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Evaluation of Muskellunge Introduction in Green River Lake

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by

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ABSTRACT

Muskellunge (1977-1978) and tiger muskellunge (1979-1981) were stocked in Green River Lake at approximately 1 fingerling/acre with fish averaging 6 inches in length to establish an additional fishery and replace the loss of the native Green River muskellunge population following impoundment. A fishery did not develop until annual muskellunge stockings ≥9.0 in were initiated in 1982. Beginning in 1982, stockings were alternated between 12-14 in and 8-10 in muskellunge. There was significantly higher survival of the year classes from 12-14 in versus 8-10 in muskellunge stockings. The year class strength was 4.2 times higher for the larger size stockings, based on CPUE from electrofishing. Growth of muskellunge indicated most year classes recruited into the legal-size range (≥30 in) at age 2+. The harvest objective of increasing the sport fish yield by either a minimum of 10% or 1 lb/acre was achieved in 1987. A total of 2,771 muskellunge was caught, with 1,014 of this total being harvested; 75% of the legal-size muskellunge in the catch were harvested. The total biomass of muskellunge harvested was 10,047 lb (1.22 lb/acre), a 9.6% addition to the fish yield. Muskellunge anglers accounted for 8.7% of the fishing trips on the lake and harvested muskellunge at a rate of 0.02 fish/hour. Negative public reaction to the muskellunge introduction prompted an angler attitude survey in 1987 which revealed only 26% of all anglers opposed the stocking program. Annual muskellunge stockings will be continued and evaluated with annual stockings of 1,864 and 3,449 12-in fish on alternate years.

INTRODUCTION

Brewer (1980) determined Kentucky had 14 streams with appreciable native muskellunge populations, but considerable muskellunge stream habitat had been destroyed or degraded by impoundment and/or pollution. Muskellunge (*Esox masquinongy*) are native to the Green River basin (Clay 1974); however, the impoundment of Green River Lake (1969) eliminated the Green River muskellunge population above the dam. The Minor E. Clark Fish Hatchery was constructed in 1973 by the Kentucky Department of Fish and Wildlife Resources with one goal of producing muskellunge fingerlings for maintenance stockings of native muskellunge streams as recommended by Brewer (1980). Cave Run Lake (8,270 acres) impounded part of the Licking River drainage that contained a good muskellunge population; most of the spawning areas were lost by impoundment in 1974. An annual muskellunge stocking program was initiated in the reservoir in 1974 and Axon (1978) documented the establishment of a successful lake fishery from these stockings. The muskellunge harvest yielded a 17-27% increase in total pounds of all fish harvested during 1976-1979. To sustain the fishery, 9-in muskellunge were recommended (1979) due to poor survival of 6-in fish after the first year of impoundment.

Green River Lake was selected for muskellunge stockings in 1977 due to the success of the Cave Run Lake muskellunge fishery and the loss of native muskellunge stream to impoundment in Green River Lake. Green River Lake contained standing timber similar to Cave Run Lake which was considered excellent muskellunge habitat. During this time frame, the popularity of intensive rearing of hybrids between muskellunge and northern pike (tiger muskellunge) became popular in northern states since tiger muskellunge survived at higher rates and exhibited a higher catch rate for anglers than pure-bred muskellunge (Beyerle 1973 and 1981). Therefore, the original objective of this study was to compare the relative success of stocking pure-bred muskellunge and tiger muskellunge. The poor survival of 6-in fingerlings of both pure-bred muskellunge and tiger muskellunge in Green River Lake prevented the original comparison. The Minor Clark Fish Hatchery modified some of their muskellunge pond production in 1982, creating the availability of a limited supply of 12-13 in muskellunge. The objective of this study was then modified to evaluate the relative success of 9-in versus 12-in advanced muskellunge fingerlings in Green River Lake. This investigation was conducted within Dingell-Johnson Project F-40, Segment 2-10, Statewide Fisheries Research Project; Subsection I: Sport Fishery Investigations.

Study Area

Green River Lake is a Corps of Engineers' impoundment built in 1969 for flood control; it is also operated for water quality control, recreation, and fish and wildlife activities. The dam is located at mile 305.7 on the Green River in Taylor County, Kentucky. The lake, at summer pool, impounds 8,210 surface acres encompassing 27.5 miles of Green River and 11 miles of Robinson Creek. Winter drawdown begins on September 15 in which the pool level is lowered 11 feet (664 ft msl) to a winter pool acreage of 6,650 acres. The dam is equipped with multi-level outlet structures capable of regulating downstream water temperature. Discharge water temperature was changed in 1983 from a coldwater release to a coolwater release, an intermediate level between the standard coldwater and normal stream temperature curve.

Green River Lake is a warm, monomictic lake which is stratified between June and October, with an anoxic hypolimnon. The lake has an average depth of 27 feet, a maximum depth of 83 feet, and a well-developed thermocline between 20-24 feet. Kentucky Division of Water (1988) rates Green River lake as mesotrophic using the Carlson Trophic State (TSI) Index for chlorophyll-a. The lake has approximately 633 acres of standing timber in coves, along main-lake shoreline areas, and along primary and secondary channels in the upper reaches of the lake.

Materials and Methods

All muskellunge and tiger muskellunge stocked in Green River Lake were produced and reared at the Minor Clark Fish Hatchery. Muskellunge were stocked at public access sites in which sites near standing timber were favored. Similar size (approximately 6 in) pure-bred muskellunge (1977-1978) and tiger muskellunge (1979-1981) were stocked at about 1 fingerling per acre (Table 1). Beginning in 1982, larger fingerling muskellunge (>12 in) became available and the stocking regime was modified to stocking these larger muskellunge on even-numbered years dependent upon the available production. Therefore, stocking rates fluctuated from 0.2-0.4 fingerlings per acre. On alternate years, muskellunge were planned to be stocked at 1 fingerling per acre at an average size of 9 in. This was met every year except for 1983 when a severe disease problem reduced available numbers to 0.5 fingerlings per acre. Figure 1 displays the average surface temperature at the stocking site each year.

Two cove-rotenone studies, one in each major arm of the lake, were conducted annually from 1979-1981 with total acreage ranging from 5.4-6.3 acres. A single study (3.46 acres) was conducted in 1986 in the Robinson Creek arm. Cove-rotenone procedures were similar throughout the study. The cove was blocked prior to 0800 hours on the first day with a 0.5-in block net, and emulsified rotenone (2.5 or 5%) was dispersed via a boat venturi to obtain a rate of 1 ppm. Surfacing fish were dipped for 3 successive days and sorted to both species and inch groups with weights of fish gathered on the first day only. Data from the years with multiple studies were combined each year and presented as per acre values. The available predator-prey (AP/P) model (Jenkins and Morias 1977) was utilized to analyze cove-rotenone data for deficiencies in prey. Data were adjusted for open water based on the Douglas Lake rotenone study (Hayne et al. 1967).

Gill netting was only conducted in 1979 and 1980 utilizing experimental nets, 250-foot long by 8-foot deep, and containing five 50-foot panels of 0.5, 1.0, 1.5, 2.0, and 2.5 in mesh. These nets were fished for a total of 12 net-nights in June and October 1979 and 9 net-nights in September 1980.

Boat-mounted electrofishing gear was used initially in the fall of 1979 to augment gill net samples for muskellunge; beginning in 1980, both spring and fall electrofishing samples were collected. Main-lake shoreline areas and tributary arms were electrofished for muskellunge with records maintained regarding hours of electrofishing time, number of muskellunge captured, and number of muskellunge observed. The original intent of electrofishing was to utilize a mark-recapture method to develop a population estimate. Captured muskellunge received a monel self-piercing jaw tag which was attached on the anterior-basal edge of the dorsal fin; the size of the tag was dependent on the size of the fish. Poor survival of stocked muskellunge prevented the capture of sufficient fish to develop a population estimate. However, electrofishing was continued in subsequent years utilizing catch per unit effort as an index to year class strength. Survival rate from age t and t+1 was obtained from the ratio $S = \frac{N_{t+1}}{N_t}$, where N represents the CPUE for each age (Ricker 1975). Captured muskellunge were measured to the nearest 0.10 in and 0.01 lb and scale samples were removed from an area above the lateral line near the mid-point between the operacle flap and the origin of the dorsal fin. Scales were later viewed on an Eberbach scale projector and appropriate measurements were obtained to determine back-calculated growth rates using the direct-proportion method. Aging of muskellunge became very difficult; tagging with the previously described jaw tag was continued as a method for annulus verification in subsequent years of recapture. In 1986, the right pectoral fin was clipped on all muskellunge prior to stocking to assist with the aging process.

The Green River Lake muskellunge population was simulated using a yield-per-recruit model (Ricker 1975) on a Lotus 1-2-3 spreadsheet developed by Gary Isabell, Ohio Division of Wildlife. The model incorporated length and weight at age developed for Green River Lake muskellunge. Natural mortality between ages 1 and 2 was calculated from Green River Lake data while the instantaneous natural mortality (0.17) for all other years was calculated from an annual mortality rate for La Court Orielles muskellunge (Lyons and Margenau 1986). Fishing mortality (0.28) was based on the exploitation observed at Cave Run Lake (Axon 1978). Initial recruit number used in the model was calculated by hand based on the stocking number and adjusted for post-stocking and over-winter mortalities. Survival rate from fall to spring was calculated from Green River Lake CPUE data. The mean survival (stocking time to fall) of 53.3% for 12 in muskellunge in 4 lakes in Wisconsin (Serns and Andrews 1986) was used in the model. The post-stocking survival for 9-in muskellunge (12%) was calculated by adjusting this 12-in muskellunge survival rate by a factor of 4.4, the relative difference between fall CPUE for large versus small muskellunge fingerlings (also adjusted for differences in stocking densities). Predictive yield for two successive stockings were computed based on existing and hypothetical stocking rates and hypothetical minimum length limits.

Creel surveys were conducted on Green River Lake from 1979-1982 and in 1987. The 1979 and 1980 survey was in cooperation with the U.S. Fish and Wildlife Service (National Reservoir Research Program), U.S. Army Corps of Engineers, and the Kentucky Department of Fish and Wildlife Resources (KDFWR). A stratified-random design was utilized for harvest estimates and aerial counts were used to derive angler pressure. The survey year was stratified into 3 seasons and the days were stratified as weekdays and weekend days. Data tabulation and complete methodology were described by Aggus et al. (1981).

A non-uniform probability creel survey design (Pfeiffer 1966) was used for the 1981-1982 and 1987 surveys conducted during the months of March through October with the exception of 1987 when the survey concluded in November. The lake was divided into two equal areas and probabilities were assigned to each half-day period based on known fisherman pressure from other major reservoirs; the week was divided into 14 half-day periods. A departmentally-hired creel clerk worked a half-day period in one randomly-selected area for 4 days per week. The survey period was divided into an interview time period and a randomly selected 2-hour instantaneous fishermen count. Standard creel data information was compiled utilizing a Fortran program (1981-1982) and a Statistical Analysis System (SAS) program in 1987.

An angler opinion survey was conducted during the 1987 creel survey. Anglers were asked a series of response-dependent questions (Figure 2) designed to determine angler opinions regarding the muskellunge stocking program on the lake.

A statewide voluntary mail-in survey was also used to monitor the relative contribution of annual muskellunge stockings to the Green River Lake muskellunge fishery. Boat docks, bait shops, country stores, and other establishments along with creel clerks and conservation officers were provided with self-addressed, postage-paid coin envelopes containing a questionnaire. Participating anglers who completed the questionnaire concerning the size, location of catch, method of fishing, etc., and who enclosed a scale sample from a harvested muskellunge were mailed a clutch-back pin resembling a muskellunge and a certificate (first fish only). Muskellunge scales were read annually to assign a year class, and both average length and weight were calculated per year class. Back-calculated lengths were not used due to variability among anglers in measuring their catch.

RESULTS

The total fish standing stock varied from 202 lb/acre (1986) to 359 lb/acre (1980), according to results of cove-rotenone studies (Table 2). Forage fish standing stock values ranged from 20-69% (40-247 lb/acre) of the total standing stock; therefore, change in forage fish populations primarily influenced the fluctuations in total standing crop. Gizzard shad is the only clupeid species in Green River Lake; biomass of other forage species represent an insignificant amount to the total forage base. Biomass of intermediate-size gizzard shad (4-7 in group) was the dominant size range responsible for these fluctuations in total gizzard shad biomass. The schooling nature of gizzard shad obviously produced a sampling bias since the largest gizzard shad biomass (247 lb/acre) in 1980 was dominated by the 176 lb/acre of intermediate-size gizzard shad. However, Figure 3 shows that the lowest overall production (number/acre) for fingerling-size gizzard shad was in 1979, which should have translated to low numbers of intermediate size shad in 1980. Relative levels of fingerling- and intermediate-size gizzard shad numbers between 1980 and 1981 corresponded; but, data gaps between 1981-1986 prevent any explanation for the low numbers of intermediate-size shad in 1986.

Other dominant fish groups and/or species sampled in cove studies were carp, spotted sucker, redhorse suckers, bluegill, longear sunfish, channel catfish, white crappie, and black basses. White crappie were usually sampled in large numbers; but, their schooling nature around submerged habitat also biases their relative abundance estimates. White bass, a pelagic species, were infrequently sampled in these cove studies, although a good population exists in Green River Lake. Muskellunge were also infrequently sampled in cove studies, except in 1986, when 19 lb/acre of muskellunge were sampled in a single cove. This was considered an abnormality, but this cove contains good muskellunge habitat, i.e. standing timber adjacent to a secondary creek channel. The water temperature was 73°F in the back of this cove while the main lake surface water temperature was 83°F; apparently, a spring influences the water temperatures in this cove.

Largemouth, spotted, and smallmouth bass represented 58.8, 31.2, and 9.9% of the black bass biomass, respectively (Table 3). Largemouth bass is the dominant black bass species in Green River Lake, yet habitat for adult smallmouth bass is poorly sampled in cove studies. In 1986, the single cove study was in the Robinson Creek arm of the lake which contains less smallmouth bass habitat than the Green River arm. Excluding smallmouth bass data, there were good spawns of the remaining black bass in all 4 years sampled. Intermediate-size spotted bass nearly co-equaled or surpassed numbers of intermediate-size largemouth bass each year, but the numbers of harvestable-size largemouth bass consistently exceeded harvestable-size spotted bass, creating the major difference in total poundage for each species.

Plots of the average AP/P values based on cove-rotenone studies are presented in Figure 4. The straight diagonal line on each graph is the theoretical desirable ratio of 1:1 in which there is sufficient available prey for every inch group of predators; therefore, all points lying above this line imply there is sufficient prey available for a given-size predator. The model assumes that any fish, regardless of species, can be prey during some course of its lifetime and various species are adjusted on basis of mouth size. Data for all 4 years sampled indicated there was no deficiency in prey for any size group of predators.

Gill netting results are summarized in Table 4, with both spring and fall data combined for 1979 and only fall data collected in 1980. Individual inch class data were not presented since this gear was inefficient in collecting the target species, muskellunge. Only one 15.7 in muskellunge (1978 year class) was collected during a total of 33 net nights. Dominant species in the catch were white crappie, channel catfish, carp, and gizzard shad.

Age and Growth

A total of 550 muskellunge was used to calculate a length-weight relationship (Figure 5). The equation used to describe this relationship was $\log_e W = -9.730 + 3.419 (\mathrm{Log}_e L)$. Data were pooled for years and sex since small sample sizes precluded testing this relationship between year classes and/or years sampled and no fish were sacrificed to examine for sex. Sampled muskellunge ranged in size from 9 to 43 in long with average weights of 0.14 and 21.00 lb, respectively. The legal minimum-size muskellunge (30 in) weighed an average of 7.00 lb.

A total of 446 muskellunge was utilized in determining the average back-calculated lengths by age (Table 5). Aged muskellunge represented 9 year classes (1977-1979, 1982-1987); however, sample sizes significantly increased in 1982 following the stocking of $\geq$9 in muskellunge. All year classes of muskellunge attained legal size (30 in) at age 2+. There was no trend in any different growth rates between the smaller (8-10 in) and larger (12-14 in) muskellunge stockings. Differences among growth rates between year classes were felt to be due to variability in scale reading.

Difficulty was encountered with interpreting annuli on scales and infrequent recaptures of tagged muskellunge failed to provide a reliable data set of yearly growth increments. During years of 12-14 in fingerling stockings, there were problems associated with hatchery checks since these muskellunge were transferred to larger ponds at approximately 9 inches in length. Fingerlings of the 1986 year class revealed that 91% of the muskellunge also laid down a false annuli in late summer at age 1+. The reason for this false mark is not understood; it could be a function of summer temperature stress, availability of forage, or a combination of both. Information on forage availability is unknown, but young-of-year gizzard shad should provide available forage for age 1+ muskellunge unless they are spatially segregated. False marks were also detected from similar age muskellunge from other year classes since back-calculated lengths did not correspond to length-frequency data. Known-age muskellunge have not been tracked for enough years to indicate if false annuli develop in the late summer on a routine basis. However, growth increments for older age muskellunge compared favorably with length-frequency data.

Food Habits

Muskellunge were not routinely sacrificed for food habit analysis due to their trophy status and low population density. However, in 1987 a small sample (9 fish) of age 1+ muskellunge (23.1-25.7 in long) were examined for stomach contents. All these fish contained gizzard shad ranging from 5.5 to 8.0 inches in length, except for one 7-in crappie. A 13.1 (age 0+) muskellunge contained a 4.8 in gizzard shad.

Electrofishing

Results of electrofishing for muskellunge are presented in Table 6. Overall effort from 1979-1982 was low with some seasonal samples taken only in the headwaters; however, the low number of captured muskellunge was indicative of the poor survival of the first 5 year classes (1977-1981) of muskellunge and tiger muskellunge stocked at a length of 5.75-7.8 in. Both total numbers and CPUE (catch per unit effort) of muskellunge significantly increased in the spring of 1983 following the 1982 fall stocking of 1,554 muskellunge averaging 13.5 in long. The spring 1987 electrofishing sample has been graphically portrayed in Figure 6 to show the size distribution of the muskellunge population following the recruitment of the previous five year classes. The CPUE varied from 0.51 muskellunge/hour (fall 1984) to 5.23 muskellunge/hour (1986), with sightings of additional muskellunge ranging from 3-50 per year. The CPUE for fall 1984 was depressed because samples were taken prior to the fall introduction of the 1984 year class; the next lowest catch rate was 0.66 muskellunge/hour in the spring of 1984. Samples were dominated by age 0+ and age 1+ muskellunge due to their higher density and decreased ability to electrofish the older and larger muskellunge.

Electrofishing samples were stratified into age 0+ and age 1+ for relative comparisons between the two size groups of muskellunge stocked beginning in 1982. The CPUE was compared for fall samples of age 0+ muskellunge and spring and fall samples of age 1+ muskellunge (Figures 7-9); however the comparison for age 1+ muskellunge in the spring provided equal numbered years (3 year classes each) for the two size groups (8-10 in and 12-14 in) of muskellunge stockings. The CPUE for age 1+ muskellunge from the large fingerling stocking ($x = 2.1$) consistently exceeded the CPUE for age 1+ muskellunge from the smaller fingerling stocking ($x = 0.5$). A Wilcoxon-ranked sum test of pooled data ($n = 56$) for this comparison also indicated a significant statistical difference ($p<0.0001$). The overall spring CPUE for large fingerlings at age 1+ was 4.2 times better than the CPUE for small fingerlings sampled at the same age, despite higher stockings rates for years receiving smaller fingerlings. The CPUE data for the large fingerlings in the fall (x = 1.3) exceeded the CPUE for small fingerlings (x = 0.4); although fall data was only available for 2 year classes of the small fingerlings.

The fall CPUE for age 0+ muskellunge was compared between the strongest year class of small fingerlings (1985) and the strongest year class of large fingerlings (1986). This comparison revealed a ratio of CPUE of 4.4:2.4 for large:small fingerlings or a catch rate of 1.8 times better for large fingerlings than for similar age small fingerlings. The 1985 year class of small fingerlings was stocked at a rate 2.5 times greater than the 1986 year class which translates into 4.5 times better survival (1.8 X 2.5 = 4.5) for larger fingerlings.

Survival estimates based on electrofishing CPUE were calculated for overwinter survival for age 0+ muskellunge for 4 year classes and survival between age 1+ and age 2+ for the 1986 year class only. Survival rates for other age muskellunge were not calculated due to the inability to always assign accurate ages to muskellunge. The calculated overwinter survival rate for the 1983, 1985, and 1987 year classes of muskellunge (small fingerling stockings) was 0.34, 0.32, and 0.52, respectively; however, the 1987 year class data was based on very low sample sizes. Contrarily, the overwinter survival was 0.60 for large fingerlings for the only year class (1986) in which data allowed an accurate estimate. Since the 1986 year class was easily tracked (fin-clipped), a survival rate of 0.63 was calculated between ages 1+ and 2+.

Population Simulations

Population simulations were made on yearly intervals and combined for 2-year intervals to correspond to our current stocking strategy. For instance, simulation 1 in Table 7 is based on our current stocking regime of 1 small fingerling (9 in) per acre per year (8,200 muskellunge) on odd-numbered years and large fingerlings (≥12 in) stocked on even-numbered years. The average number of large fingerlings stocked during the previous stockings has been 3,449 muskellunge; therefore, this value was utilized throughout other simulations. The simulated sum of the 2-year yield for our current stocking regime was 768 muskellunge that weighed 8,203 lb. Simulation 2 encompassed a reduced stocking of 1,864 12-in fish on odd-numbered years by a by a factor of 4.5 times; this reduction reflects the relative-difference observed in electrofishing CPUE for small versus large fingerling muskellunge. This simulation indicated a moderate increase in yield to 930 muskellunge weighing 9,943 lb due to the relative difference in survival from stocking to the following spring for large fingerlings. Confidence with these survival rates is weak and is the reason this simulation will be tested in future years with separate marked year classes of muskellunge.

Simulations 3-6 involve annual stockings of large fingerlings at the existing rate of 3,449 fish and the reduced rate of 1,864 fish at various size limits, i.e. 36 in and 38 in. Yield in numbers moderately increased with simulation 3 at a 36 in size limit and an annual stocking of 3,449 muskellunge, while substantial increases in yields by weight were calculated for both simulations 3 and 4 at the 36 in and 38 in size limits, respectively. Simulations 5 and 6 reveals substantial decreases in number and weight yield for reduced stocking rates of (1,864 fish) large muskellunge at both 36 and 38-in size limits.

Simulation 7 involved stocking the average number between the 2 years suggested in simulation 2 which translates into identical yields. However, simulations 8 and 9 are essentially simulation 2 at higher minimum size limits which decreased the number of fish creeled and maintained similar yields in weight. Therefore, simulations 8 and 9 at higher size limits will only result in greater average-size fish in the creel and more numbers for catch and release $\geq$30 in, but a reduced yield in numbers.

Angler Opinion Survey

A total of 874 anglers participated in an angler attitude survey during the routine creel survey (Table 8). Muskellunge fishermen comprised 18.2% (159) of the anglers; 52.9% (100) of these anglers had been successful at least once at catching a muskellunge. In addition, 168 (23.5%) non-muskellunge fishermen had been successful at catching a muskellunge in the past. Muskellunge anglers overwhelmingly (73%) supported the muskellunge stocking program, while only 48% of the non-muskellunge anglers favored the stocking program, and 23% had no opinion. Overall, 53% of all anglers favored the stocking program, 26% opposed, and 21% had no opinion. Forty-eight percent of the non-muskellunge anglers who opposed muskellunge stockings in Green River Lake (or 12% of the total non-muskellunge anglers) felt muskellunge "hurt their fishing".

Harvest

Total fish harvest (Table 9), both numbers and pounds (except for 1982), increased during each survey year (1979-1982, 1987). Numbers of fish harvested varied from 20,137 fish (2.5 fish/acre) in 1979 to 312,504 fish (38.1 fish/acre) in 1987, while yield in weight increased from 28,228 lb (3.4 lb/acre) in 1979 to 105,681 lb (12.9 lb/acre) in 1982 and 104,364 (12.7 lb/acre) in 1987. Total fish harvest rates for 1979-1980 were 0.24 fish/hour and 0.26 fish/hour, respectively, when an access site (completed trip) survey was conducted. However, the mean total fish harvest rate for the three remaining creel survey years was 1.18 fish/hour (range = 0.96-1.57 fish) when a roving creel survey was conducted by KDFWR. This harvest rate difference is related to differences in the calculation methods within the two types of creel surveys. Crappie consistently dominated the harvest by numbers and dominated the harvest by weight for every creel survey year except 1979. The best crappie harvest occurred in the final year (1987) when an estimated 222,654 crappie were harvested that weighed 52,739 lb (6.4 lb/acre). The average-size crappie in the 1987 creel survey was 8.3 inches in length or 0.24 lb in weight. Excluding muskellunge and black basses, other important species in the harvest were white bass, sunfish,and catfish.

Black basses were second only to crappie in terms of fishing pressure for a particular species group. The best harvest of black bass numbers occurred in 1987,although yield in weight was higher in 1979 due to differences in the length-weight relationships utilized. The black bass harvest in 1987 was dominated by largemouth bass (76.2%) followed by spotted bass (17.5%) and smallmouth bass (6.2%). The average size largemouth bass harvested was 15.1 in long (1.77 lb), while the released legal-size bass (≥12 in) averaged a length of 13.7 in.

Muskellunge harvest was absent in the 1979 survey and insignificant (<50 muskellunge/year) from 1980-1982. The final creel survey year (1987) reflects the recruitment of larger muskellunge (>9 in) stocked in Green River Lake beginning in 1982 into the fishery. A total of 2,771 muskellunge was caught in 1987 with 1,014 of this total being harvested. The total biomass of muskellunge harvested was 10,047 lb (1.22 lb/acre) or a 9.6% addition to the harvest by weight. The average-size muskellunge harvested was 33.8 in long and 9.34 lb. Muskellunge anglers accounted for 8.7% of the fishing trips on the lake and harvested muskellunge at a rate of 0.02 fish/hour (50 hours/fish). Anglers only released 27% of the muskellunge ≥30 inches in length (legal size limit); a size distribution of the catch (Figure 10) indicates most muskellunge are harvested as soon as they recruit into the fishery. The best fishing months for muskellunge in 1987 (Table 11) were April (146 fish), May 201 fish), June (210 fish), and July (260 fish). The harvest of muskellunge by year class in 1987 (Table 11) indicated the 1984 year class (54.3%) dominated the harvest, followed by the 1983 year class (34.3%) and the 1985 year class (11.4%). Representatives from the 1982 year class were absent in the creel, but mistakes in aging these fish cannot be discounted.

Mail-In Survey

Mail-in survey returns included a scale sample, but a lack of confidence in aging of these fish required the omission of age specific data. A summary of returns from 1980-1987 (Figure 11) revealed significant increases in returns beginning in 1985 and continuing through 1987. Again, these results are the product of the stronger year classes, beginning in 1982, recruiting into the fishery. A monthly distribution of 1987 returns (Figure 13) indicates June to be the best month for muskellunge fishing. Trolling was the dominant fishing method specified by muskellunge anglers.

DISCUSSION

The original objective of this study was to compare relative differences in survival and contributions to the creel of similar size pure-bred muskellunge and tiger muskellunge. Tiger muskellunge at the time of stocking were deemed superior to pure-bred muskellunge for the following reasons: increases in hatchery production due to intensive rearing (Beyerle 1984), increases in survival (Wiethman and Anderson 1977), ability to survive in a variety of habitats including a wider range of water conditions (Hesser 1978), and increased susceptibility to angling and faster growth (Schrouder 1973). Muskellunge stockings from 1977-1978 and tiger muskellunge stockings 1979-1981 failed to develop a significant population based on electrofishing, mail-in survey, and creel survey results. The failure of small fingerling stockings (5.75-8.0 in) was the impetus for stocking larger fingerlings (≥9.0 in) beginning in 1982. Creel survey results in 1987 indicate a muskellunge fishery had developed that met our original harvest objective (1 lb/acre or 10% addition to the yield) following the stocking of these larger fingerlings. Muskellunge from three year classes (1983-1985) of large fingerlings comprised the harvest. Electrofishing results indicated the CPUE for age 1+ muskellunge stocked at 12-14 in was significantly greater than the CPUE for 8-10 in muskellunge.

Muskellunge stocking sizes have been the subject of many investigations; however, most of these studies have been conducted in more northern latitudes and mainly in natural lakes where muskellunge or northern pike is the dominant predator. Johnson (1982) determined in 2 of 10 cases that larger muskellunge fingerlings (9.8-12.0) had significantly higher survival than smaller fingerlings (7.1-9.6 in); in the remainder of the trials, survival was not significantly different. Unpublished data from Deer Lake in Wisconsin indicated 12 in muskellunge had a three-fold increase in survival above 8.0 in muskellunge (Addis, J.T., personal communication, Wisconsin DNR). The best survival to the first fall was achieved by stocking the largest fingerlings in 59 study lakes; however, Hanson (1986) felt similar results may have been achieved by stocking proportionally greater numbers of smaller fingerlings.

The failure of smaller fingerling stockings (1977-1981) and a poorer survival of 8-10 in fingerlings are probably related to summer stocking temperatures and predation. The predation factor for tiger muskellunge (1979-81) was further compounded by the intensive rearing practice since Beyerle (1984) determined 8-in tiger muskellunge reared extensively survived 4-16 times higher than intensively-reared fingerlings. Beyerle reported this survival to be strongly related to the density of predators (largemouth bass) $\geq$12 in and probably the abundance of soft-rayed forage fishes. Survival of other esocids fingerlings in other lakes have been influenced by size of fish stocked (Stein 1981, Andrew 1983), density of large predators (Stein 1981), time of stocking (Johnson 1982), and a combination of these factors coupled with forage abundance (Carline et al 1986). Johnson (1982) examined several of the aforementioned variables in 20 water bodies and determined a definite trend of increased survival of muskellunge fingerlings during late season releases when the water temperature was cooler at 60-65°F. Hess (1981) similarly reported high mortality of esocids stocked at water temperatures >86°F.

Green River Lake temperatures were consistently <65°F for all stockings of advanced muskellunge fingerlings (12-14 in) in the fall. Contrarily, all 8-10 in muskellunge fingerlings were stocked at temperatures exceeding 80°F in late July-August. The strongest year class from 8-10 in stockings of muskellunge was produced in 1985 which corresponded to the coolest lake temperature (80°F) in which three years of similar-size muskellunge were stocked. The abnormally hot, dry summer in 1987 not only created elevated lake temperatures, but was responsible for dissolved-oxygen and temperature problems for the hatchery during the production of muskellunge. The impact of this stress during the production phase cannot be dismissed as a detrimental factor affecting the survival of the 1987 year class.

The predation factor on muskellunge was not examined at Green River Lake, yet circumstantial evidence indicated predation was probably substantial. Carline et al. (1986) determined that largemouth bass predation was directly related to their density and inversely related to indices of abundance for largemouth bass prey. Largemouth bass were reported to consume hybrid muskellunge up to 62% of their own length. Utilizing this value, a 9.6, 11.2, 14.5, and 19.4-in largemouth bass can consume a 6.0, 7.0, 9.0, and 12.0-in muskellunge, respectively. The mean standing stock of black basses in Green River Lake during this study was 10.7 lb/acre with harvestable-size largemouth bass representing 2.7 lb/acre of this total. Also, a PSD of 80 and RSD_{15} of 45 in 1986 indicated this density of largemouth bass was comprised of a large portion of bass within the size range to prey upon 6.0-9.0 in muskellunge. Conversely, AP/P ratios failed to indicate any shortage of available prey during the limited data years for all size predators. However, habitat overlap of age 0+ muskellunge (or tiger muskellunge) with largemouth bass conceivably contributes to predation factors, especially muskellunge which have been thermally stressed.

Average growth rates of Green River Lake muskellunge exceeded the growth rate for all northern states and compared favorably to a similar latitude-growth rate in a Missouri reservoir (Table 12). Bishop (1967) and Stevenson and Day (1987) similarly reported muskellunge in Tennessee and Clear Fork Reservoir, Ohio, respectively,to achieve 30 inches in length at age 3+. Accelerated growth rates in Green River Lake and other aforementioned reservoirs was presumably due to the gizzard shad forage base. Hess and Heartwell (1978) concluded gizzard shad was the best forage fish for esocids, but gizzard shad rarely occur in the muskellunge native range. Gizzard shad was the major component of the Green River Lake muskellunge diet based on the limited food-habit information, and gizzard shad was the dominant forage species in all cove-rotenone studies. Both muskellunge and tiger muskellunge fed primarily on gizzard shad in Stockton Lake (Goddard and Redmond 1978) and Pomme de Terre Lake (Vasey 1972) in Missouri.

The thought of muskellunge stockings impacting on other sport fishes, eg. black bass and crappie, has often been expressed by anglers at Green River Lake. The stocking of an additional predator in a reservoir is always associated with a cause and effect relationship when fishing success for another desirable fish species is deemed below expectations. The predation factor of muskellunge on these two fish groups (black bass and crappie) is unknown and the evidence in support of the antithesis is circumstantial. Gammon and Hasler (1965) and Schmity and Hetfield (1965) found noticeable decreases in perch and bass populations in a 43-acre George Lake and 36-acre Corine Lake in Wisconsin, respectively, following high density (9.3-11.0 fish/acre) muskellunge stockings; however, no other forage fish was available in these lakes. In studies of northern pike, muskellunge, and their hybrids, Weithman and Anderson (1976) determined all three esocids would select clupeid or cyprinid prey in preference to centrarchids, and centrarchids over channel catfish. The muskellunge population was the highest in 1987 based on electrofishing CPUE, mail-in survey returns, and creel survey results. Creel results in 1987 determined the harvest of both black basses and crappie to be highest among the 5 creel-survey years. The available prey/predator model in 1986 indicated no deficiency in available prey (primarily gizzard shad). Largemouth bass PSD's have consistently remained >70, the RSD_{15} was $\geq$45 in 1986-87, and Wr values have remained in the acceptable range. Density of three major size groups (8.0-11.9, 12.-14.9, $\geq$15 in) of largemouth bass, based on electrofishing CPUE, displayed an upward trend from 1984-1985, with slight decreases occurring in all three size groups in 1986. This decrease was felt to be related to poor electrofishing efficiency in the abnormally dry (clear water concentration) spring of 1986. Crappie numbers and size structure in Green River Lake are being examined in separate studies. Poor year classes of crappie in 1985 and 1986 are considered to be related to environmental conditions and not a predation problem associated with muskellunge stocking (personal communication, Lance Durfey, KDFWR). Finally, the angler attitude survey revealed only 26% of all anglers opposed the muskellunge stocking program at Green River Lake, indicating the negative attitudes and concerns were not as severe as first perceived.

Muskellunge harvest is difficult to compare among water bodies since their harvest are influenced by variable rates of catch and release. For instance, a total of 72% of the legal-size muskellunge catch in Green River Lake (1987) was harvested compared to 49% at Cave Run Lake in 1987. The low release rate of 28% versus 51% at Cave Run Lake is probably related to anglers not being as willing to release legal-size fish at Green River Lake, which is expected to improve as more anglers gain experience catching legal-size muskellunge. Discounting the variability associated with catch and release, the Green River Lake harvest rate (0.12 muskellunge/acre) was intermediate among the following rates: 0.45 fish/acre in Chautanga Lake, New York (Mooradian and Shepherd 1973), 0.25 fish/acre in Lake St. Clair, Michigan (Shrouder 1973), 0.28 fish/acre in Little Green Lake, Wisconsin (Hacker 1973), 0.09 fish/acre in Cave Run Lake (Axon 1978), and 0.08 fish/acre in Pomme de Terre Reservoir, Missouri (Belusz 1978). The harvest rate of Green River Lake muskellunge by muskellunge anglers (0.02 muskellunge/hour or 50 hours/legal-size fish) also compared favorably to other studies: 61 hour/muskellunge at Lake Chautauga, New York (Mooradian and Shepherd 1973), 66.6 hour/muskellunge at Pomme de Terre Reservoir, Missouri (Beluez 1978), of 71 hour/muskellunge for eight Wisconsin lakes (Hanson 1986), and 59 hour/muskellunge for Cave Run Lake (Axon 1978). A more recent estimate of muskellunge fishing success is the use of catch rates versus harvest rates since muskellunge fisheries have become very popular to utilizing catch and release. However, values in the literature for catch rates are many times synonymously used as harvest rates precluding interpretation of this statistic. Catch and release programs ultimately increase catch rates and decrease harvest numbers by maintaining a larger number of legal-size fish in the population (Dent 1986).

The muskellunge fishery at Green River Lake continues to develop with the recruitment of more year classes; the harvest goal was achieved during the 1987 creel survey. An additional creel survey was completed on Green River Lake in 1988 following the completion of this project which also indicated the muskellunge harvest objective was achieved. The total muskellunge harvest decreased to 0.63 lb/acre in 1988 (1.22 lb/acre in 1987), but still represented a 15% addition to the total yield. Total harvest of other species simultaneously decreased due to the lower fishing pressure (20 man-hours/acre) in 1988 which was presumably a function of hot, drought conditions and the extreme clear water conditions. Most importantly, the 1988 creel results indicated a decline in harvest and catch of age 3+ muskellunge from the 1985 year class when 9 inch muskellunge were stocked, yet the sublegal catch of age 2+ muskellunge (1986 year class - 12 inch muskellunge stocked) was good. This post-project creel data provides further evidence of better survival of the larger fingerlings (>12 in) and a correlation between good muskellunge harvest and perhaps the annual muskellunge harvest is correlated with recruitment of year classes of larger muskellunge fingerlings (>12 in).

The future of the Green River Lake muskellunge fishery is contingent upon stocking muskellunge fingerlings >9 in long. The previously mentioned differences in survival to age 1+ between stockings of 8-10 and 12-14 in muskellunge support the need to provide more consistent year classes by stocking muskellunge ≥12 inches in the fall. Both observed and calculated differences in survival dictate the larger fingerlings should be stocked, yet this survival must be balanced with production costs. Based on forage alone, approximately 3.3 9-in muskellunge can be reared for every 12-13 in muskellunge (from the 9.0

in size), yet a reduced stocking rate in the lake (utilizing 12-13 in muskellunge) would equate to nearly equal poundage as currently being produced with no additional cost (personal communication, Dan Brewer, KDFWR). The population simulation (No. 2) utilizing an alternating stocking rate of 1,864 and 3,449 12-in muskellunge each year predicted a yield with slightly greater numbers and pounds of muskellunge than the current stocking regime. The relative difference in the model was associated with the higher calculated overwinter survival for 12-in muskellunge versus 9-in muskellunge. Confidence in this survival estimate is low since an estimate could only be calculated for one year class. Annual growth rates for large and small fingerlings were similar and there is no reason to suspect a difference (0.32 versus 0.63) in overwinter survival of this magnitude. Monthly mortality estimates were not generated but most of the mortality for 9 in fish was suspected to occur in the first 30-60 days following stocking. Based on this limited data, the Green River Lake muskellunge population should be tracked following the stocking of a minimum of two-year classes of each suggested stocking number (total of 4 year classes).

The option of modifying existing minimum size limit restriction was also examined under various stocking regimes. Higher size limits, as expected, would produce higher yields in weight, but sacrifice numbers. The current objective is solely based on harvest in terms of weight and modification of objectives and angler attitudes would be necessary before any modification of size limits are considered. A higher rate (>28%) of catch and release of legal-size muskellunge is expected to eventually parallel the level of approximately 50% observed at Cave Run Lake, which will serve to reduce angler mortality on fish 30 in and longer.

CONCLUSIONS

The muskellunge fishery at Green River Lake met our harvest objective in 1987 following the stockings of larger (>9 in) muskellunge beginning in 1982. A significant difference in survival of 12-14 in versus 8-10 in muskellunge was observed presumably due to lower predation and cooler water temperatures during the fall stocking. Growth of both size classes of muskellunge was similar with most fish attaining the legal-size (30 in) at age 2+. No negative impacts on other major sport fishes (black basses and crappie) and the forage base (gizzard shad) was measurable or felt to be related to muskellunge stockings. Negative attitudes toward muskellunge stockings were not as severe as perceived and the stockings were increasing fishing opportunities by providing a trophy fishery and diversifying the fishery.

RECOMMENDATIONS

Continue maintenance stockings of muskellunge since any natural reproduction will be inadequate to support a fishery.

Stock larger muskellunge (12 in) in the fall of the year at the present level of hatchery capabilities (x = 3,449) on even-number years and stock equivalent size fish on the odd-number years at a rate of 1,860 muskellunge year.

Fin-clip all muskellunge for the next 4 years with a separate clip for each year class and clip a minimum of 2 year classes from each stocking rate. Fin-clips will avoid any aging problems which have plagued this project.

Conduct intensive electrofishing in the fall (post stocking) and spring to compare the survival of the two stocking rates.

Conduct a minimum of 2 years of creel surveys beginning in 1992 when the first year class of reduced stocking recruits into the fishery to relate relative survival of the two stocking rates to the contribution of the creel and to compare to the simulation results.

Promote both the wise use of the muskellunge fishery at Green River Lake through educational and public relations programs and the use of catch and release with proper handling techniques.

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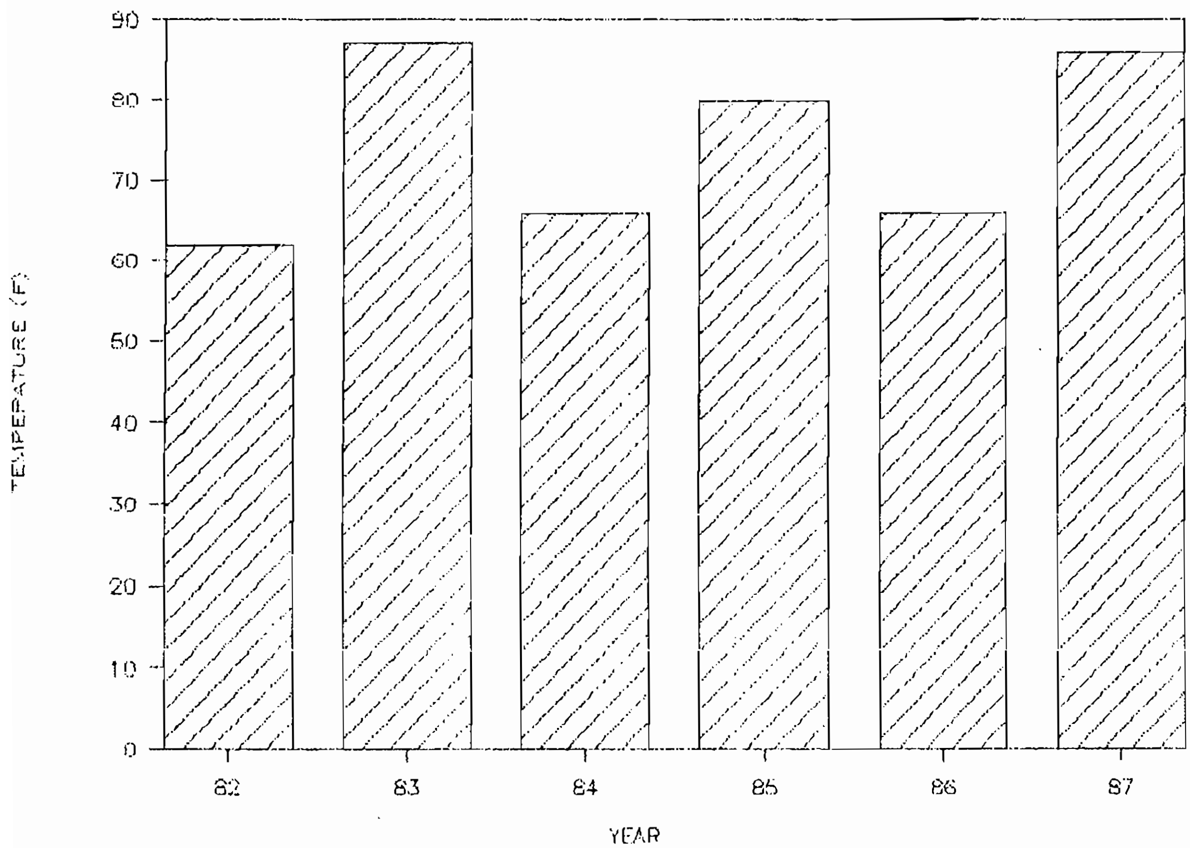

Figure 1. The average surface temperature at Green River Lake during the stocking period for muskellunge from 1982-1987.

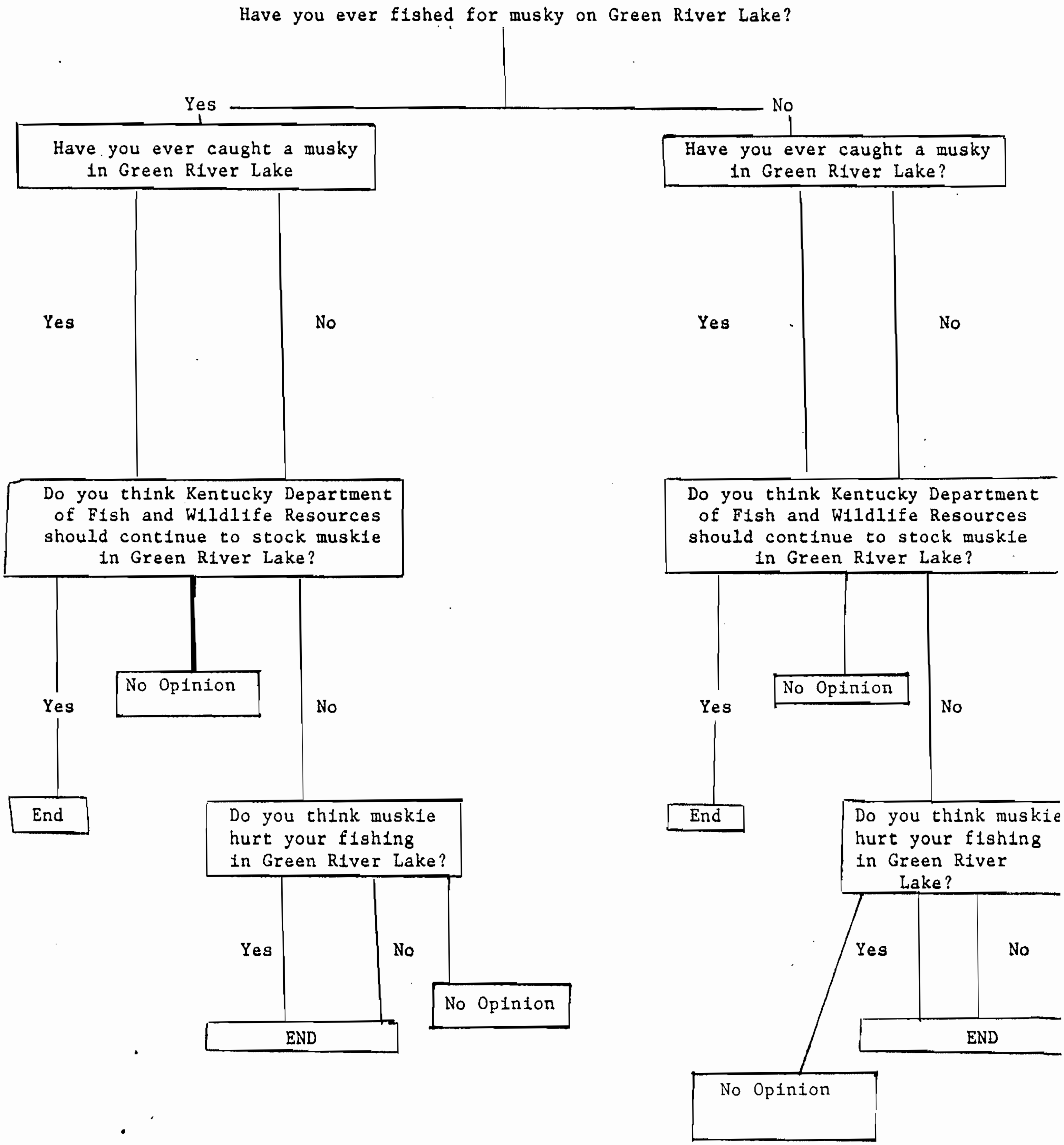

Figure 2. Sample questionnaire utilized by Green River Lake creel clerk in 1987 to survey angler opinions regarding the musky stocking program.

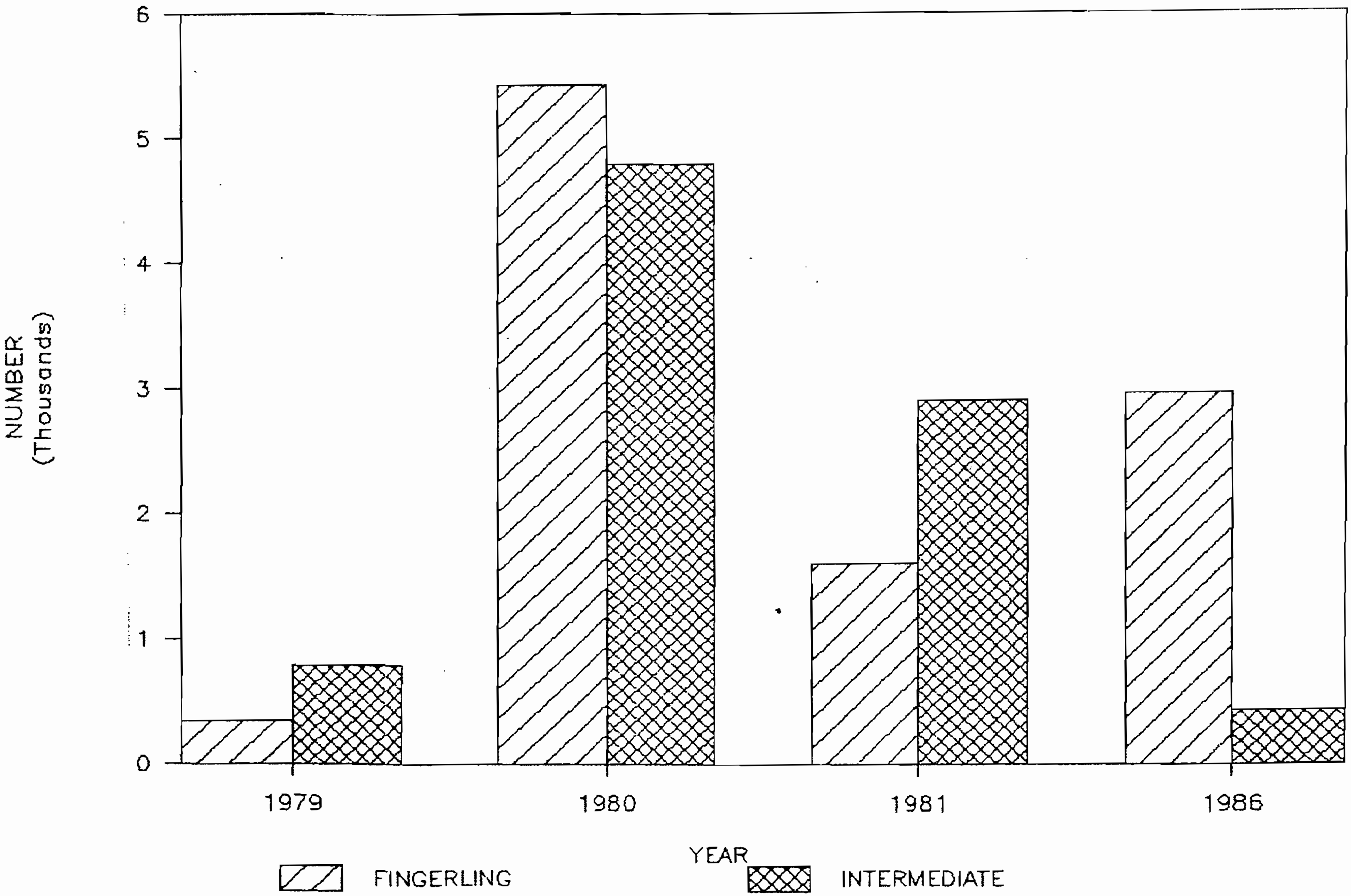

Figure 3. Fingerling and intermediate-size gizzard shad numbers derived from cove-rotenone studies at Green River Lake, 1979-1981, 1986.

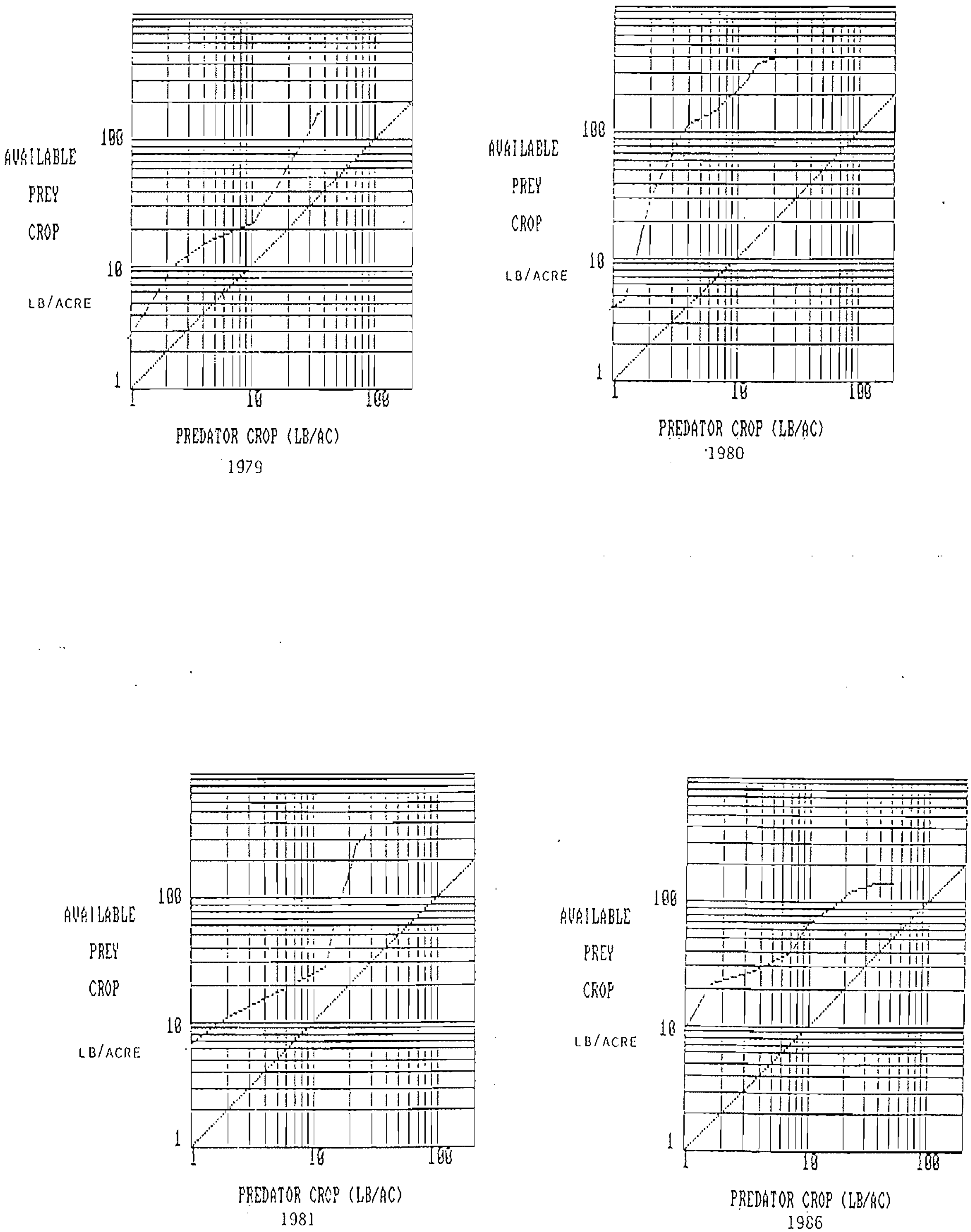

Figure 4. Available prey/predator (AP/P) plots by year of cove-rotenone studies conducted in Green River Lake (1979-1981, 1986).

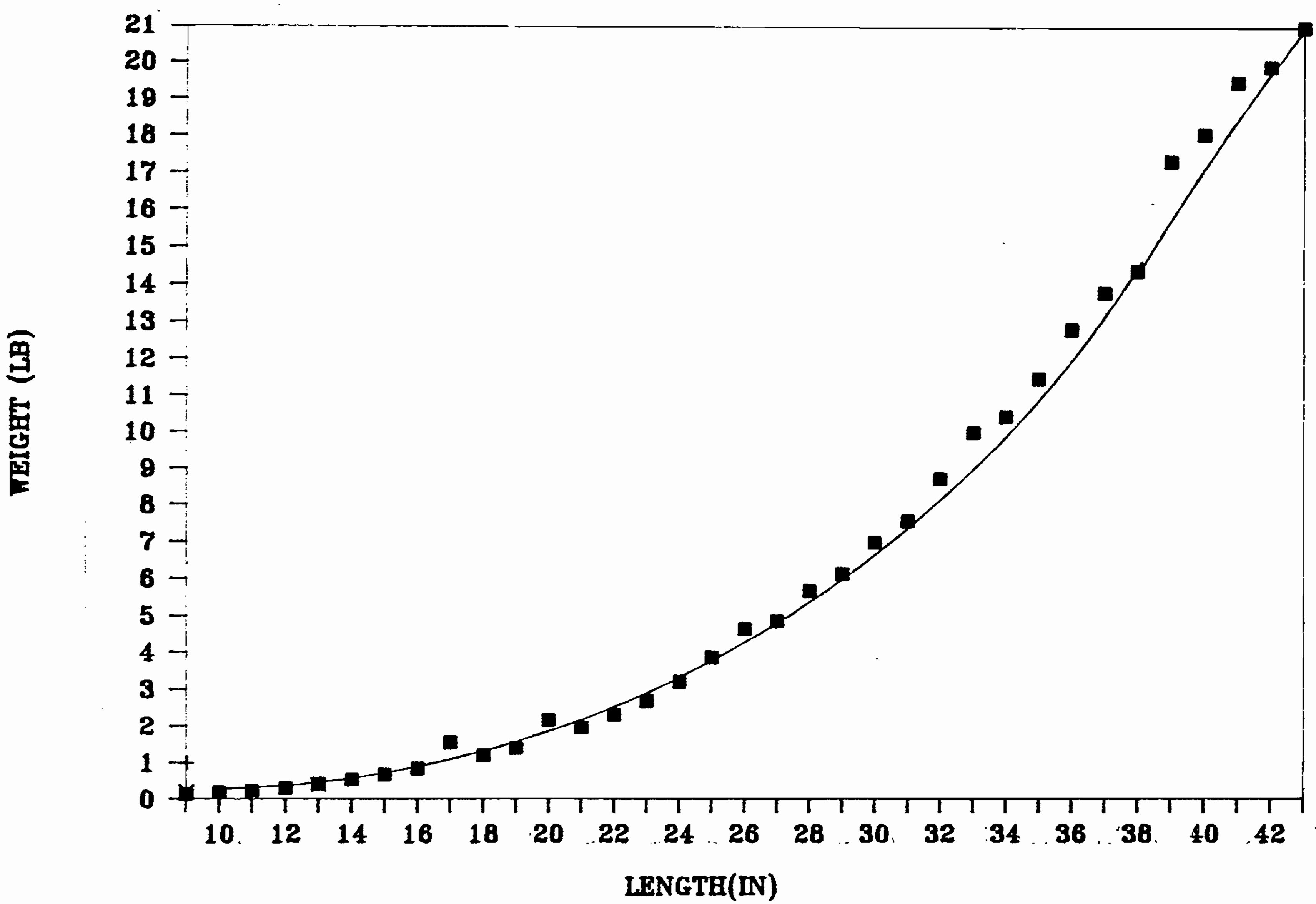

Figure 5. Length-weight relationship for muskellunge in Green River Lake, 1979-1987.

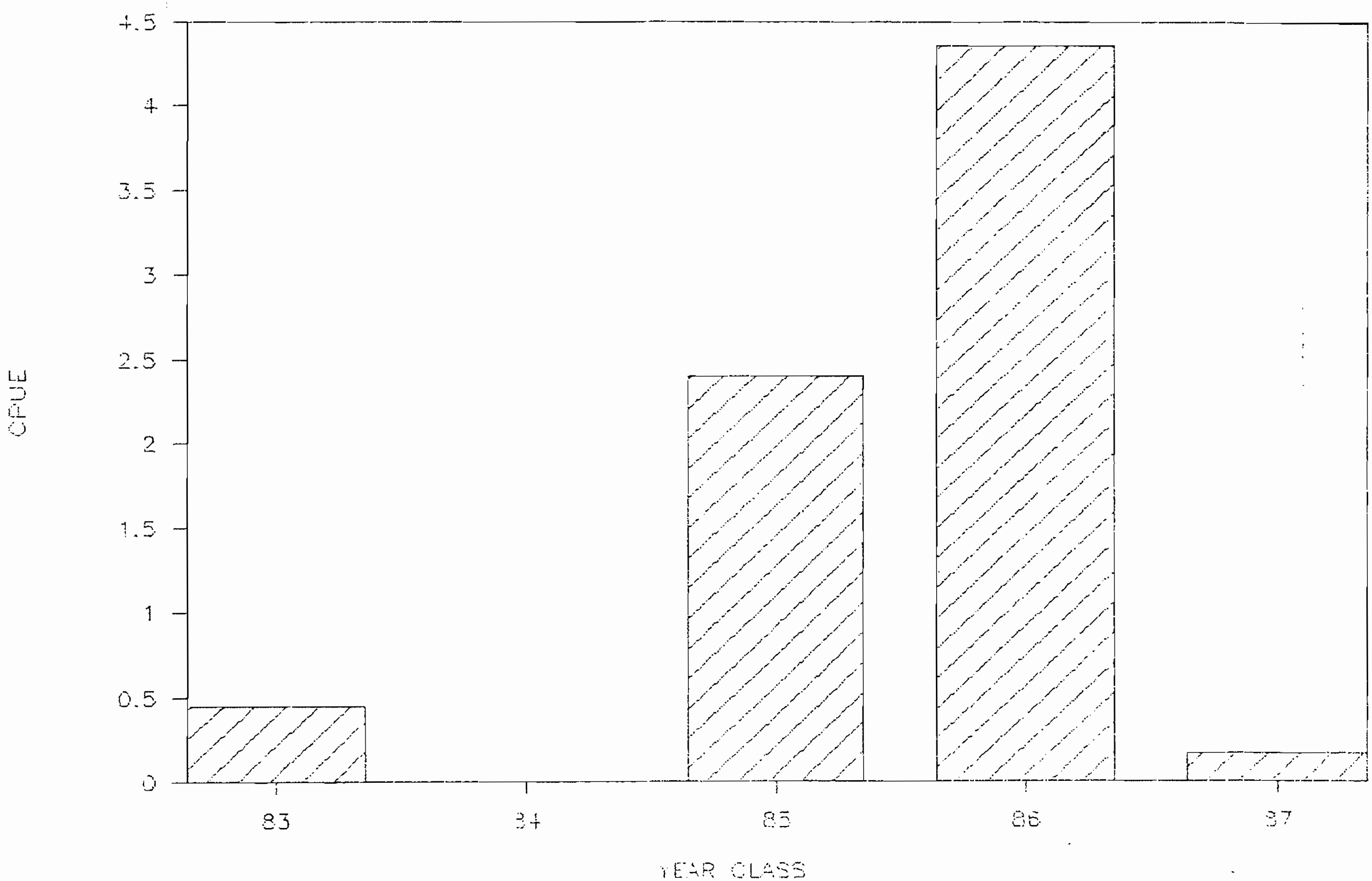

Figure 7. Fall electrofishing CPU for Age 0 muskellunge at Green River Lake, 1983-1987.

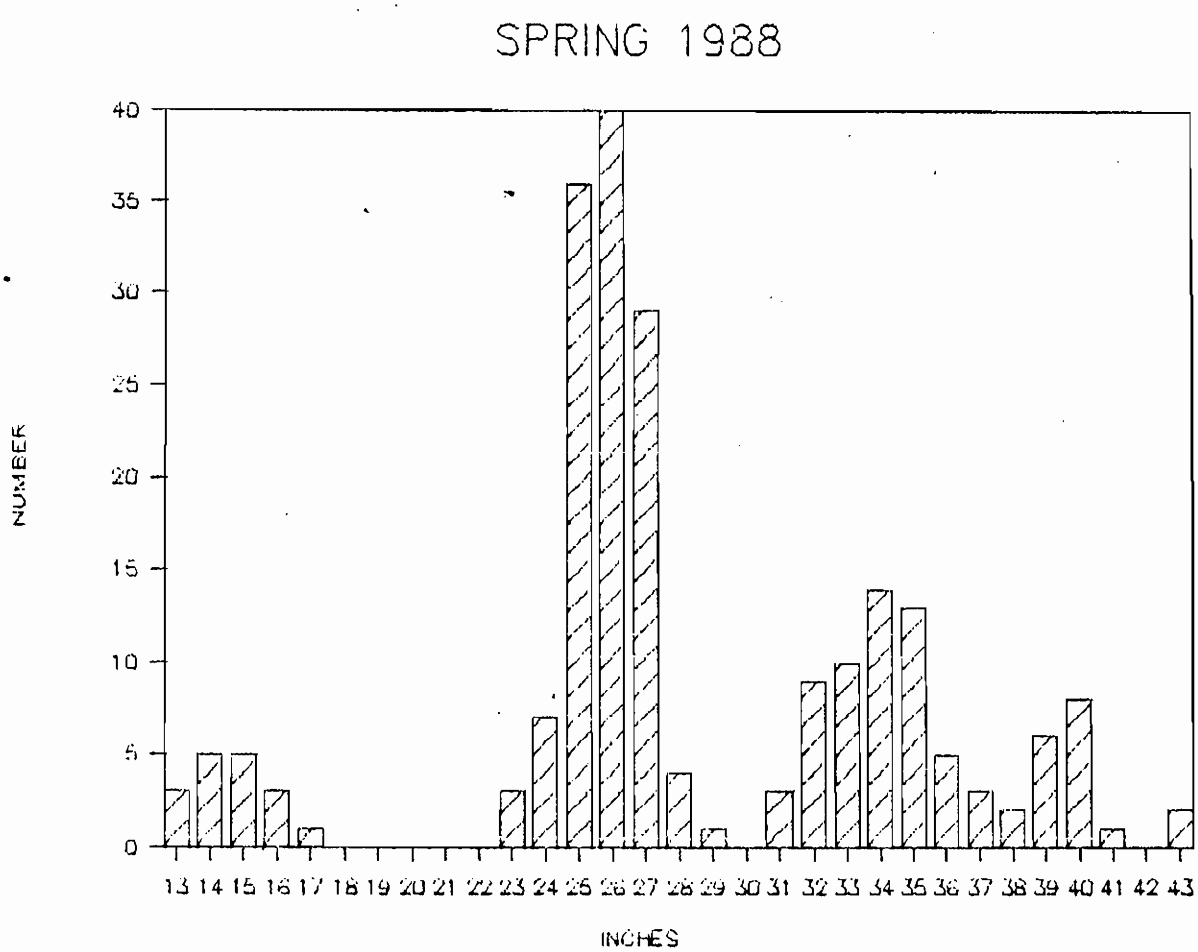

Figure 6. Muskellunge length distribution derived from the spring 1988 electrofishing sample in Green River Lake.

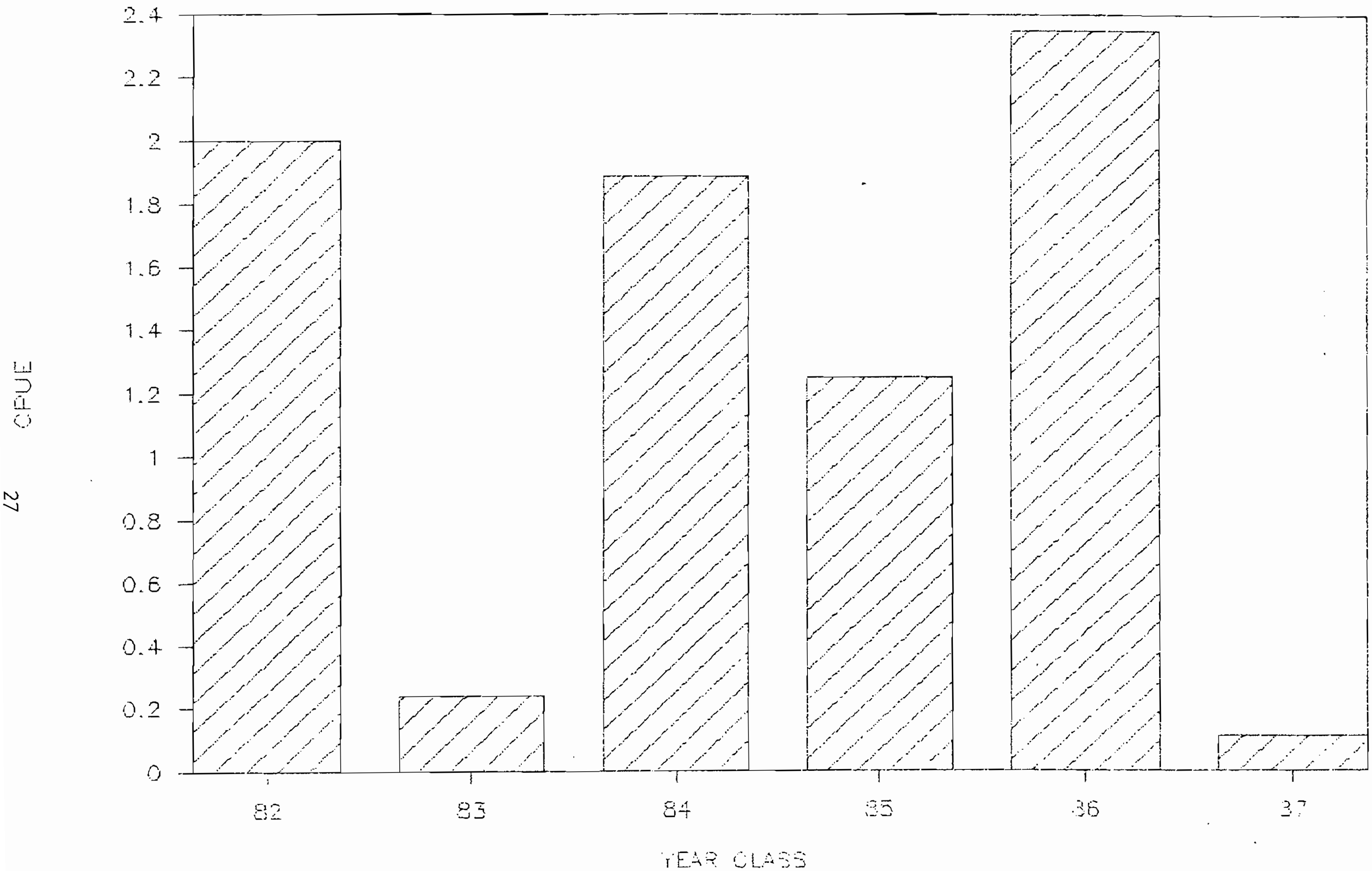

Figure 8. Spring electrofishing CPU for Age 1+ muskellunge at Green River Lake, 1982-1986.

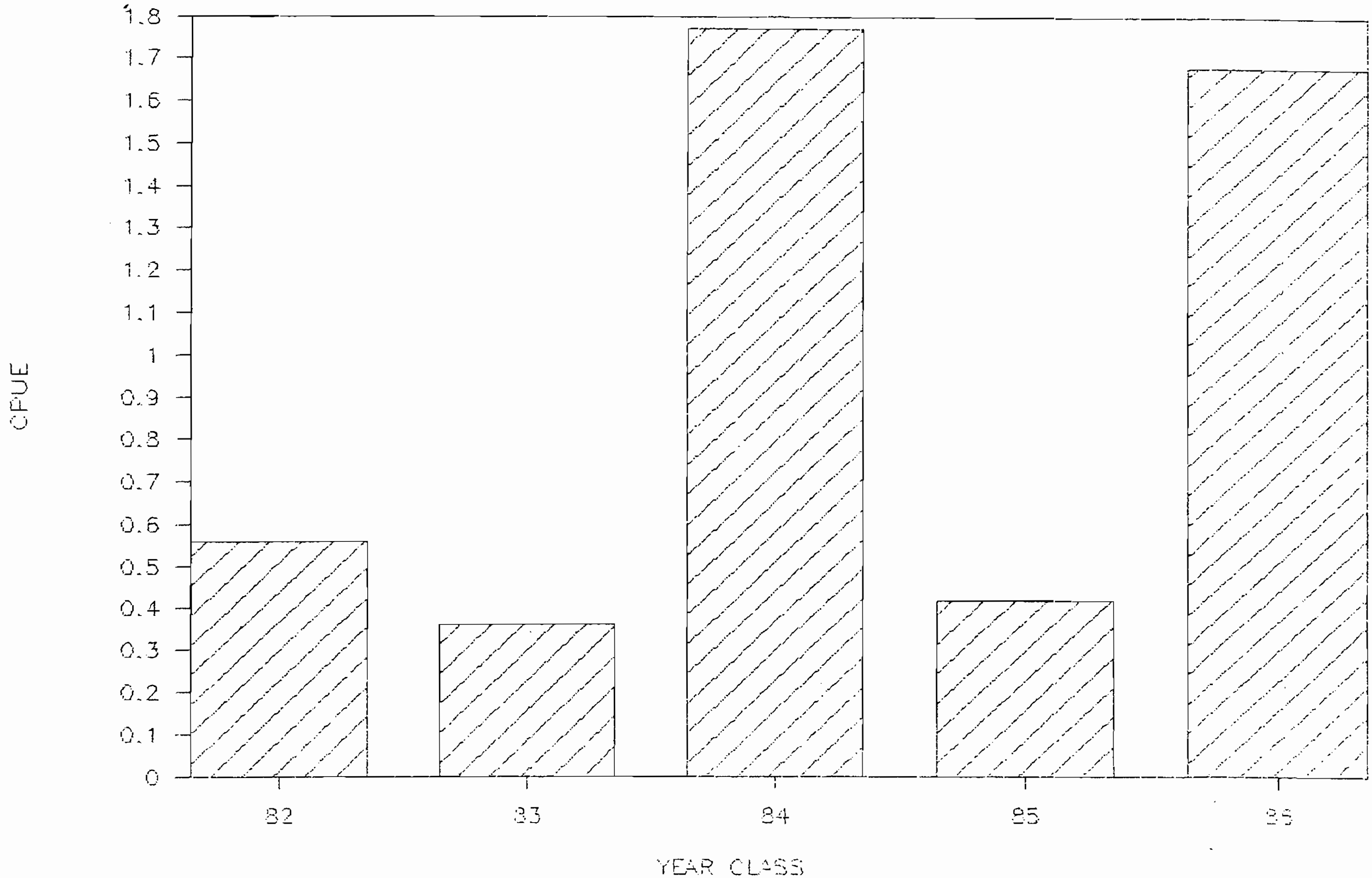

Figure 9. Fall electrofishing CPU for Age 1+ muskellunge at Green River Lake, 1982-1986.

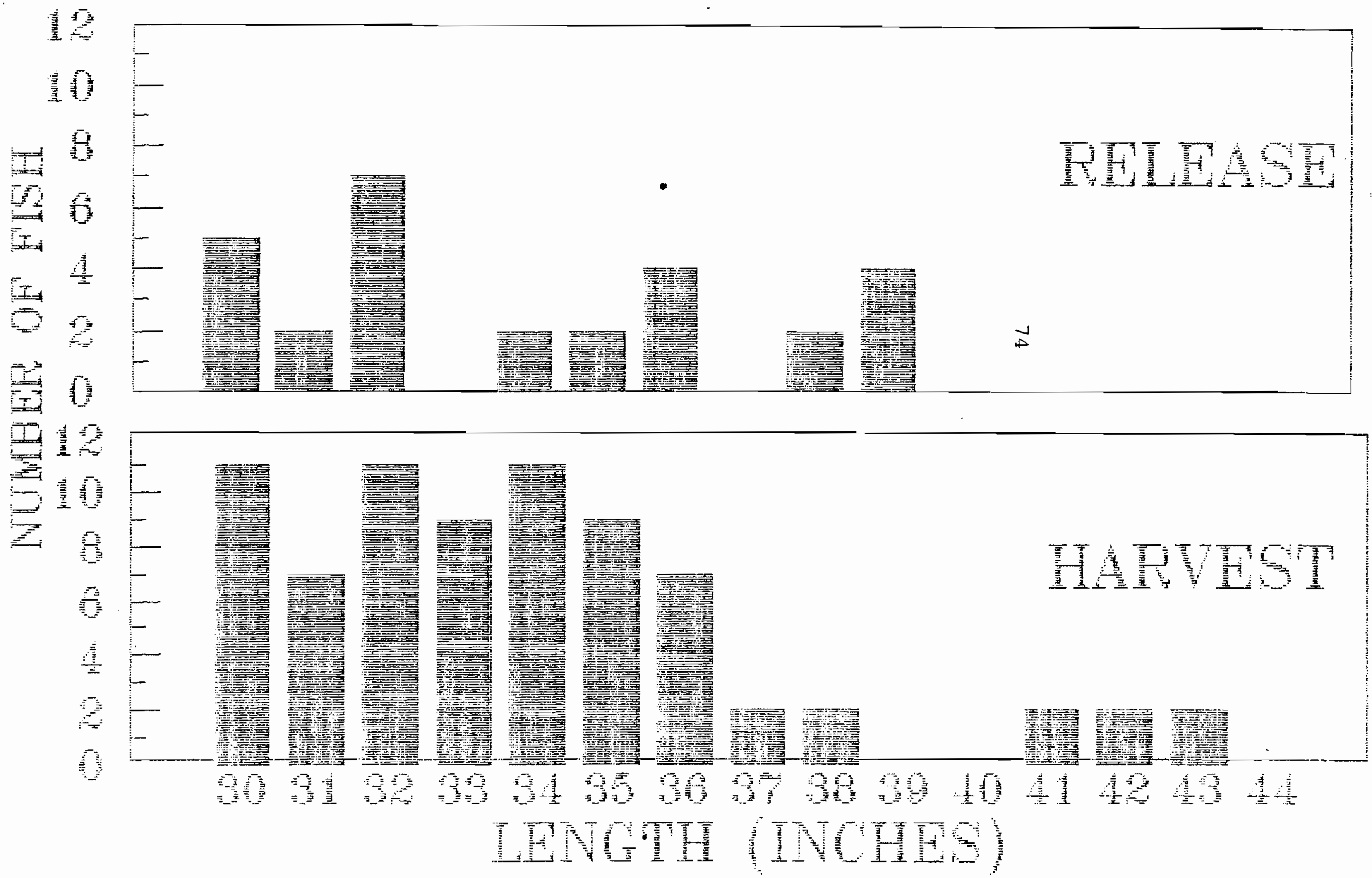

Figure 10. Length-frequency of muskellunge in the Green River Lake creel survey, 1987.

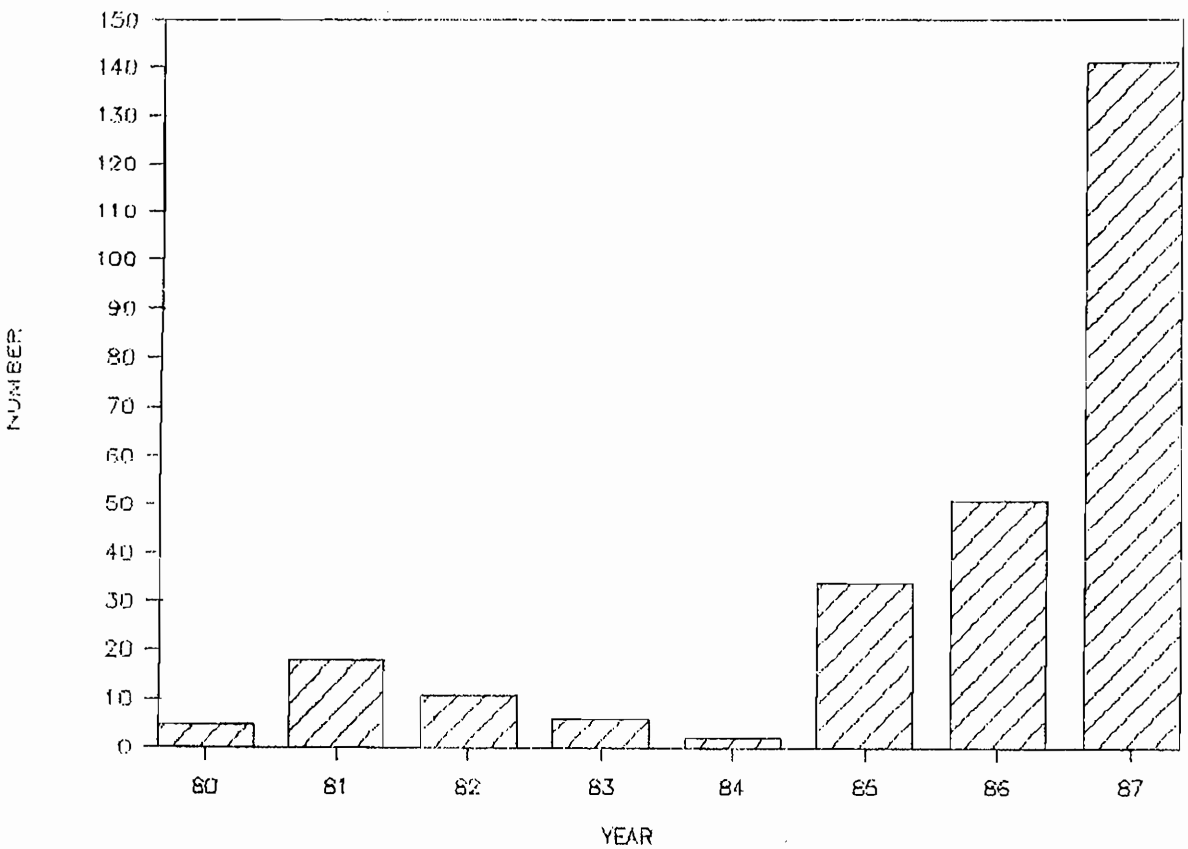

Figure 11. Mail-in survey muskellunge returns from Green River Lake, 1980-1987.

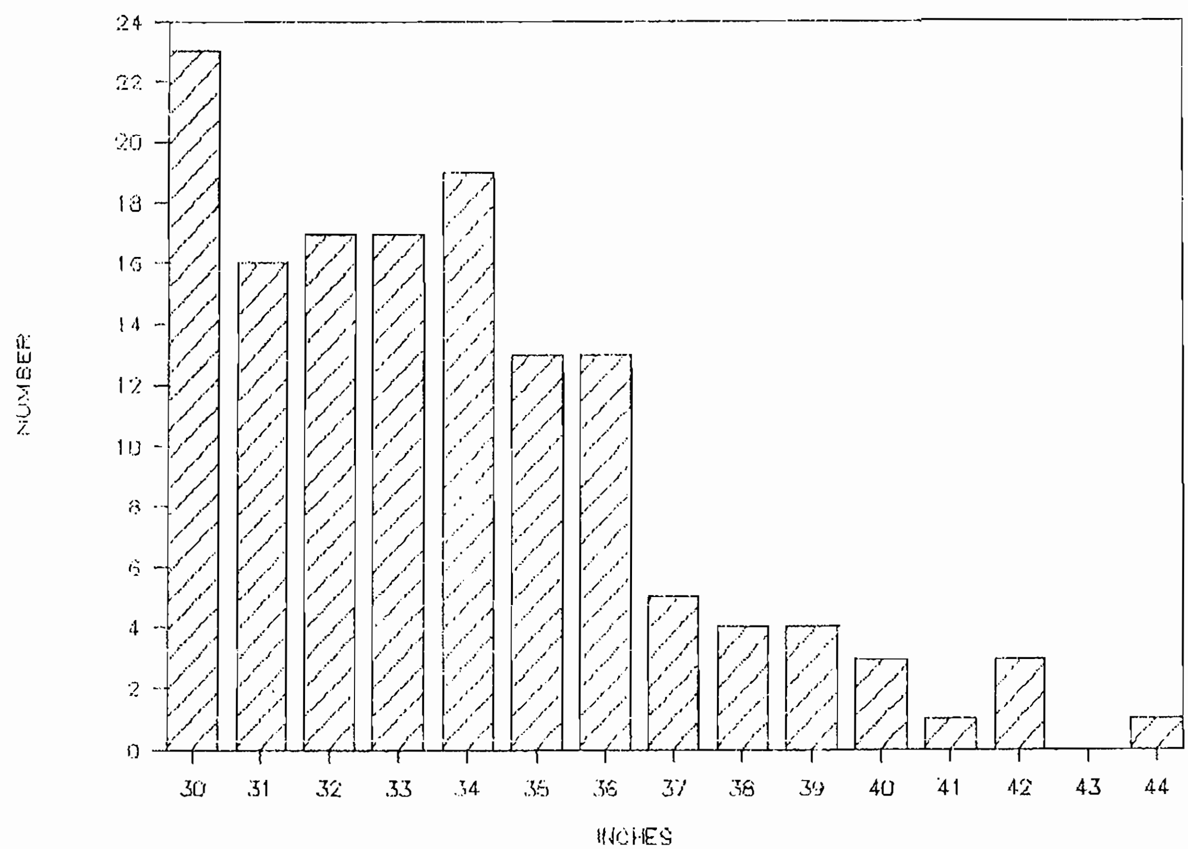

Figure 12. Length-frequency of 1987 mail-in survey returns for muskellunge from Green River Lake, 1987.

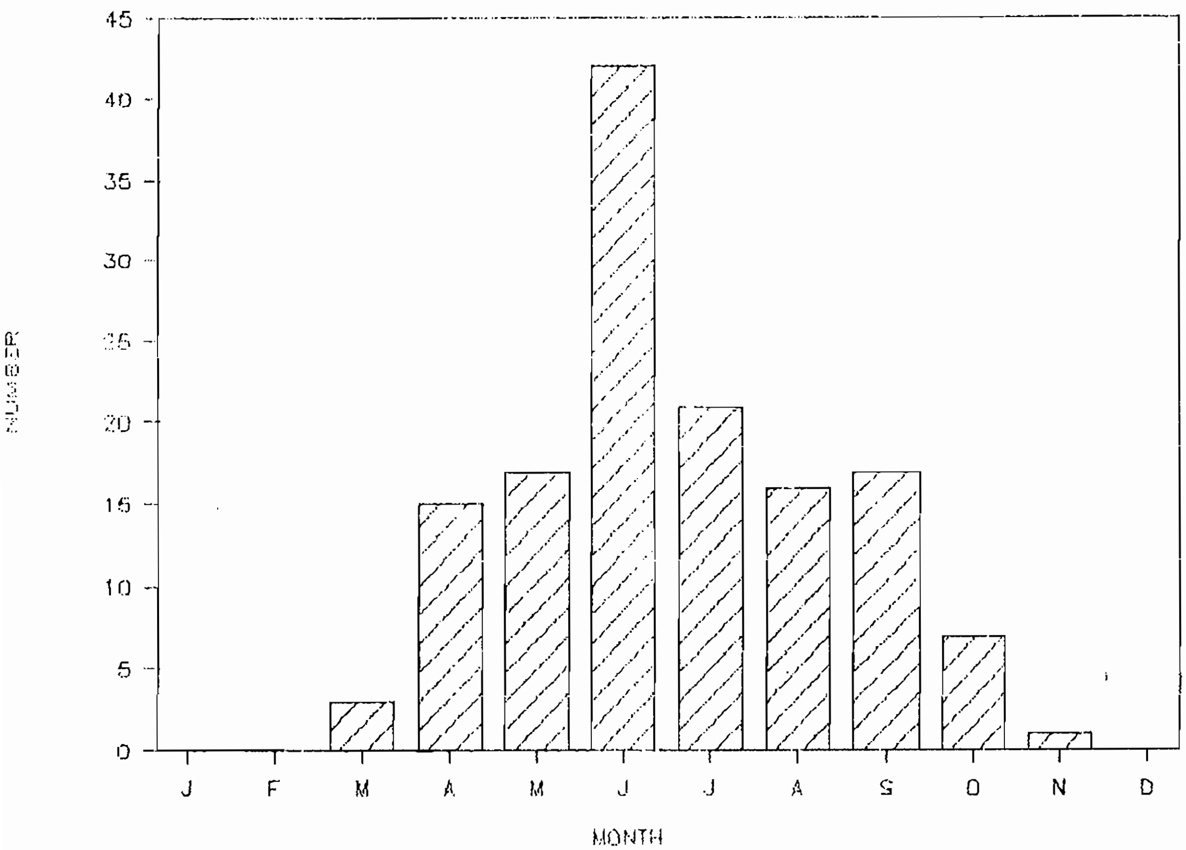

Figure 13. Monthly distribution of mail-in survey returns for muskellunge from Green River Lake, 1987.

Table 1. Muskellunge and tiger muskellunge stockings in Green River Lake (8,210 a).

	Year	Number	No./acre	Length(in) ($\bar{x}$ length)	Number/lb
Muskellunge	1977	6,182	0.8	5.8 - 7.8	---
Muskellunge	1978	8,325	1.0	6.0 - 8.0	16.0 - 20.5
Tiger muskellunge	1979	8,213	1.0	6.0 - 6.5	25.0
Tiger muskellunge	1980	9,008	1.1	6.1 - 6.9	18.4
Tiger muskellunge	1981	8,340	1.0	6.2 - 6.9	17.0 - 23.5
Muskellunge	1982	1,554	0.2	13.4 - 13.6 (13.5)	2.2 - 2.3
Muskellunge	1983	4,096	0.5	8.0 - 9.5 (8.9)	7.4 - 11.0
Muskellunge	1984	3,528	0.4	12.3	4.0
Muskellunge	1985	8,512	1.0	8.0 - 10.0 (9.2)	7.2 - 8.3
Muskellunge	1986	3,406	0.4	13.4	2.3
Muskellunge	1987	8,299	1.0	8.3 - 8.6 (8.4)	9.7 - 10.6

Table 2. Standing crop values (lb/acre) derived from cove-rotenone samples collected in Green River Lake from 1979-1981 and 1986.

	1979	1980	1981	1986
GAME FISHES				
Muskellunge	1.58	1.57		18.67
Tiger muskellunge		0.02		
White bass	0.69	0.15	0.57	1.07
Largemouth bass	7.05	6.65	6.66	4.93
Smallmouth bass	0.90	2.36	1.05	
Spotted bass	4.72	2.11	3.79	2.76
Black crappie			0.04	
White crappie	8.17	11.26	17.99	2.96
Grass pickerel			0.01	0.02
Total	23.11	24.12	30.11	30.41
FOOD FISHES				
Channel catfish	6.22	5.49	3.68	18.38
Flathead catfish	3.71	0.26	0.84	2.42
Total	9.93	5.79	4.52	20.80
PREDATOR FISHES				
Longnose gar	0.03		0.09	
Total	0.03		0.09	
PISCIVOROUS TOTAL	33.11	29.86	34.72	51.21
PANFISHES				
Rockbass		0.05	0.06	
Bluegill	18.53	13.56	29.17	13.17
Green sunfish	0.21	0.50	1.26	1.02
Longear sunfish	12.09	8.51	11.13	9.39
Warmouth	4.04	2.83	4.17	1.99
Hybrid sunfish	0.01			
Total	34.89	25.42	45.79	25.57
COMMERCIAL FISHES				
Hogsucker	0.58	0.46	0.31	0.09
Redhorse sucker	9.66	10.49	10.18	10.79
Spotted sucker	5.86	1.97	6.27	7.77
Carp	55.77	42.69	46.11	61.04
Bullhead	0.21		t	0.05
Drum				0.56
Total	72.08	55.10	67.88	80.30
FORAGE FISHES				
Gizzard shad	68.21	246.88	161.40	39.88
Shiners		0.06		0.01
Misc. cyprinids	0.11	0.21	0.10	0.70
Top. minnows			t	
Madtom	0.26	0.35	0.53	0.23
Darters	0.96	0.93	2.53	3.44
Orangespotted sunfish			t	
Brook silverside	0.13	0.37	0.11	0.53
Goldfish	0.20			
Total	69.87	248.80	164.77	44.81
NON-PISCIVOROUS TOTAL	176.87	329.32	273.44	150.68
GRAND TOTAL	209.96	359.18	308.16	201.89

t $<$ 0.01 lb

Table 3. Number and pounds per acre by size group of the three species of black bass in Green River Lake derived from cove-rotenone studies.

Species	Size group[a]	1979 No.	1979 Lb(%)	1980 No.	1980 Lb(%)	1981 No.	1981 Lb(%)	1986 No.	1986 Lb(%)	$\bar{x}$ No.	$\bar{x}$ Lb(%)
Largemouth bass	Fingerling	92	0.98	135	1.13	105	0.95	179	1.27	128	1.08
	Intermediate	13	2.80	18	3.18	18	2.94	9	1.10	15	2.51
	Harvestable	2	3.27	2	2.33	1	2.77	2	2.54	2	2.72
	Total	107	7.05 (55.3)	155	6.65 (59.8)	124	6.66 (57.9)	190	4.93 (64.1)	145	6.31 (58.8)
Spotted bass	Fingerling	101	0.65	87	0.61	47	0.42	50	0.38	71	0.52
	Intermediate	17	2.50	8	1.18	21	3.22	10	2.17	14	2.27
	Harvestable	2	1.57	t	0.32	t	0.15	t	0.21	1	0.56
	Total	120	4.72 (37.3)	95	2.11 (19.0)	68	3.79 (33.0)	61	2.76 (35.9)	86	3.35 (31.2)
Smallmouth bass	Fingerling	3	0.01	24	0.28	10	0.12			9	0.10
	Intermediate	1	0.26	3	0.65	5	0.93			2	0.46
	Harvestable	1	0.63	1	1.43					1	0.51
	Total	4	0.90 (7.1)	28	2.36 (21.2)	15	1.05 (9.1)			12	1.07 (9.9)

[a]Fingerling = 1-4 inch group; Intermediate = 5-11 inch group; and harvestable ≥12 inch class.

t < 0.4 fish/acre.

Table 4. Summary of fish caught by experimental gill netting for muskellunge in Green River Lake during 1979 and 1980.

Species	1979		1980	
	No.	%	No.	%
Muskellunge	1	t		
White bass	21	2	7	4
Largemouth bass	3	t	1	t
Spotted bass	7	1	7	4
White crappie	408	45	65	35
Bluegill	12	1	1	t
Warmouth	2	t	11	6
Longear sunfish	3	t	1	t
Channel catfish	195	21	30	16
Flathead catfish	2	t		
Golden redhorse	12	1	7	4
Black redhorse	3	t		
Shorthead redhorse			1	t
Northern hog sucker	2	t		
Spotted sucker	2	t	2	t
Carp	203	22	28	15
Black bullhead	3	t		
Yellow bullhead	1	t		
Longnose gar	7	1		
Gizzard shad	15	2	27	14
Logperch	10	1		
Total	912		188	

t < 0.5%.

Table 5. Back-calculated length (in) at age for muskellunge from Green River Lake.

		Age					
		1	2	3	4	5	6
1987	1	13.3					
1986	75	14.8	25.9				
1985	92	13.8	27.0	31.9			
1984	150	15.1	25.2	30.5	34.6		
1983	66	15.1	26.1	31.5	34.8	38.4	
1982	42	15.1	25.4	33.6	34.7	38.2	41.1
1979	3	14.4	22.5	27.6	33.0	36.0	39.0
1978	14	14.0	25.1	30.7	34.8	37.2	
1977	3	13.0	22.7	27.4			
Mean		14.8	25.8	31.6	34.7	38.1	40.7
Number	446	446	288	161	86	17	5
Smallest		10.1	18.4	23.5	31.3	35.9	39.0
Largest		19.8	29.3	34.9	39.4	42.5	43.0
Std. error		0.10	0.14	0.63	0.17	0.46	0.77
95% ConLo		14.5	25.4	30.1	34.4	37.1	38.7
95% ConHi		14.9	26.0	32.6	35.0	39.1	42.7

Table 6. Muskellunge catch by inch group based on electrofishing at Green River Lake 1979-1988.

	Inch group																																						Description
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	Total	CPUE	Time (h)	No. sighted	of sighted fish
Fall 1979														1		1			1																	3		1.0	1	1
Spring 1980																	3			1																4		a		
Fall 1980															1				1			1														3		a		
Spring 1981																																				0		15.0	2	1 >30 in 1 sublegal
Fall 1981																																				0		10.0		
Spring 1982																																				0		8.4		
Spring 1983				2	1	4	6	2	1																				1		1					18	2.25	8.0	14	13 1982 yc 1 >30 in
Fall 1983		2	1	1									2		1	2											1									11	1.24	8.9	10	3 - 1982 yc 1 - 1983 yc 6 - unknown
Spring 1984						2	1			1				1		1	1	1																		8	0.66	12.2	3	2 - 1983 yc 1 - 1982 yc
Fall 1984[b]													1		3		1		2																	7	0.51	13.7	3	3 - 1984 yc
Spring 1985			4	8	18	16	1								2	2	1	2	3	2	4	4														67	2.69	24.9	37	22 - 1984 yc 10 - 1983 yc 3 > 30 in 2 unknown
Fall 1985	4	16	9	10	3					1		1	6	11	6	5	1					1	2	2	2											80	4.57	17.5	46	28 - 1985 yc 16 - 1984 yc 2 >30 in

Table 6 continued.

	Inch group																																						Description of
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	Total	CPUE	Time (L)	No. sighted	sighted fish
Spring 1986					2	4	6	3	5			1		1	1	2	8	9	4	1	2				1	2	3									55	3.44	16.0	15	10 - 1985 yc 14 - 1984 yc 1 >30 in
Fall 1986							73										1	3	1	2		3	1		3			1								88	5.23	16.8	7	5 - >30 in 2 - 1985 yc
Spring 1987				10	19	25	20	8	4	1							4	10	21	5	6	5	6	13	9	7	7	1		1	1					183	4.96	36.9	92	56 - 1986 yc 17 - 1985 & 84 yc
Fall 1987			2	2	1				1		1		8	11	15	10	5	1					3	3	2	4	2	2								73	2.36	30.9	14	10 - 1986 yc 4 - >30 in
Spring 1988				3	5	5	3	1						3	7	36	40	29	4			3	9	10	14	13	5	3	2	6	8	1		2		213	2.60	81.9	50	24 - 1986 yc 7 - 1987 yc 19 >30 in 1 unknown

[a]Time not recorded

[b]Sample taken prior to stocking of the 1984 year class

Table 7. Muskellunge populations simulations based on various stocking numbers size-limit restrictions.

	1		2		3		4		5		6		7		8		9	
	Current stocking regime 30" size limit		Suggested stocking regime 30" size limit		Stocking large musky each year 36" size limit		Stocking large musky each year 38" size limit		Stocking large musky at reduced rate 36" size limit		Stocking large musky at reduced rate 38" size limit		Stocking large musky at average between (1,864 & 3,449) 30" size limit		Stocking large musky at average between (1,864 & 3,449) 36" size limit		Stocking large musky at average between (1,864 & 3,449) 38" size limit	
	Year		Year		Year		Year		Year		Year		Year		Year		Year	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Size of stocking	9 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in	12 in
Stocking number	8,200	3,449	1,864	3,449	3,449	3,449	3,449	3,449	1,864	1,864	1,864	1,864	2,657	2,657	2,657	2,657	2,657	2,657
Survival to Fall	x0.12	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53	x0.53
(Based on literature)	984	1,838	933	1,839	1,839	1,839	1,839	1,839	1,839	1,839	1,839	1,839	1,416	1,416	1,416	1,416	1,416	1,416
Survival to Spring	x0.32	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63	x0.63
(Based on study data)	314	1,158	626	1,158	1,158	1,158	1,158	1,158	626	626	626	626	892	892	892	892	892	892
Predicted Yield (Ricker) No.	164	604	326	604	469	469	347	347	253	253	188	188	465	465	361	361	267	267
Weight (lb)	1,749	6,454	3,489	6,454	6,367	6,367	5,872	5,872	3,442	3,442	3,174	3,174	4,971	4,971	4,905	4,905	4,523	4,523
Total Yield (2 yrs) No.	768		930		938		694		506		376		930		722		534	
Lb.	8,203		9,943		12,734		11,744		6,884		6,348		9,942		9.810		9 046	

Table 8. Angler response to 1987 muskellunge opinion survey conducted on Green River Lake.

	Muskellunge angler		Non-muskellunge angler		All angler	
	No.	%	No.	%	No.	%
Number	159	18.2	715	81.8	874	100.0
Musky caught	100	62.9	168	23.5	268	30.7
Musky not caught	59	37.1	547	76.5	606	69.3
Should stock	116	72.9	343	48.0	459	52.5
Should not stock	21	13.2	208	29.1	229	26.2
No stocking opinion	22	13.9	164	22.9	186	21.3
*Musky do cause damage	24	55.8	178	47.8	202	48.7
*Musky do not cause damage	10	23.2	101	27.2	111	26.7
*No damage opinion	9	21.0	93	25.0	102	24.6

*Percentages based on totals from should not stock and no stocking opinion categories only.

Table 9. Sport fish harvest, and fishing pressure (man-h/acre) for principal species in Green River Lake 1980-1982, 1987 and (in parentheses are per acre values).

	Black basses	White bass	Crappie	Sunfish	Musky	Catfish	Carp	Total
1979								
No.	5,087 (0.62)	2,447 (0.30)	10,271 (1.25)	1,164 (0.14)		1,005 (0.12)	163 (0.02)	20,137 (2.46)
%	25.3	12.2	51.0	5.8		5.0	0.8	
Lb	12,057 (1.47)	4,024 (0.49)	7,329 (0.89)	163 (0.02)		4,368 (0.53)	287 (0.04)	28,228 (3.44)
%	42.7	14.3	26.0	0.6		15.5	1.0	
Pressure								21.9
1980								
No.	4,583 (0.56)	5,576 (0.68)	28,370 (3.46)	5,843 (0.71)	40 (t)	309 (t)		44,722 (5.45)
%	10.2	10.5	63.4	13.1	0.1	0.7		
Lb	8,797 (1.07)	9,754 (1.19)	11,378 (1.39)	1,083 (0.13)	381 (0.05)	1,092 (0.13)		32,485 (3.96)
%	27.0	30.0	35.0	3.3	1.2	3.4		
Pressure								23.7
1981								
No.	6,506 (0.79)	7,963 (0.97)	129,942 (15.85)	28,203 (3.44)	42 (0.01)	1,405 (0.17)	1,458 (0.18)	175,519 (21.4)
%	3.7	4.5	74.0	16.1	t	0.7	0.8	
Lb	10,873 (1.33)	9,185 (1.12)	49,157 (5.99)	5,117 (0.62)	441 (0.05)	2,356 (0.29)	2,461 (0.30)	79,590 (9.71)
%	13.7	11.5	61.8	6.4	0.6	3.0	3.1	
Pressure	7.80	1.01	9.34	0.98	0.23	0.10	0.13	21.1
1982								
No.	5,128 (0.62)	19,170 (2.34)	183,917 (22.43)	11,676 (1.42)	39 t	872 (0.10)	725 (0.09)	221,527 (27.0)
%	2.3	8.7	83.0	5.3	t	0.4	0.3	
Lb	8,244 (1.00)	17,261 (2.11)	74,181 (9.05)	2,206 (0.27)	632 (0.08)	1,811 (0.22)	1,356 (0.17)	105,681 (12.9)
%	7.8	16.3	70.2	2.1	0.6	1.7	1.3	
Pressure	5.03	1.35	9.32	0.60	0.16	0.12	0.12	17.2
1987								
No.	6,878 (0.84)	12,345 (1.50)	222,654 (27.12)	59,089 (7.20)	1,014 (0.12)	8,884 (1.08)	1,369 (0.17)	312,504 (38.06)
%	2.2	4.0	71.2	18.9	0.3	2.8	0.4	
Lb	11,561 (1.41)	9.021 (1.10)	52,739 (6.42)	8,069 (0.98)	10,047 (1.22)	8,792 (1.07)	3,904 (0.5)	104,364 (12.71)
%	11.1	8.6	50.5	7.7	9.6	8.4	3.7	
Pressure	8.96	2.91	15.54	3.02	3.38	1.71	0.33	38.9

t ≤ 0.05%, 0.05/acre

Table 10. Monthly harvest of muskellunge in Green River Lake during 4 March through 28 November 1987.

Month	No.	Lb	Average length (in)	Average weight (lb)
March	46	388.2	33.0	8.68
April	146	1,345.1	33.6	9.19
May	201	1,928.7	34.0	9.60
June	210	1,843.0	33.1	8.79
July	260	2,322.4	33.3	8.94
August	86	1,624.2	41.5	18.82
September	12	90.8	32.0	7.82
October	50	468.3	33.7	9.28
November	5	35.8	32.0	7.82

Table 11. Monthly harvest by year class of muskellunge in Green River Lake derived from a creel survey conducted 4 March through 28 November 1987.

Year class	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total no.	%
1983	23	84	86	26	26	86		17		348	34.3
1984	22	62	115	158	156			33	5	551	54.3
1985				26	78		12			116	11.4
Total	45	146	201	210	260	86	12	50	5	1,015	

Table 12. Comparisons of muskellunge lengths (in) at age with this study.

	Age									
	1	2	3	4	5	6	7	8	9	10
Wisconsin (Johnson 1971)		15.5	23.2	26.8	29.5	32.6	34.2	36.9	37.0	38.5
Pomme de Terre Lake Missouri (Belusz 1978)	12.2	22.1	29.1	35.2	36.7	39.7	42.2	45.5		
Minnesota Average (Carlander 1969)	6.9	12.5	17.1	21.5	25.8	29.0	33.4	39.1	43.5	45.5
Pennsylvania Average (Carlander 1969)	7.8	17.2	24.5	29.7	33.9	37.7	40.8	43.5	44.6	45.8
Kentucky - Cave Run Lake (Axon 1978)	10.3	19.6	25.4	30.6	34.7	38.0	41.0			
This Study	14.7	25.7	31.4	34.7	38.1	40.7				