenaw County anglers represented 45.25%±2.17% during before period and 51.08%±2.58% during after period. Anglers traveling from other counties or states represented 8.59%±1.22% during before period and 14.57%±1.82% during after period.

The greater proportion of local anglers (Washtenaw County) interviewed during after period, in both control and treatment sections, was offset by a decline in number of urban Wayne County anglers traveling to these sections of the Huron River. It is unclear whether catch-and-release fishing regulations in the treatment section influenced this trend. Anglers living in Wayne County must travel more than 25 mi and may have simply found other areas to fish. Fajen (1981) reported that during 6 years of catch-and-release fishing for smallmouth bass on Courtois Creek, 4% of anglers interviewed were local (Crawford County, Missouri). After a 12 in minimum size limit was initiated, 19% of anglers were local. However, on Huzzah Creek under a continuous 12 in minimum size limit, percentage of local anglers increased from 11% to 23%. Similar to our study, Fajen (1981) noted a decline in proportion of anglers traveling the 40-60 miles from St. Louis, Missouri. Percentage of St. Louis anglers declined from 83% to 25% at Courtois Creek and 73% to 43% in Huzzah Creek.

Fish Population Survey

Abundance of smallmouth bass.— In Bell-to-Mast section, no significant differences in abundance indices (as measured by CPUE per acre) of smallmouth bass were detected for 3 size groups of fish between treatment periods (Table 10). Indices of smallmouth bass, by age group, did not change significantly between treatment periods, Table 11.

In Mast-to-Delhi section, indices of smallmouth bass 6.0-11.9 in decreased significantly (Table 10). Mean number of smallmouth bass captured per acre during before period was 9.35±1.14 and 4.86±1.14 during after period. However, we were unable to detect significant changes in abundance for corresponding individual age groups (Table 11). Smallmouth bass indices for fish ≥12 in increased significantly, from 0.62±0.24 during before period to 1.12±0.24 during after period, as did numbers of corresponding age-4 and -5 fish. Age-4 fish increased from 0.48±0.20 to 1.12±0.20, and age-5 from 0.24±0.12 to 0.54±0.12. Fajen (1981) reported results similar to ours in Courtois Creek, Missouri. Following size regulation changes going from no minimum size limit to catch-and-release angling, catch per hour of smallmouth bass increased by a factor of 1.9 and population densities, of all size smallmouth bass, by a factor of 1.3 with the greatest increase in numbers occurring for smallmouth bass 5.0 - 12.9 in.

Burkett et al (1986) and Clapp and Clark (1989) have shown that angling vulnerability differs between individual largemouth and smallmouth bass. Some individuals may be captured numerous times while others are never captured. Individuals with high vulnerability are captured, based on size, as they first enter a fishery, while individuals with low vulnerability may never be captured by anglers yet remain present in population density estimates. Clapp and Clark (1989) reported that 18% of smallmouth bass in their study accounted for 54% of all hooking events and 36% of their bass were never hooked. One fish in their study was captured 9 times. Angling success may be improved more than expected based solely on changes in fish abundance by allowing these more vulnerable fish to remain in a fishery.

Abundance of-rock bass.— In Bell-to-Mast section, abundance of rock bass ≥6.0 in increased from 10.34±2.44 during before period to 17.26±2.44 during after period (Table 12). Abundance of age-3 fish increased from 5.46±1.46 to 10.17±1.46 during respective periods, Table 13.

In Mast-to-Delhi section, abundance of rock bass 4.0-5.9 in increased significantly from 9.52±2.40 during before period, to 15.46±2.40 during after period (Table 12). Increases in abundance indices were also detected for age-4 and -5 rock bass. Age-4 rock bass increased from 1.59±0.52 to 2.81±0.52, and age-5 rock bass increased from 0.32±0.14 to 0.93±0.14.

Rock bass were sought by Huron River anglers less frequently during after period in both treatment sections. This decline in popularity corresponded to lower harvest and harvest rates and increase in abundance. Incidental catch-and-release of rock bass was not recorded. However, the observed tendency of anglers to release a greater proportion of captured smallmouth bass during after period in both treatment sections may have also occurred for rock bass.

Growth of smallmouth bass.— In Bell-to-Mast section, mean length decreased significantly for smallmouth bass age 0 to 2 (Table 14). During before and after periods age-0 bass were 4.26±0.01 in and 4.08±0.01 in; age-1 bass were 7.73±0.05 in and 7.58±0.05 in; and age-2 were 10.32±0.10 in and 10.09±0.10 in. However, age-3 and -4 smallmouth were significantly larger. During before and after periods age-3 bass were 11.41±0.12 in and 12.18±0.12 in; and age-4 bass were 13.22±0.23 in and 14.03±0.23 in.

In Mast-to-Delhi section, similar to the control section, age-0 to -2 smallmouth bass in the treatment section were significantly smaller during after period (Table 14). During before and after periods age-0 bass were 3.72±0.01 in and 3.62±0.01 in; age-1 bass were 6.83±0.05 in and 6.00±0.05 in; and age-2 bass were 9.54±0.10 in and 8.54±0.10 in. However, no significant changes in mean lengths of older bass were detected.

Growth of rock bass.— In Bell-to-Mast section, mean length at age was significantly less for age-1, -3, and -4 rock bass (Table 15). During before and after periods age-1 rock bass were 3.74±0.01 in and 3.63±0.01 in; age-3 rock bass were 6.70±0.03 in and 6.53±0.03 in; and age-4 rock bass were 7.39±0.05 in and 7.18±0.05 in.

In Mast-to-Delhi section, mean length at age was significantly less for age 1 and 2 (Table 15). During before and after periods age-1 rock bass were 3.94±0.01 in and 3.67±0.01 in; and age-2 rock bass were 5.75±0.02 in and 5.52±0.02 in.

Survival of smallmouth bass.— In Bell-to-Mast section, survival from fall age 3 to fall age 4 was significantly less during after period, 0.2400±0.0474, compared to before period, 0.3910±0.0474 (Table 16). Survival was not significantly different for any other age groups.

In Mast-to-Delhi section, survival from fall age 1 to fall age 2 was significantly less during after period, 0.1992±0.0474, compared to before period, 0.4827±0.0474 (Table 16). Survival was significantly better for older, larger smallmouth bass. During before and after periods age 2 to 3 survival was 0.4777±0.0474 and 0.6500±0.0474; age 3 to 4 survival was 0.4464±0.0474 and 0.5604±0.0474; and age 4 to 5 survival was 0.0417±0.0474 and 0.1686±0.0474.

On average, smallmouth bass in our treatment section become vulnerable to a 12-in size limit during their fourth year of life. Increase in survival during this period corresponds to a greater proportion of captured bass being released by anglers. However, only the significant increase in survival in the treatment section corresponded with a significant increase in abundance indices of age-4 and -5 smallmouth bass.

Survival of rock bass.— In Bell-to-Mast section, survival from age 1 to 2 was significantly less during after period, 0.6790±0.0357, than during before period, 0.7545±0.0357 (Table 17). Also, survival from age 4 to 5 was significantly less during after period, 0.1648±0.0357, than during before period, 0.2986±0.0357.

In Mast-to-Delhi section, survival from age 2 to 3 was significantly greater during after period, 0.5270±0.0357, than during before period, 0.4360±0.0357 (Table 17). All other survival rates were not significantly different.

Smallmouth bass redd counts

Spawning activity was minimal through May 8, 1992 (Table 18). Peak nest building occurred on, or slightly before, May 11 and spawning activity continued through May 21. Spawning activity declined after May 15. Level and timing of spawning activity were similar in both control and treatment sections of the Huron River. At Zeeb Road, mean daily water temperatures first exceeded 15.0°C from the first to the third week in May (Table 19). MacLean et al (1981) reports that smallmouth bass begin spawning as water temperatures move above 15.0°C. Their findings correspond with our on-site observations of spawning activity in May 1992. Because the opening of bass fishing season begins the last Saturday in May, some male smallmouth bass would still be actively involved in nest guarding, and probably be more vulnerable to angling. Year class strength may be influenced, due to predation on unguarded nests, by fishing for smallmouth bass while they are on nests (Latta 1963). Kieffer et al (1995) reports that smallmouth bass played to exhaustion (>2 min) took 4 times longer to return to the nest than those played briefly (<20 s), thus leaving the nest unguarded for a longer period of time. Catch-and-release regulations protected spawning bass in our treatment section from harvest, although predation on unguarded nests may have occurred while adults were being caught and released.

Water temperatures

During summer months air temperatures are often greater than river water temperatures due to groundwater input (Benson 1953; Hendrickson et al. 1973) Macan (1958) reported July and August air temperatures 2-3°C above that of Beck River, England. Southeastern Michigan experienced cooler summer air temperatures during after period. Air temperature data for the city of Ann Arbor, located on the Huron River downstream of our study area, (Climatological Data, Michigan; National Oceanic and Atmospheric Administration) revealed that more degree days >18.3°C were accrued annually during before period than during after period. A total of 1529 degree days were accrued during before period and 1208 degree days during after period.

Water temperatures decreased downstream within our 10-mi study area (Table 20). Of the three temperature monitoring stations, Group Camp consistently accrued more degree days over 14.9°C and 24.9°C than did Mast Road or Zeeb Road. Likewise, Mast Road accrued more degree days than did Zeeb Road. No degree days above 29.0°C were observed at our three monitoring stations. Water temperatures in the Huron River are mostly below the optimum temperature growth range of 25-29.0°C given by Shuter et al (1980). Corresponding to cooler down stream water temperatures, smallmouth bass for each age group sampled were significantly smaller in treatment section. Rock bass, however, were significantly larger in treatment section. Cherry et al (1977) found that preferred temperatures of rock bass and smallmouth bass were not significantly different, but rock bass generally preferred cooler water.

When water temperatures fall below 15.0°C, once spawning has commenced, year class strength may be negatively influenced (Rawson 1945, Latta 1963). Once water temperatures rise above 15.0°C in the Huron River, they appear to remain relatively stable throughout the spawning period. During 6 years of temperature monitoring we did not observe a single occurrence of water temperatures falling below 15.0°C at a time when abandoning nests would have been crucial to spawning success.

A significant positive linear relationship existed between mean length of fall age-0 smallmouth bass and degree days >14.9°C (Figure 2). No relationship was detected between mean length of fall age-1 rock bass and degree days >14.9°C (Figure 3).

Management Implications

We concluded that catch-and-release fishing for smallmouth bass in the Mast-to-Delhi stretch of the Huron River was popular with anglers and increased abundance and survival of bass ≥12 in. Anglers understood fishing regulations pertaining to our study area and released 95% of the smallmouth bass ≥12 in caught. Anglers catch and catch rates of these larger bass increased, as did population indices and estimated survival rates.

Results of our study of smallmouth bass and rock bass from 1985-93 follow those of Bovee et al (1994) from 1983-89. Bovee et al (1994) concluded that for smallmouth bass and rock bass: adult populations are related to factors affecting recruitment; year class strength is related to young-of-year habitat (via river flow); strong year classes and temperature both influence growth during the first year of life.

Our study further corroborates the single pass marking run method for monitoring population densities of smallmouth bass given by Lyons and Kanehl (1993). Evaluation of adult populations of smallmouth bass (≥age 4) using mark-and-recapture methods was not possible due to scarcity of marked fish in our recapture runs. Proportionately, we recaptured fewer fish as they became larger, thus our initially marked fish represented a smaller proportion of the estimated population. If larger fish were less likely to be recaptured, as we suspect, over estimation of abundance would occur. Certainly, accurate population estimates are more useful than population indices. However, erroneous population estimates lead to incorrect results.

Use of the single-pass, population method also appears appropriate for our evaluation of rock bass. Making recapture runs 1.5 weeks following marking runs greatly influenced population estimates of rock bass and smallmouth bass. We suspect fish movement occurred during this time period as on a number of occasions clipped fish were collected, none should have been present, when adjacent upstream stations had been previously sampled. We do not recommend making recapture runs more than 2 days following marking in an open system.

Age-0 rock bass were not sampled efficiently. The consistent discrepancies between cohort numbers of age 0 and 1 reported by Bovee et al (1994) were also present with the population index method of Lyons and Kanehl (1993). Thus, any determinations we would have made in regards to numbers or size of age-0 rock bass would surely have been in err.

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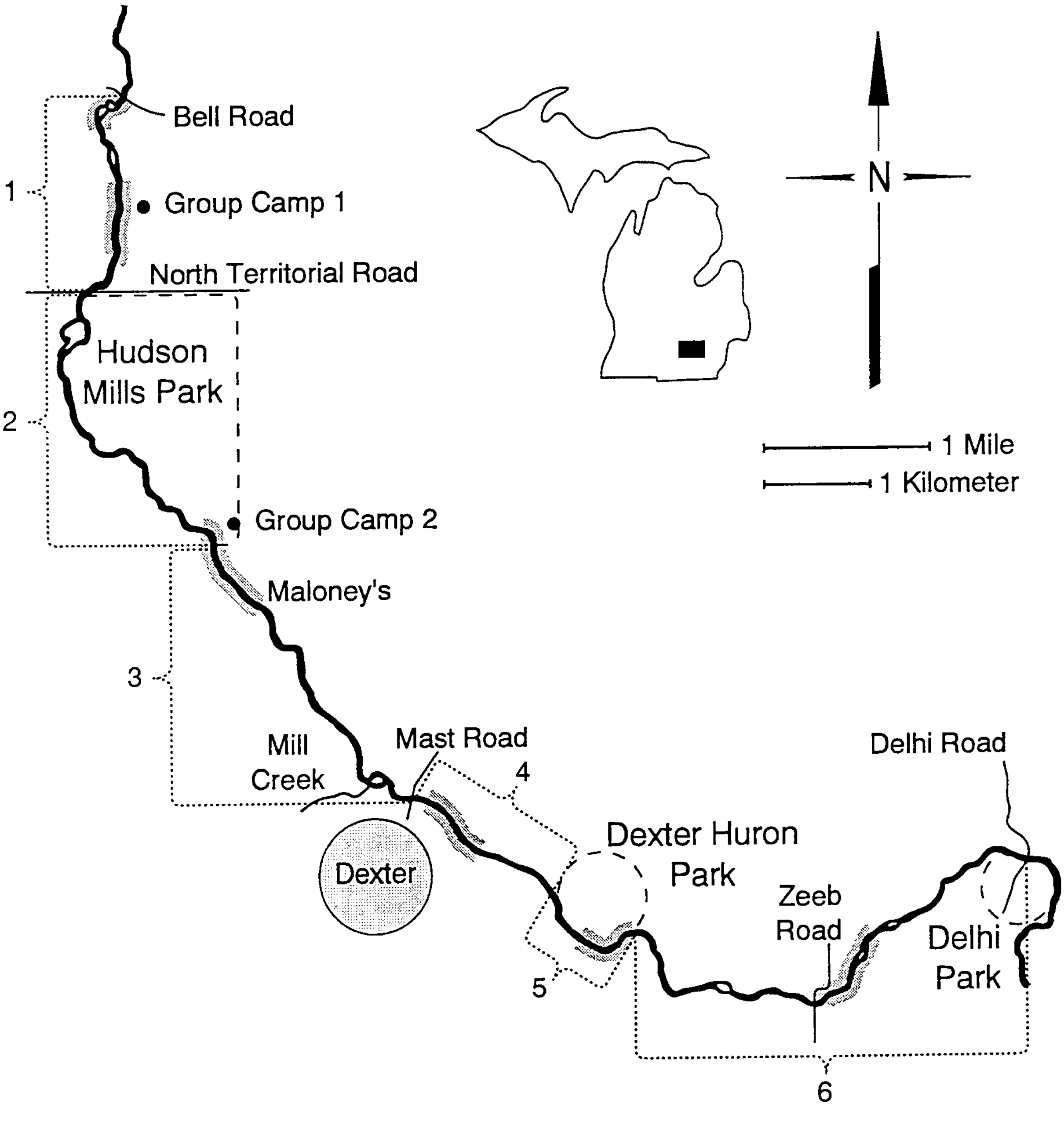

Figure 1.—Huron River study sections. Upper 5 miles, Bell Road to Mast Road, served as the control section and the lower 5 miles, Mast Road to Delhi Road, served as the treatment section. Numbered subsections were identified to stratify catch survey. Fish population sampling areas are wide-shaded areas of river.

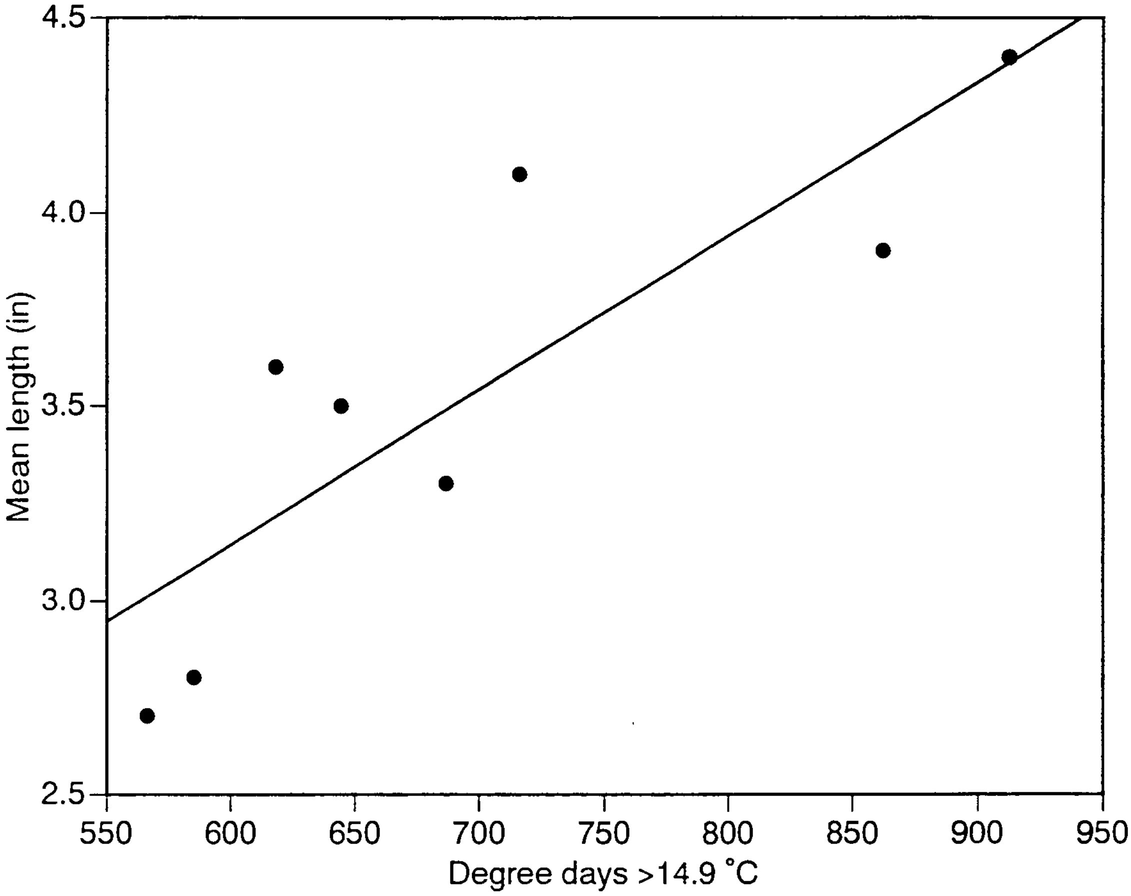

Figure 2.—Relationship of mean length (in) of fall age 0 smallmouth bass and water degree days >14.9 °C at Zeeb Road station and Group Camp for 1991-93; and Mast Road 1992-93 [r=0.84, y=0.76+0.0040(x)].

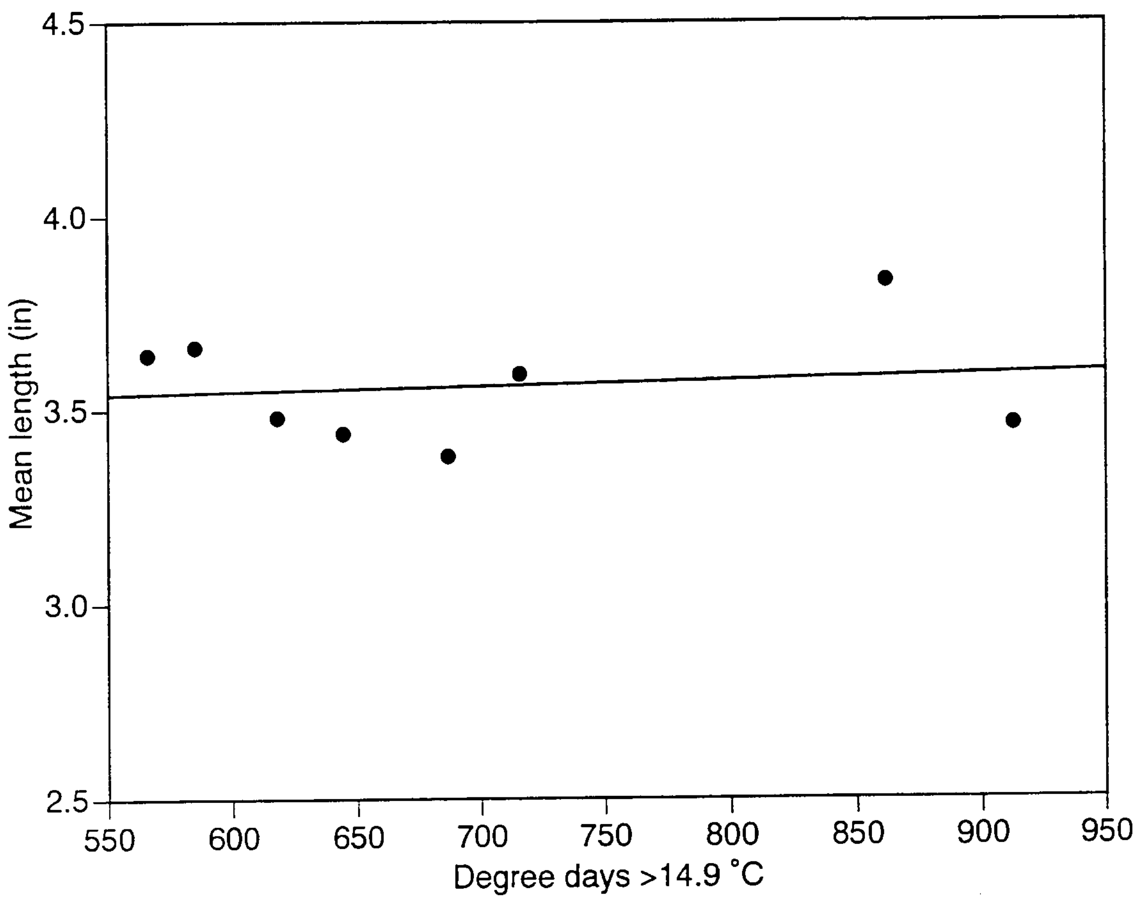

Figure 3.—Relationship of mean length (in) of fall age I rock bass and water degree days >14.9 °C at Zeeb Road station and Group Camp for 1991-93; and Mast Road 1992-93 [r=0.12, y=3.458+0.0001(x)].

Table 1. Fish population sampling stations on the Huron River.

Station No./name	Description	Treatment group/size in acres
1. Bell Road	From Bell Road downstream 1/4 mile (T.1S, R.4E, Sec. 12)	Control 2.78 a
2. Group Camp	Huron Clinton Metropolitan Authority Group Camp Number 1. From 1/4 mile upstream of canoe landing to 1/4 mile below landing. (T.1S, R.4E, Sec. 13)	Control 10.34 a
3. Maloney's	From canoe landing site, Group Camp Number 2, Hudson Mills Metropark, downstream 1/2 mile. (T.1S, R.4E, Sec. 25)	Control 8.61 a
4. Mast Road	From approximately 100 yards below Mast Road (Dexter) downstream 1/2 mile. (T.1S, R.5E, Sec. 32)	Treatment 7.22 a
5. Dexter-Huron Park	From lower end of Dexter-Huron Metropark upstream 1/4 mile. (T.2S, R.5E, Sec. 5)	Treatment 3.03 a
6. Zeeb Road	From approximately 100 yards below Zeeb Road downstream 1/2 mile. (T.2s, R.5E, Sec. 9)	Treatment 8.95 a

Table 2.–Anglers response to the 1992 survey question, "Are you allowed to keep smallmouth bass or largemouth bass from this area of the Huron River?" Responses are given with 90% confidence limits in parenthesis.

Response	Bell to Mast Rd	Mast to Delhi Rd
Yes	68% (9%)	2% (4%)
No	13% (7%)	88% (8%)
Unsure	19% (8%)	10% (8%)
Sample size	75	48

Table 3.–Mean fishing effort, catch, and catch per hour of smallmouth bass in control section (Bell to Mast Road). Confidence bounds for the 90% level of significance are in parentheses. The "Sig" rows indicate if mode estimates were significantly different between time periods, where (+) indicates an increase and (0) indicates no significant difference.

			Number			CPH		
			Released		Harvested	Released		Harvested
Time Period (Regulation)	Mode of Angling	Effort (Hours)	<12 in	≥12 in	≥12 in	<12 in	≥12 in	≥12 in
1985-88 (12-in minimum)	Boat	359 (±144)	144 (±77)	12 (±26)	4 (±3)	0.318 (±0.250)	0.033 (±0.075)	0.011 (±0.010)
	Shore	2,012 (±250)	345 (±114)	18 (±9)	3 (±3)	0.172 (±0.060)	0.009 (±0.005)	0.002 (±0.002)
	Wading	2,445 (±296)	1,984 (±473)	137 (±51)	58 (±24)	0.812 (±0.217)	0.056 (±0.022)	0.024 (±0.010)
1990-93 (12-in minimum)	Boat	617 (±201)	442 (±186)	52 (±33)	12 (±20)	0.716 (±0.383)	0.084 (±0.060)	0.019 (±0.033)
	Sig	(0)	(+)	(0)	(0)	(0)	(0)	(0
	Shore	2,168 (±251)	778 (±213)	48 (±22)	31 (±20)	0.359 (±0.107)	0.022 (±0.010)	0.014 (±0.010)
	Sig	(0)	(+)	(0)	(+)	(+)	(0)	(0)
	Wading	2,524 (±291)	3,089 (±714)	344 (±128)	118 (±67)	1.224 (±0.316)	0.136 (±0.053)	0.047 (±0.027)
	Sig	(0)	(0)	(+)	(0)	(0)	(+)	(0)

Table 4.–Mean fishing effort, catch, and catch per hour of smallmouth bass in treatment section (Mast to Delhi Road). Confidence bounds for the 90% level of significance are in parentheses. The "Sig" rows indicate if mode estimates were significantly different between time periods, where (+) indicates an increase, (-) indicates a decrease, and (0) indicates no significant difference.

			Number			CPH		
			Released		Harvested	Released		Harvested
Time Period (Regulation)	Mode of Angling	Effort (Hours)	<12 in	≥12 in	≥12 in	<12 in	≥12 in	≥12 in
1985-88 (12-in minimum)	Boat	473 (±138)	110 (±70)	7 (±8)	5 (±6)	0.233 (±0.164)	0.015 (±0.018)	0.011 (±0.013)
	Shore	1,658 (±217)	769 (±213)	48 (±29)	54 (±20)	0.464 (±0.142)	0.029 (±0.018)	0.033 (±0.013)
	Wading	2,322 (±297)	2,561 (±495)	134 (±50)	74 (±35)	1.103 (±0.256)	0.058 (±0.023)	0.032 (±0.016)
1990-93 (catch-and-release)	Boat	360 (±124)	118 (±86)	16 (±16)	0 (±0)	0.328 (±0.264)	0.044 (±0.046)	0.000 (±0.000)
	Sig	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	Shore	1,234 (±204)	1,308 (±423)	190 (±77)	40 (±50)	1.060 (±0.384)	0.154 (±0.081)	0.032 (±0.040)
	Sig	(-)	(0)	(+)	(0)	(+)	(+)	(0)
	Wading	2,294 (±289)	2,650 (±596)	662 (±250)	8 (±11)	1.155 (±0.297)	0.289 (±0.115)	0.004 (±0.005)
	Sig	(0)	(0)	(+)	(-)	(0)	(+)	(-)

Table 5.–Mean fishing effort, catch, and catch per hour of rock bass in control section (Bell to Mast Road). Confidence bounds for the 90% level of significance are in parentheses. The "Sig" rows indicate if mode estimates were significantly different between time periods, where (-) indicates a decrease and (0) indicates no significant difference.

Time Period	Mode of Angling	Effort (Hours)	Harvested	Catch per hour
1985-88	Boat	359 (±144)	3 (±5)	0.008 (±0.014)
	Shore	2,012 (±250)	302 (±86)	0.150 (±0.047)
	Wading	2,445 (±296)	358 (±163)	0.146 (±0.069)
1990-93	Boat	617 (±201)	2 (±3)	0.003 (±0.005)
	Sig	(0)	(0)	(0)
	Shore	2,168 (±251)	163 (±105)	0.075 (±0.050)
	Sig	(0)	(0)	(0)
	Wading	2,524 (±291)	86 (±67)	0.034 (±0.027)
	Sig	(0)	(-)	(-)

Table 6.–Mean fishing effort, catch, and catch per hour of rock bass in treatment section (Mast to Delhi Road). Confidence bounds for the 90% level of significance are in parentheses. The "Sig" rows indicate if mode estimates were significantly different between time periods, where (-) indicates a decrease and (0) indicates no significant difference.

Time Period	Mode of Angling	Effort (Hours)	Harvested	Catch per hour
1985-88	Boat	473	0	0.000
		(±138)	(±0)	(±0.000)
	Shore	1,658	80	0.048
		(±217)	(±34)	(±0.022)
	Wading	2,322	174	0.075
		(±297)	(±84)	(±0.037)
1990-93	Boat	360	0	0.000
		(±124)	(±0)	(±0.000)
	Sig	(0)	(0)	(0)
	Shore	1,234	12	0.010
		(±204)	(±15)	(±0.012)
	Sig	(-)	(-)	(-)
	Wading	2,294	14	0.006
		(±289)	(±13)	(±0.006)
	Sig	(0)	(-)	(-)

Table 7.–Percentage of anglers fishing in the Bell-to-Mast and Mast-to-Delhi sections by targeted species during the years 1985-88 and 1990-93. Responses are given with 90% confidence limits in parenthesis. The "Sig" columns indicate if percentages are statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant difference.

	Bell to Mast Road			Mast to Delhi Road		
Mode, Targeted species	1985-88	1990-93	Sig	1985-88	1990-93	Sig
Boat						
Smallmouth bass	41.30% (12.19%)	50.62% (9.25%)	(0)	50.77% (10.36%)	55.56% (9.76%)	(0)
Other species	0.00% (0.00%)	0.00% (0.00%)	(0)	7.69% (5.52%)	6.94% (5.00%)	(0)
Anything	58.70% (12.19%)	49.38% (9.25%)	(0)	41.54% (10.21%)	37.50% (9.51%)	(0)
Sample size	46	81		65	72	
Shore						
Smallmouth bass	25.49% (2.15%)	27.01% (2.65%)	(0)	33.70% (2.90%)	50.53% (4.22%)	(+)
Rock bass	5.57% (1.13%)	0.00% (0.00%)	(-)	1.95% (0.85%)	0.00% (0.00%)	(-)
Other species	9.16% (1.42%)	6.32% (1.45%)	(0)	11.14% (1.93%)	2.10% (1.21%)	(-)
Anything	59.78% (2.42%)	66.67% (2.81%)	(+)	53.20% (3.06%)	47.37% (4.21%)	(0)
Sample size	1114	759		718	380	
Wading						
Smallmouth bass	55.68% (2.82%)	76.09% (3.12%)	(+)	61.42% (3.15%)	83.33% (2.61%)	(+)
Rock bass	2.63% (0.91%)	0.00% (0.00%)	(-)	2.31% (0.97%)	0.00% (0.00%)	(-)
Other species	8.12% (1.55%)	4.54% (1.52%)	(-)	9.57% (1.90%)	4.17% (1.40%)	(-)
Anything	33.57% (2.69%)	19.37% (2.89%)	(-)	26.70% (2.86%)	12.50% (2.32%)	(-)
Sample size	837	506		648	552	

Table 8.–Percentage of anglers fishing in the Bell-to-Mast and Mast-to-Delhi sections by bait type used during the years 1985-87 and 1991-93. Responses are given with 90% confidence limits in parenthesis. The "Sig" columns indicate if percentages are statistically significant between time periods, where (+) indicates an increase, (-) indicates a decline and (0) indicates no significant difference.

	Bell to Mast Road			Mast to Bell Road		
Bait used	1985-87	1991-93	Sig	1985-87	1991-93	Sig
Worms	60.97% (2.02%)	48.73% (2.57%)	(-)	45.48% (2.55%)	38.34% (2.94%)	(-)
Crayfish	6.94% (1.06%)	2.63% (0.82%)	(-)	11.76% (1.65%)	4.86% (1.30%)	(-)
Hellgrammites	4.01% (0.81%)	5.85% (1.21%)	(0)	8.07% (1.39%)	3.91% (1.17%)	(-)
Artificial	18.66% (1.62%)	27.19% (2.28%)	(+)	25.75% (2.24%)	32.25% (2.83%)	(+)
Fly Fishing	5.73% (0.97%)	12.48% (1.70%)	(+)	5.83% (1.20%)	17.81% (2.32%)	(+)
Other	3.69% (0.78%)	3.12% (0.89%)	(0)	3.11% (0.89%)	2.83% (1.00%)	(0)
Sample size	1570	1026		1029	741	

Table 9.–Percentage of anglers fishing in the Bell-to-Mast and Mast-to-Delhi sections by county of residence during the years 1985-88 and 1990-93. Responses are given with 90% confidence limits in parenthesis. The "Sig" columns indicate if percentages are statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant difference.

	Bell to Mast Road			Mast to Bell Road		
Residence	1985-88	1990-93	Sig	1985-88	1990-93	Sig
Washtenaw	25.62% (1.59%)	31.33% (2.06%)	(+)	45.25% (2.17%)	51.08% (2.58%)	(+)
Wayne	61.15% (1.79%)	50.65% (2.22%)	(-)	46.16% (2.17%)	34.35% (2.45%)	(-)
Other	13.23% (1.24%)	18.02% (1.70%)	(+)	8.59% (1.22%)	14.57% (1.82%)	(+)
Sample size	2,018	1,382		1,421	1,016	

Table 10.–Mean number of smallmouth bass per acre captured on electrofishing marking runs. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant difference.

Section, time periods	2.0-5.9 in	6.0-11.9 in	12.0+ in
Bell to Mast Road			
1985-88	14.82 (9.39)	4.93 (1.14)	0.57 (0.24)
1990-93	23.04 (9.39)	3.98 (1.14)	0.92 (0.24)
Significance	(0)	(0)	(0)
Mast to Delhi Road			
1985-88	50.45 (9.39)	9.35 (1.14)	0.62 (0.24)
1990-93	40.91 (9.39)	4.86 (1.14)	1.12 (0.24)
Significance	(0)	(-)	(+)

Table 11.–Mean number of smallmouth bass per acre by age group captured on electrofishing marking runs. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (+) indicates an increase and (0) indicates no significant difference.

Section, time periods	0	1	2	3	4	5
Bell to Mast Road						
1985-88	14.81 (9.32)	3.13 (1.39)	1.24 (0.36)	1.02 (0.26)	0.23 (0.20)	0.37 (0.12)
1990-93	23.08 (9.32)	2.74 (1.39)	1.06 (0.36)	0.91 (0.26)	0.41 (0.20)	0.34 (0.12)
Significance	(0)	(0)	(0)	(0)	(0)	(0)
Mast to Delhi Road						
1985-88	48.40 (9.32)	7.97 (1.39)	2.30 (0.36)	1.24 (0.26)	0.48 (0.20)	0.24 (0.12)
1990-93	36.52 (9.32)	6.84 (1.39)	1.44 (0.36)	0.73 (0.26)	1.12 (0.20)	0.54 (0.12)
Significance	(0)	(0)	(0)	(0)	(+)	(+)

Table 12.–Mean number of rock bass per acre captured on electrofishing marking runs. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (+) indicates an increase and (0) indicates no significant difference.

Section, time periods	2.0-3.9 in	4.0-5.9 in	6.0+ in
Bell to Mast Road			
1985-88	39.20 (31.04)	34.00 (19.14)	10.34 (2.44)
1990-93	77.80 (31.04)	57.66 (19.14)	17.26 (2.44)
Significance	(0)	(0)	(+)
Mast to Delhi Road			
1985-88	7.38 (2.39)	9.52 (2.40)	9.14 (2.44)
1990-93	9.68 (2.39)	15.46 (2.40)	13.57 (2.44)
Significance	(0)	(+)	(0)

Table 13.–Mean number of rock bass per acre by age group captured on electrofishing marking runs. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (+) indicates an increase and (0) indicates no significant difference.

Section, time periods	Age 1	2	3	4	5
Bell to Mast Road					
1985-88	40.57 (26.04)	24.60 (14.44)	5.46 (1.46)	2.17 (0.52)	0.41 (0.14)
1990-93	67.42 (26.04)	47.24 (14.44)	10.17 (1.46)	2.97 (0.52)	0.48 (0.14)
Significance	(0)	(0)	(+)	(0)	(0)
Mast to Delhi Road					
1985-88	8.29 (3.24)	6.41 (3.24)	3.81 (1.46)	1.59 (0.52)	0.32 (0.14)
1990-93	9.96 (3.24)	12.78 (3.24)	5.36 (1.46)	2.81 (0.52)	0.93 (0.14)
Significance	(0)	(0)	(0)	(+)	(+)

Table 14.–Mean length of smallmouth bass in fall population samples. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant difference.

Section, time periods	Age 0	1	2	3	4	5
Bell to Mast Road						
1985-88	4.26 (0.01)	7.73 (0.05)	10.32 (0.10)	11.41 (0.12)	13.22 (0.23)	15.17 (0.30)
1990-93	4.08 (0.01)	7.58 (0.05)	10.09 (0.10)	12.18 (0.12)	14.03 (0.23)	15.04 (0.30)
Significance	(-)	(-)	(-)	(+)	(+)	(0)
Mast to Delhi Road						
1985-88	3.72 (0.01)	6.83 (0.05)	9.54 (0.10)	10.87 (0.12)	12.69 (0.23)	13.38 (0.30)
1990-93	3.62 (0.01)	6.00 (0.05)	8.54 (0.10)	10.95 (0.12)	12.69 (0.23)	13.37 (0.30)
Significance	(-)	(-)	(-)	(0)	(0)	(0)

Table 15.–Mean length of rock bass in fall population samples. Confidence bounds for the 90% level of significance are in parentheses. The "Significance" rows indicate if changes were statistically significant between time periods, where (-) indicates a decrease and (0) indicates no significant difference.

Section, time periods	Age 1	Age 2	Age 3	Age 4	Age 5
Bell to Mast Road					
1985-88	3.74 (0.01)	5.28 (0.02)	6.70 (0.03)	7.39 (0.05)	7.91 (0.11)
1990-93	3.63 (0.01)	5.32 (0.02)	6.53 (0.03)	7.18 (0.05)	8.00 (0.11)
Significance	(-)	(0)	(-)	(-)	(0)
Mast to Delhi Road					
1985-88	3.94 (0.01)	5.75 (0.02)	6.98 (0.03)	7.72 (0.05)	8.27 (0.11)
1990-93	3.67 (0.01)	5.52 (0.02)	6.97 (0.03)	7.62 (0.05)	8.23 (0.11)
Significance	(-)	(-)	(0)	(0)	(0)

Table 16.–Mean annual survival of smallmouth bass by age for fall population indexes. Confidence intervals for the 90% level of significance are in parenthesis. The "Sig." columns indicate if survival changes were statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant differences.

	Bell to Mast Road			Mast to Delhi Road		
Age	1985-88	1990-93	Sig.	1985-88	1990-93	Sig.
0-1	0.2602 (0.0474)	0.1850 (0.0474)	(0)	0.2046 (0.0474)	0.2487 (0.0474)	(0)
1-2	0.4954 (0.0474)	0.4282 (0.0474)	(0)	0.4827 (0.0474)	0.1992 (0.0474)	(-)
2-3	0.2881 (0.0474)	0.2908 (0.0474)	(0)	0.4777 (0.0474)	0.6500 (0.0474)	(+)
3-4	0.3910 (0.0474)	0.2400 (0.0474)	(-)	0.4464 (0.0474)	0.5604 (0.0474)	(+)
4-5	0.1667 (0.0474)	0.2500 (0.0474)	(0)	0.0417 (0.0474)	0.1686 (0.0474)	(+)

Table 17.–Mean annual survival of rock bass by age for fall population indexes. Confidence intervals for the 90% level of significance are in parenthesis. The "Sig." columns indicate if survival changes were statistically significant between time periods, where (+) indicates an increase, (-) indicates a decrease and (0) indicates no significant difference.

	Bell to Mast Road			Mast to Delhi Road		
Age	1985-88	1990-93	Sig.	1985-88	1990-93	Sig.
1-2	0.7545 (0.0357)	0.6790 (0.0357)	(-)	0.8726 (0.0357)	0.9368 (0.0357)	(0)
2-3	0.3146 (0.0357)	0.2619 (0.0357)	(0)	0.4360 (0.0357)	0.5270 (0.0357)	(+)
3-4	0.3251 (0.0357)	0.2769 (0.0357)	(0)	0.4500 (0.0357)	0.4725 (0.0357)	(0)
4-5	0.2986 (0.0357)	0.1648 (0.0357)	(-)	0.1972 (0.0357)	0.2626 (0.0357)	(0)

Table 18.–Results of smallmouth bass spawning redd counts (number of redds) during May 1992. Counts are indicative of spawning activity within each section.

Day in May	Bell to Mast	Mast to Delhi
4	0	0
5	2	1
8	4	0
11	42	37
13	42	31
15	43	35
21	25	31

Table 19.–Daily mean water temperatures during May at Zeeb Road. Predicted beginning of smallmouth bass spawning for each year is marked with an asterisk (*).

Day in May	Year					
	1987	1988	1989	1991	1992	1993
1	12.5	11.8		14.7	12.4	13.8
2	11.9	12.7		13.0	13.2	14.1
3	12.0	12.6		13.1	12.4	14.1
4	12.9	12.6		13.4	12.0	14.4
5		12.8	13.0	14.3	12.2	15.0
6		13.9	11.0	13.4	12.6	16.7*
7	14.5	14.8	9.8	12.6	13.4	16.9
8	14.7	15.2	10.6	12.4	14.2	17.4
9	15.7	15.4	11.2	12.7	15.4	18.2
10	17.5*	14.1	11.5	14.4	16.2*	19.3
11	18.2	14.2	12.1	15.6	17.3	20.2
12	17.5	14.2	11.7	16.8*	18.0	19.2
13	16.6	15.4	10.2	18.3	18.6	18.0
14	17.2	15.3*	10.5	19.6	17.4	18.1
15	17.0	15.5	11.2	20.2	17.0	18.3
16	17.4	16.2	12.8	21.1	18.3	16.7
17	18.7	15.2	14.6	22.0	19.3	17.0
18	18.9	17.6	15.4	21.8	18.9	15.7
19	16.6	16.2	*	18.9	18.9	15.9
20	17.2	16.5	15.8	18.3	19.7	15.4
21	19.8	17.6	15.8	19.2	20.5	15.1
22	21.6	18.5	16.8	20.1	21.3	16.8
23	18.7	18.9	17.1	21.6	20.5	15.7
24	16.6	18.8	17.6	22.4	17.5	17.1
25	17.0	16.2	17.9	22.7	15.8	15.3
26	18.9	16.4	18.5	22.5	15.6	17.0
27	21.5	18.0	17.2	22.4	15.6	15.5
28	22.5	18.6	16.5	23.0	16.5	16.8
29		20.1	16.7	24.2	17.5	17.0
30	24.1	21.2	18.8	25.0	16.9	17.3
31	24.1	21.9	18.7	25.4	16.3	15.3

Table 20.–Water degree days >14.9° C, >24.9° and >29.0° C. Water temperatures were recorded for the time period: May 22-July 3 and July 16-September 11.

Year	Temperature°C	Group Camp	Mast Road	Zeeb Road
1991	14.9	912.5	-	862.1
	24.9	23.9	-	21.7
	29.0	0.0	-	0.0
1992	14.9	618.1	585.6	566.2
	24.9	0.0	0.0	0.0
	29.0	0.0	0.0	0.0
1993	14.9	716.1	686.6	644.4
	24.9	10.1	6.7	2.4
	29.0	0.0	0.0	0.0

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