River Basin Operations
Water Resources

POPULATION SURVEY OF SAUGER (*Stizostedion canadense*) IN CHICKAMAUGA RESERVOIR 1989

August 1990

TABLE OF CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

The authors especially thank Anders Myhr of the Tennessee Wildlife Resources Agency for his help in outlining activities to be accomplished in 1989 sampling, reviewing the draft report and assistance in carrying out the reward tagging program that was critical to the success of this study. We also express our gratitude to the principal reviewers of the drafts, in addition to Mr. Myhr these included: Johnny P. Buchanan, John J. Jenkinson, Robert Wallus, and Neil M. Woomer.

EXECUTIVE SUMMARY

Adult sauger densities in upper Chickamauga Reservoir continued to decline in 1989 with only 1,173 estimated in the spawning run. Success of the sauger spawn appears directly related to the level and regularity of nighttime water releases through Watts Bar Dam during the spawning period. Small year classes were produced when April nighttime releases were below the historical average for this time period and large year classes were produced when April nighttime releases were above average. This relationship allows for generalized projections of year class strength. Predictions based on 1988 and 1989 April discharges are for limited recruitment to the adult sauger population in 1990 and 1991. We recommend investigating the possibility of managing April nighttime releases from Watts Bar Dam as a means of enhancing sauger spawning success.

The Tennessee Wildlife Resources Agency announced plans to stock 250,000 fingerlings into Chickamauga Reservoir in both 1990 and 1991 as a result of findings of this four year cooperative sauger study. It is recommended population estimates be continued annually through the 1993 spawning season to monitor effectiveness of these stockings in returning the Chickamauga sauger population to pre-drought levels.

Impacts of Sequoyah Nuclear Plant operation on migrating sauger could not be determined in 1989 as sampling in the vicinity of the plant diffuser in late-winter was prevented by spilling at Watts Bar Dam. Sampling is again scheduled in late-winter 1990. When Watts Bar Nuclear Plant becomes operational, sampling in the vicinity of its diffuser during pre-spawn and spawning periods is recommended.

INTRODUCTION

In 1986 the Tennessee Valley Authority (TVA), in cooperation with the Tennessee Wildlife Resources Agency (TWRA), initiated an intensive program to determine the status of the sauger population in upper Chickamauga Reservoir and to identify potential impacts of operation of Watts Bar (WBN) and Sequoyah (SQN) Nuclear Plants on this important sport fish. Results of this program from 1986 through 1988 documented annual population densities, spawning location, spawning habitat characteristics, pre- and post-spawn movement patterns, year class strengths, and growth rates (Hevel 1988 and Hickman et al. 1989).

This report presents results from the fourth year of sampling (1989). Objectives of the project this year were to: (1) continue monitoring adult sauger population density, (2) determine factors influencing population cycles, and (3) evaluate impacts of SQN operation on sauger movements and spawning success.

DESCRIPTION OF STUDY AREA

The study area in 1989 was generally restricted to two major sites; immediately downstream of Watts Bar Dam and the previously identified spawning area (Hevel 1988 and Hickman et al. 1989) at Tennessee River mile (TRM) 520-521 (Hunter Shoals) (figure 1). Flows in upper Chickamauga are controlled by hydroelectric turbine discharges and infrequent spillway releases from Watts Bar Dam. Water temperatures fluctuate in response to discharge from the dam and environmental influences such as cold fronts and solar heating.

METHODS

From late-February to late-April 1989 Watts Bar tailwater areas were sampled with experimental and standard gill nets. Procedures were the same as used during 1986-88 sampling in upper Chickamauga Reservoir (Hickman et al. 1989). At Watts Bar Dam, nets were set in the spilling basin adjacent to the current during hydroelectric generation periods. At Hunter Shoals (TRM 521), high water velocities made it necessary to set nets when water was not being discharged from Watts Bar Dam. Set times were typically limited to two hours to reduce catch mortality.

Data recorded on each net included: date, location, length of time net was fished, and total number of each fish species collected. For each sauger captured, additional data were taken on total length (mm), weight (g), sex (when available), and notation on whether or not the specimen was "free-flowing". Sauger were considered free-flowing when eggs or milt could be observed after applying slight pressure to the ventral surface anterior to the vent. If applying pressure resulted in no milt or eggs, determination of sex was not made. Scales for age and growth evaluations were taken from 150 sauger.

Prior to release, each sauger was tagged with a numbered disc reward tag below the posterior insertion of the dorsal fin as described by Hickman et al. (1989). Tag numbers were recorded and the fish released into the same area in which they had been captured.

In the laboratory, sauger scales were pressed onto cellulose acetate slides. Scale measurements were made using a microscope equipped with a drawing attachment and a digitizing pad attached to a personal computer. Annuli were electronically marked on the pad, simultaneously entering measurements into the computer.

Data Analysis

Gill netting data from 1989 were summarized as catch per unit effort (number/hour) for all species and length-frequency percentages for sauger. Comparison of 1989 data to 1986-88 catch rates were made using Duncan's multiple range test. Sauger population size was estimated using the Thompson and Juday mark and recapture census method (Lackey 1974). Although some assumptions required for this method were violated (i.e., a closed system), this estimate of number of spawning adult sauger provided the best available measure of abundance. This multiple census method of estimation is based on the formula:

$$N = \frac{\Sigma C_t m_t}{\Sigma r_t}$$

where N = estimated population size,
C_t = total fish taken on day t,
m_t = total number of marked fish at the start of day t, and
r_t = number of recaptures in the sample C_t.

Age and growth analyses were performed using software developed by Frie (1982). The direct proportion technique was used to calculate the linear relationship between total length and scale radius and total length of each age class prior to capture. Data obtained from

sauger collected in 1989 were compared with those for sauger collected in 1986, 1987 and 1988, and with the average growth of sauger from all TVA mainstream reservoirs.

Relative weights (W_r) were calculated as a measure of fish condition. Relative weight is based on a percentage comparison of the observed weight per unit length with an accepted standard weight per unit length. It is calculated using the formula:

$$W_r = \frac{W}{W_s} \times 100$$

where W is the observed weight and W_s is the standard weight for a given length. Standard weights of sauger for comparison with Chickamauga Reservoir fish were generated from length-weight relationships for all available historical sauger data from Tennessee River mainstream reservoirs.

Fisherman catch rate of sauger was calculated by dividing the number of tag returns by the number of marked fish in the population (Lackey and Hubert 1977). This technique assumes tagged fish are subject to fishing and natural mortality at the same rates as the untagged population. Comparisons were made between 1989 results and 1986, 1987 and 1988 data.

Sauger year class strengths were compared using annual abundances of age 2 fish (32 - 39 cm in length). The percentage of age 2 fish in annual spring samples was expanded by the overall population estimate

for that year to obtain numerical estimates for age 2 sauger. These estimates (1986-89) were then compared to discharges from Watts Bar Dam during April nighttime hours (1900-0700) two years previous (1984-87).

RESULTS

The 923 hours of experimental and standard gill netting conducted in late-winter and early-spring 1989 yielded 6,131 fish representing 28 species (table 1). Gizzard shad and sauger were the most abundant species with catches per net hour (c/h) of 1.45 and 1.04, respectively. Next in abundance were channel catfish (0.92 c/h), yellow bass (0.84 c/h), skipjack herring (0.84 c/h), and white bass (0.83 c/h). Catch rates of all other species were less than 0.40 individuals per hour. A total of 537 adult sauger were tagged.

DISCUSSION

Sauger Population Dynamics

The sauger catch rate of 0.92 fish per net hour during March-April (only time period sampled during each year of study) 1989 was not significantly different (0.05 level) than the 0.97 fish per net hour during this time period in 1988 (table 2). Both of these catch rates were significantly lower than those obtained in 1986 and 1987 (2.54 and 3.89 sauger per net hour, respectively). The Thompson and Juday mark and recapture technique indicated there were 1,173 adult sauger in upper Chickamauga Reservoir during spring 1989. Comparable

estimates from previous years (figure 2) suggests a substantial, continuing decline, which collaborates with the catch rate results. A TWRA creel survey on Chickamauga Reservoir did not document any sauger harvest during 1988 or 1989, further evidencing a declining population.

Analysis of year class strengths from 1986 through 1989 (table 3), based upon percent composition of various size groups in annual gill net sampling, indicates the 1984 year class made up a large portion of the sauger population from 1986-1988. Fish spawned in 1984 were followed by a much smaller year class in 1985 with almost no sauger produced in 1986. The severity of the spawning failure in 1986 became apparent in 1988 as age 2 fish represented only 30 percent of the adult population. Age 2 sauger made up 57 to 70 percent of annual spawning migrations in 1986, 1987, and 1989. The 1987 spawn was more successful than 1986, but was 62 percent lower than the 1985 spawn.

Considerable mortality occurred between age 2 and 3 fish as evidenced by comparison of annual estimated year class densities (table 3). A total of 12,922 age 2 fish (1984 year class) were estimated in the 1986 migration with only 953 age 3 fish estimated the following year (93 percent mortality). Mortality between age 2 and 3 fish in 1987 and 1988 was 70 and 28 percent, respectively. Reasons for the high mortality rates in 1986 and 1987 are unknown, but may be associated with adult sauger densities.

Sauger growth in Chickamauga Reservoir in 1989 was similar to that reported in previous years (figure 3). Growth for all age groups continues to be slightly higher than the average growth of sauger from Tennessee River mainstream reservoirs.

Data collected in 1989 indicate the relative health of individual sauger in upper Chickamauga Reservoir continues to be good. The mean relative weight (W_r) of 105 was on the high end of the average range (100 ± 5) for sauger in Tennessee River mainstream impoundments. These results are identical to those obtained in 1988 and moderately higher than those for spring 1987 ($W_r = 98$) and 1986 ($W_r = 96$). This general increase in W_r may also be result of declining adult numbers.

Fishermen Harvest

Fishermen recaptures continue to indicate a low exploitation rate of sauger in Chickamauga Reservoir. Six percent of the tagged population was recaptured in 1989. Similarly, six, eight, and five percent recapture rates were determined for 1988, 1987, and 1986, respectively. When compared to declining estimates of adult sauger densities over these four spawning seasons, it is evident densities have little effect on exploitation rate. Therefore, a direct relationship exists between adult densities and numbers harvested.

Considerable inter-reservoir migration of adult sauger from Chickamauga Reservoir was first documented from 1986-88 by Hickman et al. (1989). In 1989, 9.4 percent of fishermen recaptures of sauger

tagged below Watts Bar Dam came from Melton Hill and Fort Loudoun Dam tailwaters. During the 1986-88 period, movement between reservoirs was approximately 15 percent.

Impacts of Watts Bar Dam Releases on Spawning Success

The status of the Chickamauga Reservoir sauger population appears critical. Although individual adult sauger are in good condition and maintain better than average growth throughout their life, the size of the population has declined continually as a result of inconsistent and poor year classes since 1984. Since few sauger live past age 4, year class strength is extremely important to the survival of the population.

Reasons for this recruitment variability have been hypothesized, but none have been substantiated previously. Hevel (1988) and Hickman et al. (1989) indicated a gradual rise in water temperature was necessary to initiate spawning activity. However, success of the sauger spawn could not be correlated with any environmental condition at that time as eggs, larvae, and juveniles were very difficult to collect due to low densities and unknown habitat of juveniles. Year class strength cannot be assessed until two years after the year class is produced and two year old fish enter the spawning migration.

High discharges during spawning seasons have been correlated with strong year class formation in walleye, a closely related species (Nelson and Walburg 1977 and Kallemeyn 1987). Nelson (1968), Scott

and Crossman (1973), and Robinson and Buchanan (1988) noted sauger spawning activity occurs mainly during nighttime hours. Comparing annual mean nighttime (1900 to 0700 hours) discharges from Watts Bar Dam during April from 1984 through 1989 and historical mean April nighttime flows (figure 4) indicates April flows were above average in 1984, below average in 1985, 1986, 1988, and 1989, and average in 1987. This trend of below average April nighttime flows was caused by prolonged drought conditions in the Tennessee Valley during the mid-1980s. As flows diminished, the sauger population of Watts Bar tailwater declined precipitously (figure 2).

Comparison of densities of age 2 sauger (first time a sauger year class can be adequately collected) in consecutive years reflect these differences in flows between individual years. The 1984 year class (produced during a "wet" year) was the strongest year class found during this four-year study (figure 5). It was produced during the highest average April nighttime discharge of the study period. Also during 1984, the number of hours Watts Bar Dam discharges were less than 2000 cfs were the lowest of the study period, averaging only 0.14 hours per night. In contrast, the poorest year class was produced during 1986, coinciding with both the lowest average nightly discharges (3,950 cfs) and the greatest average hours (8.55) of low or non-discharge periods. The 1986 year class, originating from a spawning population of 18,000+, was a relative failure, as indicated by only 373 age 2 sauger in the 1988 spawning migration.

The 1987 year class of 672 estimated individuals was about twice as strong as the 1986 year class. The improvement in year class strength between the two years is related to higher discharges in 1987. Average 1987 overnight discharges were similar to the best year, 1984, however, there was still an average of over 4 hours per night of low or non-discharge periods during April 1987. Another factor limiting the strength of the 1987 year class was the greatly reduced number of spawners (2900), compared to 1986 (18,000+).

Projecting returns of 1988 and 1989 year classes based on discharges and spawning population sizes indicates further reductions in the number of sauger below Watts Bar Dam. Low average nightly discharges occurred during April 1988 and 1989 (3,897 and 7,269 cfs, respectively). Also there were long nightly periods of low or non-discharge periods, 8.21 and 7.28 hours, respectively during these years.

Nuclear Plant Operational Impacts

The SQN diffuser is located 38 river miles below Hunter Shoals at TRM 483.4 (TVA 1985). WBN is located in upper Chickamauga Reservoir two river miles downstream of Watts Bar Dam with a diffuser located at TRM 527.8 (TVA 1986). Operational characteristics of both plants were detailed by Hickman et al. (1989). SQN units 1 and 2 operated at essentially full load throughout the 1989 sampling period. WBN did not operate during the 1989 sample period but did pump water through the cooling towers even though there was no thermal load.

WBN would seem to have a higher potential for negative influences than SQN because the diffuser outlet is just seven miles upstream of the spawning site. However, operational requirements of WBN are actually expected to enhance sauger spawning success as water must be released from Watts Bar Dam before the nuclear plant can discharge heated water into upper Chickamauga Reservoir. These expected more consistent release patterns from Watts Bar Dam will provide more suitable sauger spawning conditions. Discharge from WBN will seldom exceed 2.4 m^3/s and never exceed 5 m^3/s (maximum of 0.6 percent of the flow past the plant). Rapid dilution of this heated effluent before it reaches the spawning area lessens potential adverse impacts.

Hickman et al. (1989) suggested a potential impact of nuclear plant operation on success of the sauger spawn in upper Chickamauga Reservoir likely would be attraction of fish to the diffuser area instead of suitable spawning sites. Additionally, the altered temperature regime in the discharge plumes could upset the synchrony of gonadal development of sauger which did continue on to the spawning site.

Sampling in the vicinity of the SQN diffuser could not be accomplished during the late-winter period in 1989 (when adult sauger should have been migrating past the plant) due to high discharges through Watts Bar Dam. WBN was not operational during 1989, therefore no sampling was conducted in the vicinity of the WBN diffuser.

Conclusions

Adult sauger densities in upper Chickamauga Reservoir continued to decline in 1989. The remaining population is now estimated to contain only 1,173 adult sauger. The 1984 year class, which had been a major contributor to the spawning population over the past three years, was no longer evident. Age 2 sauger dominated the population in 1989 indicating a moderately successful sauger spawn in 1987. However, the 1987 spawn did not restore losses which occurred in 1985 and 1986 and the Chickamauga Reservoir sauger population remains at a critical level.

Growth rates and relative condition of sauger in Chickamauga Reservoir continue slightly above average for Tennessee River mainstream impoundments. Fishermen harvest rate in 1989 (six percent of the population) was similar to these observed during 1986 through 1988. It is evident numbers of adult sauger present in the reservoir have little bearing on exploitation rate. The consistency of the harvest rate, however, does indicate population size controls number of sauger harvested.

Hevel (1988) correlated gradually rising water temperatures with progression of spawning maturity and timing of the sauger spawn in Chickamauga Reservoir. Success of the spawn is now attributed to the level and regularity of water released through Watts Bar Dam during the sauger spawn. The largest year class encountered during the four years of study was produced during a "wet" year (1984). April

nighttime releases that year were consistently above the historical average while flows in 1985, 1986, 1988, and 1989 were below average. Water release rate in 1987 was similar to the historical average. Small year classes were produced during the "dry" years and a moderate-sized year class was produced in 1987.

The sauger appears to be a sensitive coolwater species which has been declining in abundance throughout the Tennessee River in recent years (Saylor et al. 1983, Woodward and Tomljanovich 1987, and Buchanan 1989). The weakest link in their life cycle is apparently in its early life history from egg deposition to the juvenile stage. Being migratory spawners, their spawning habitat is limited to headwater channel locations, where eggs and larvae are subject to the prevailing water quality and flow conditions. These factors have apparently not been conducive to the formation of strong sauger year classes during the last five years. The drought conditions experienced during 1985-89 may have pushed the sauger to the brink of extirpation in Chickamauga Reservoir.

Impacts of nuclear plant operation on the sauger spawn could not be investigated in 1989 due to late-winter spilling at Watts Bar Dam. Sampling in the vicinity of both diffusers during the pre-spawn and spawning periods of normal flow years when plants are operational will be necessary to evaluate impacts of plant operation on sauger.

Recommendations

Projections based on results obtained during 1988 and 1989 suggest limited recruitment to the adult sauger population in Chickamauga Reservoir in 1990 and 1991. Actual success of the 1988 and 1989 sauger spawns cannot be determined from data presented herein, as yearling sauger do not participate in spring spawning migrations in representative numbers. Sampling during 1990 and 1991 will allow verification of these projections. If projections are accurate, it should be possible to suggest modes of dam operation to enhance sauger spawning success.

TWRA intends to stock 250,000 fingerling sauger in Chickamauga Reservoir during 1990 and again in 1991 based upon results of this cooperative four year study. These introductions will prevent projections of sauger spawning success in 1992 and 1993. While not associated with nuclear plant or dam releases, impacts of the stockings on the density of spawning adults should be evaluated by sampling the spawning population during 1992 and 1993.

In order to better define the mechanism influencing sauger year class strength, intensive sampling of sauger eggs and larvae in the vicinity of the spawning site immediately following initiation of spawning is recommended. This activity would be directed towards determination of where and when mortality is occurring. Innovative techniques will be necessary, possibly including artificial introduction of fertilized sauger eggs at the spawning site to test sampling efficiency.

Gill net sampling in the vicinity of the SQN diffuser should again be attempted in February 1990 to determine if the heated effluent adversely impacts the adult sauger spawning migration. Once WBN becomes operational, netting during the pre-spawn and spawning period should be conducted at Watts Bar Dam, the WBN diffuser outlet, and Hunter Shoals to determine effects of WBN operation on spawning success.

LITERATURE CITED

Buchanan, J. P. 1989. Thermal variance monitoring for Browns Ferry Nuclear Plant, Wheeler Reservoir, during 1987 and 1988. Tennessee Valley Authority, Water Resources, Aquatic Biology Department, Chattanooga, Tennessee. 15pp.

Frie, R. V. 1982. Measurement of fish scales and back-calculation of body lengths using a digitizing pad and microcomputer. Fisheries 7(6):5-8.

Hevel, K. W. 1988. Survey of the population dynamics of sauger Stizostedion canadense) in Chickamauga Reservoir, Tennessee - 1986 and 1987. Tennessee Valley Authority, Office of Natural Resources and Economic Development, Division of Services and Field Operations, Norris, Tennessee. 44 pp.

Hickman, G. D., K. W. Hevel and E. M. Scott. 1989. Density, movement patterns, and spawning characteristics of sauger (Stizostedion canadense) in Chickamauga Reservoir, Tennessee - 1988. Tennessee Valley Authority, River Basin Operations, Water Resources. 53 pp.

Kallemeyn, L. W. 1987. Correlations of regulated lake levels and climatic factors with abundance of young-of-the-year walleye and yellow perch in four lakes in Voyageurs National Park. North American Journal Fisheries Management. 7: 513-521.

Lackey, R. T. 1974. Introductory fisheries science. Sea Grant, Department of Commerce, Undergrant 04-4-158-40, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 275 pp.

Lackey, R. T. and W. A. Hubert. 1977. Analysis of exploited fish populations. Sea Grant, Department of Commerce, under Grant 04-4-158-40, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 172pp.

Nelson, W. R. 1968. Reproduction and early life history of sauger, (Stizostedion canadense) in Lewis and Clark Lake. Transactions American Fisheries Society. 97(2): 159-166.

Nelson, W. R. and C. H. Walburg. 1977. Population dynamics of yellow perch (Perca flavescens), sauger (Stizostedion canadense), and walleye (Stizostedion vitreum vitreum) in four main stem Missouri River reservoirs. Journal Fisheries Research Board of Canada. 34: 1748-1763.

Robinson, H. W. and T. M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas, Fayetteville, Arkansas. 462-464.

Saylor, C. F., E. M. Scott, Jr., and D. A. Tomljanovich. 1983. An investigation of sauger spawning in the vicinity of the Clinch River Breeder Reactor Plant. Tennessee Valley Authority, Knoxville, Tennessee.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184, Fish. Res. Board of Can., Ottawa. pp. 762-766.

Tennessee Valley Authority. 1985. Aquatic environmental conditions in Chickamauga Reservoir during operation of Sequoyah Nuclear Plant, fourth annual report (1984). Water Resources, Knoxville, Tennessee.

Tennessee Valley Authority. 1986. Preoperational assessment of water quality and biological resources of Chickamauga Reservoir, Watts Bar Nuclear Plant, 1973-1985. Water Resources, Knoxville, Tennessee. pp. 488.

Woodward, A. G. and D. A. Tomljanovich. 1987. An investigation of sauger (Stizostedion canadense) spawning in Douglas tailwater, Tennessee. Tennessee Valley Authority, Knoxville, Tennessee.

Table 1. Species list, numbers collected, catch per hour, and relative abundance (%) of fish encountered during spring gill netting in the upper portion of Chickamauga Reservoir, 1989. Total effort consisted of 923 hours.

Common Name	Number Collected	Catch per Hour	Relative Abundance (%)
Spotted gar	1	0.00	0.02
Longnose gar	43	0.05	0.70
Shortnose gar	1	0.00	0.02
Skipjack herring	662	0.83	12.43
Gizzard shad	1339	1.45	21.84
Mooneye	91	0.10	1.48
Common carp	2	0.00	0.03
River carpsucker	1	0.00	0.02
Quillback carpsucker	4	0.00	0.07
Smallmouth buffalo	5	0.01	0.08
Spotted sucker	74	0.08	1.21
Unidentified redhorse	1	0.00	0.02
Golden redhorse	7	0.01	0.11
Blue catfish	299	0.32	4.88
Channel catfish	850	0.92	13.86
Flathead catfish	8	0.01	0.13
White bass	777	0.84	12.67
Yellow bass	749	0.81	12.22
Striped bass	23	0.02	0.38
Hybrid white x striped bass	2	0.00	0.03
Warmouth	1	0.00	0.02
Bluegill	10	0.01	0.16
Spotted bass	2	0.00	0.03
White crappie	5	0.01	0.08
Black crappie	12	0.01	0.20
Yellow perch	5	0.01	0.08
Sauger	956	1.04	15.59
Walleye	17	0.02	0.28
Hybrid walleye x sauger	1	0.00	0.02
Freshwater drum	83	0.09	1.35
Totals	6131	6.64	100.00

Table 2. Comparison of gill net catch rates (catch per hour) of sauger in upper Chickamauga Reservoir, 1986-89.

Year	Catch Rate	Duncan Grouping
1987	3.89	A
1986	2.54	B
1988	0.97	C
1989	0.92	C

Table 3. Year class composition (percent and estimated numbers) of annual spring gill net samples in upper Chickamauga Reservoir (1986-89).

	1986		1987		1988		1989	
	%	No.	%	No.	%	No.	%	No.
Age 1 (<32 cm)	7.2	1323	0.4	11	6.9	86	0.8	9
Age 2 (32-39 cm)	70.3	12,922	61.7	1765	29.8	373	57.3	672
Age 3 (40-44 cm)	19.8	3639	33.3	953	42.4	530	33.0	270
Age 4 (44-50 cm)	2.5	460	3.6	103	19.4	243	7.7	90
Age 5 (>50 cm)	0	0	0.5	14	0.5	6	1.3	15

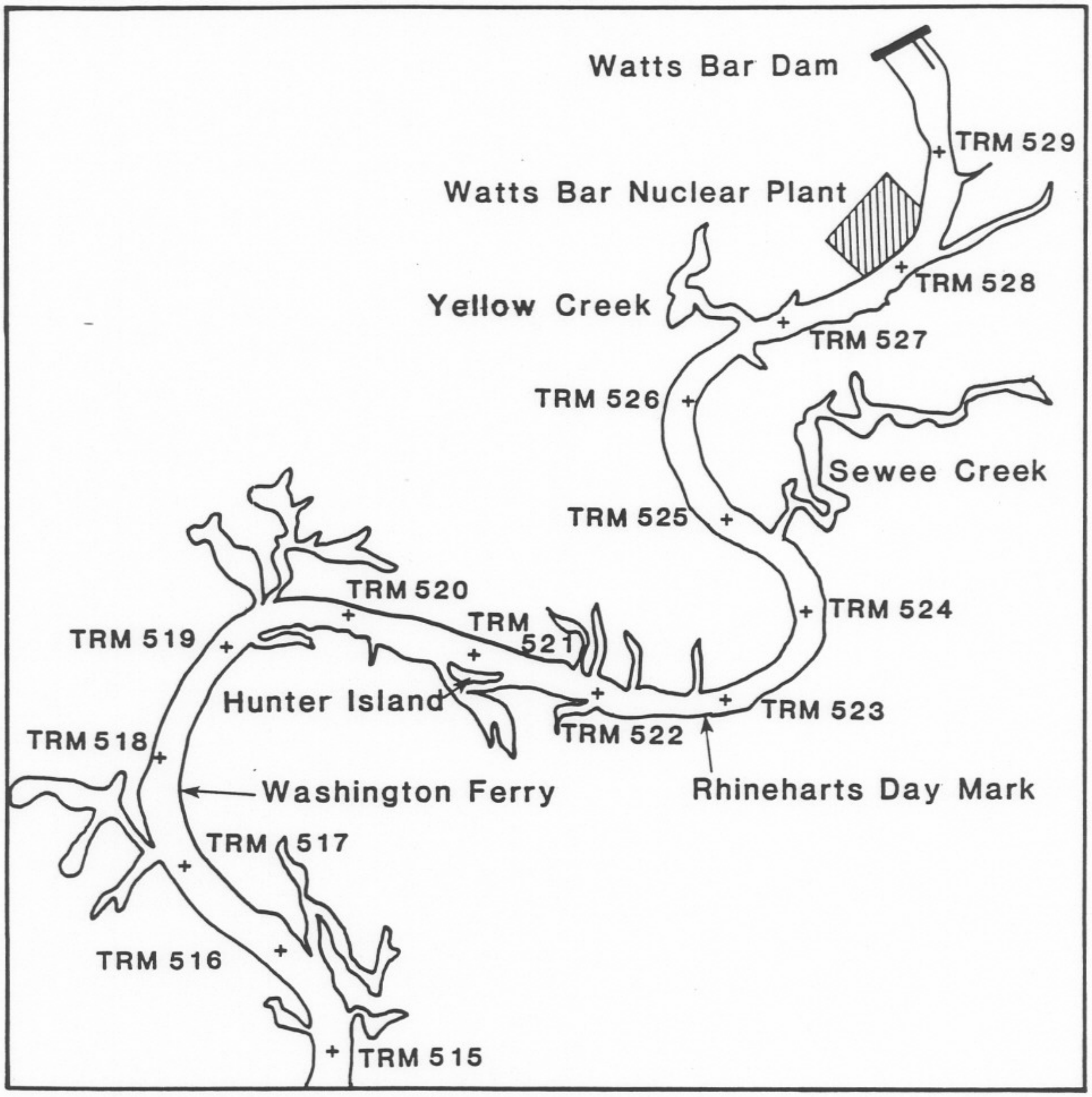

Figure 1. Upper Chickamauga Reservoir (Watts Bar tailwater).

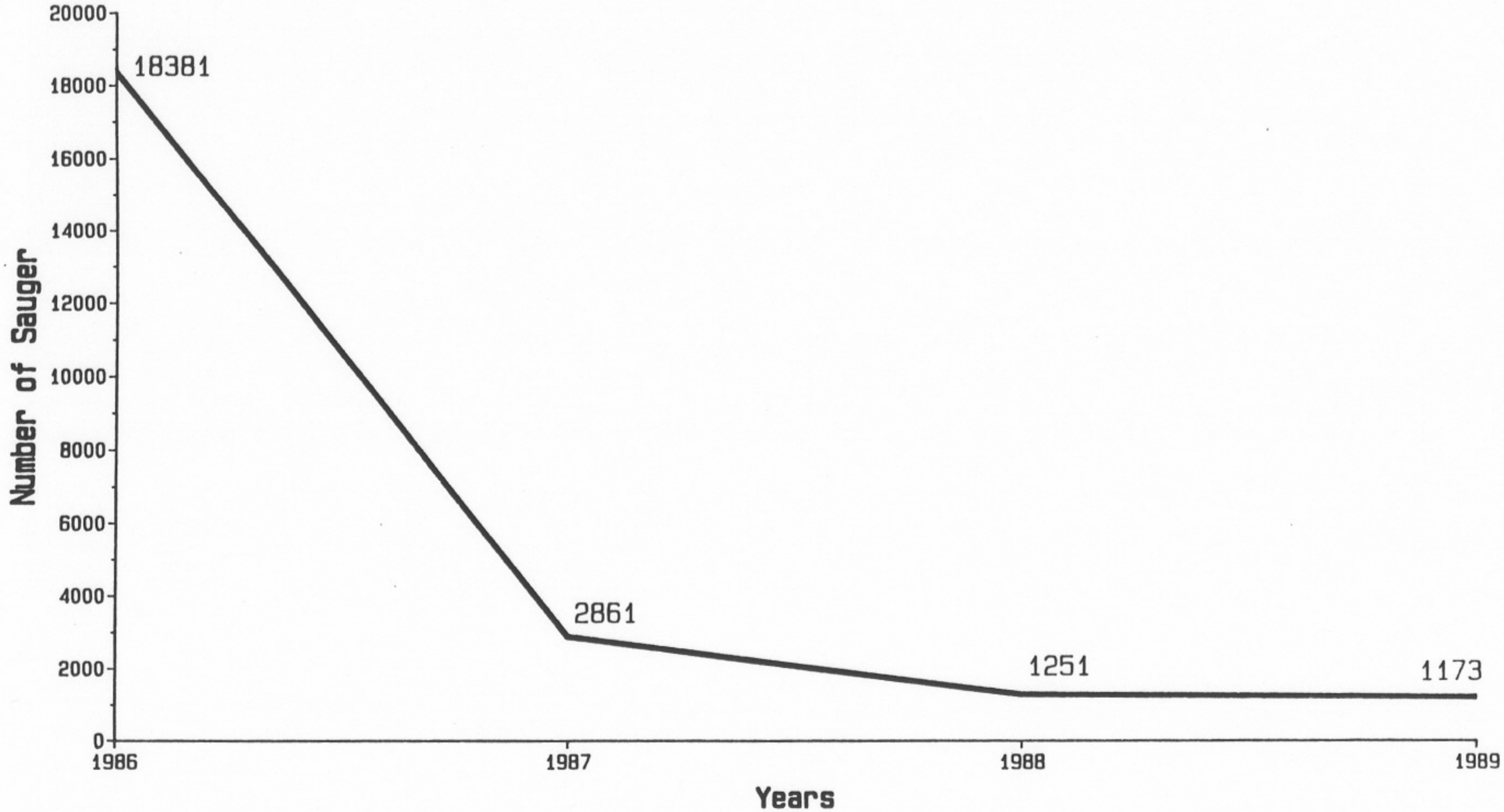

Figure 2. Estimated numbers of adult sauger in Chickamauga Reservoir from 1986-1989.

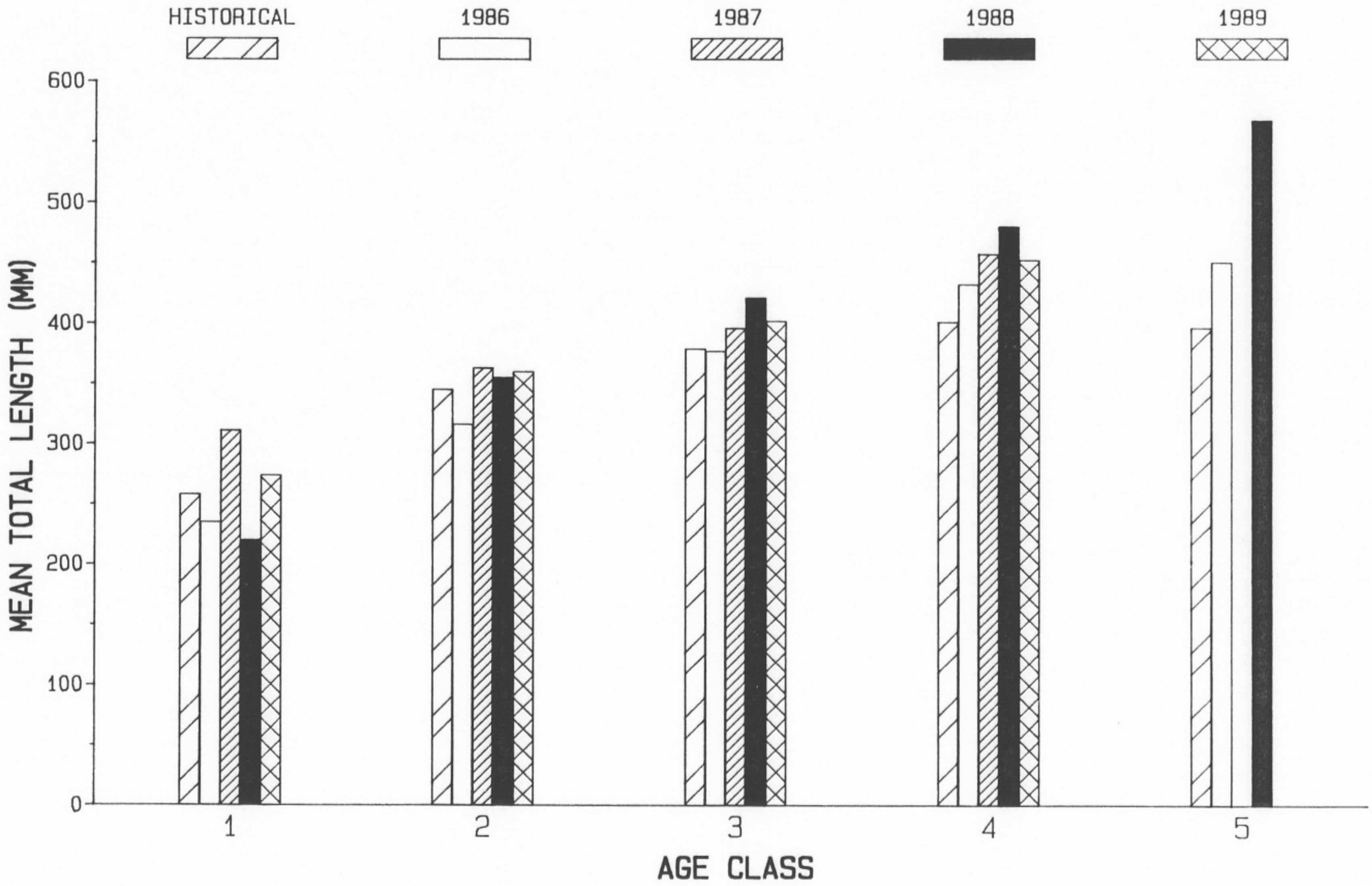

Figure 3. Comparison of mean total lengths of sauger at each age class for Tennessee River mainstream reservoirs (historical) and those collected from upper Chickamauga Reservoir during spring 1986, 1987, 1988, and 1989.

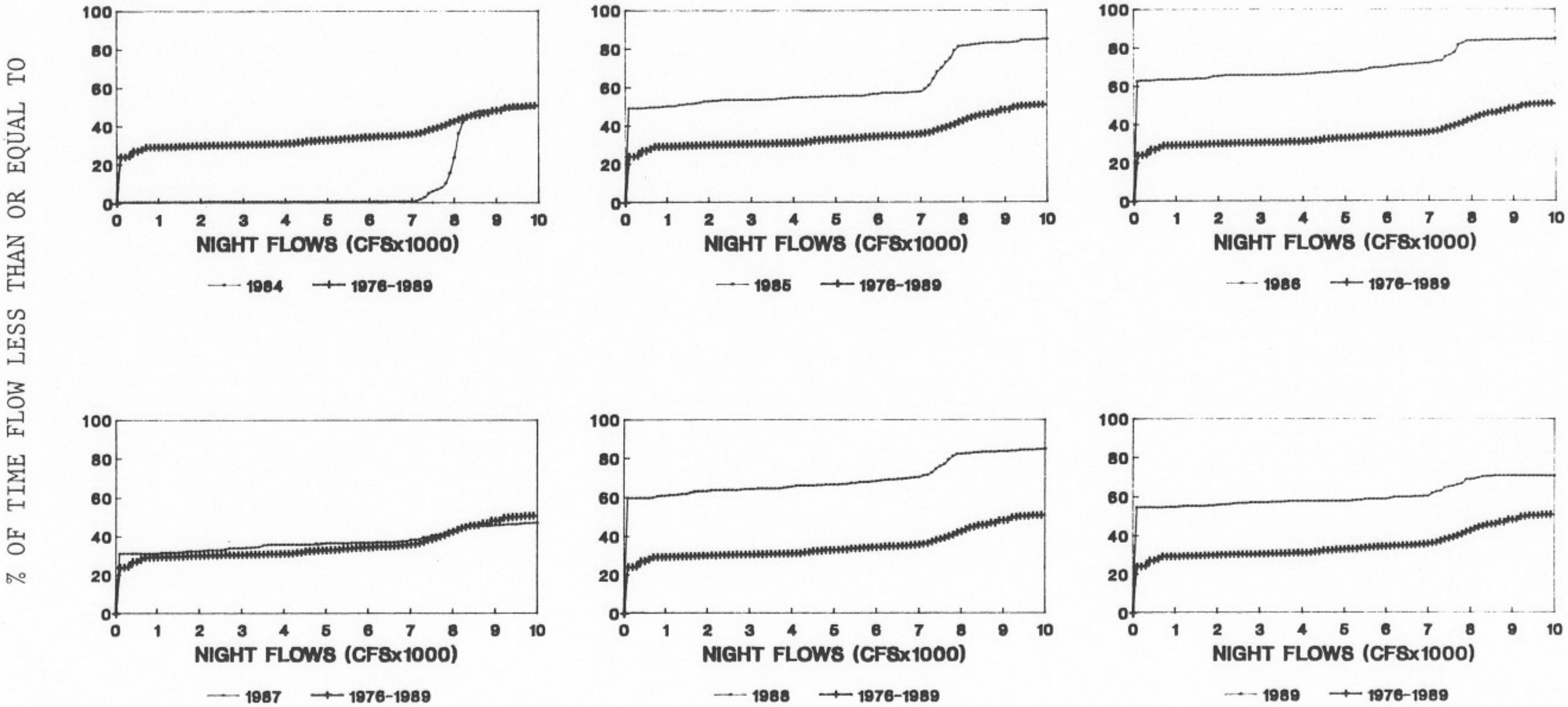

Figure 4. Comparison of April nighttime discharges from Watts Bar Dam during 1984-89 with historical averages.

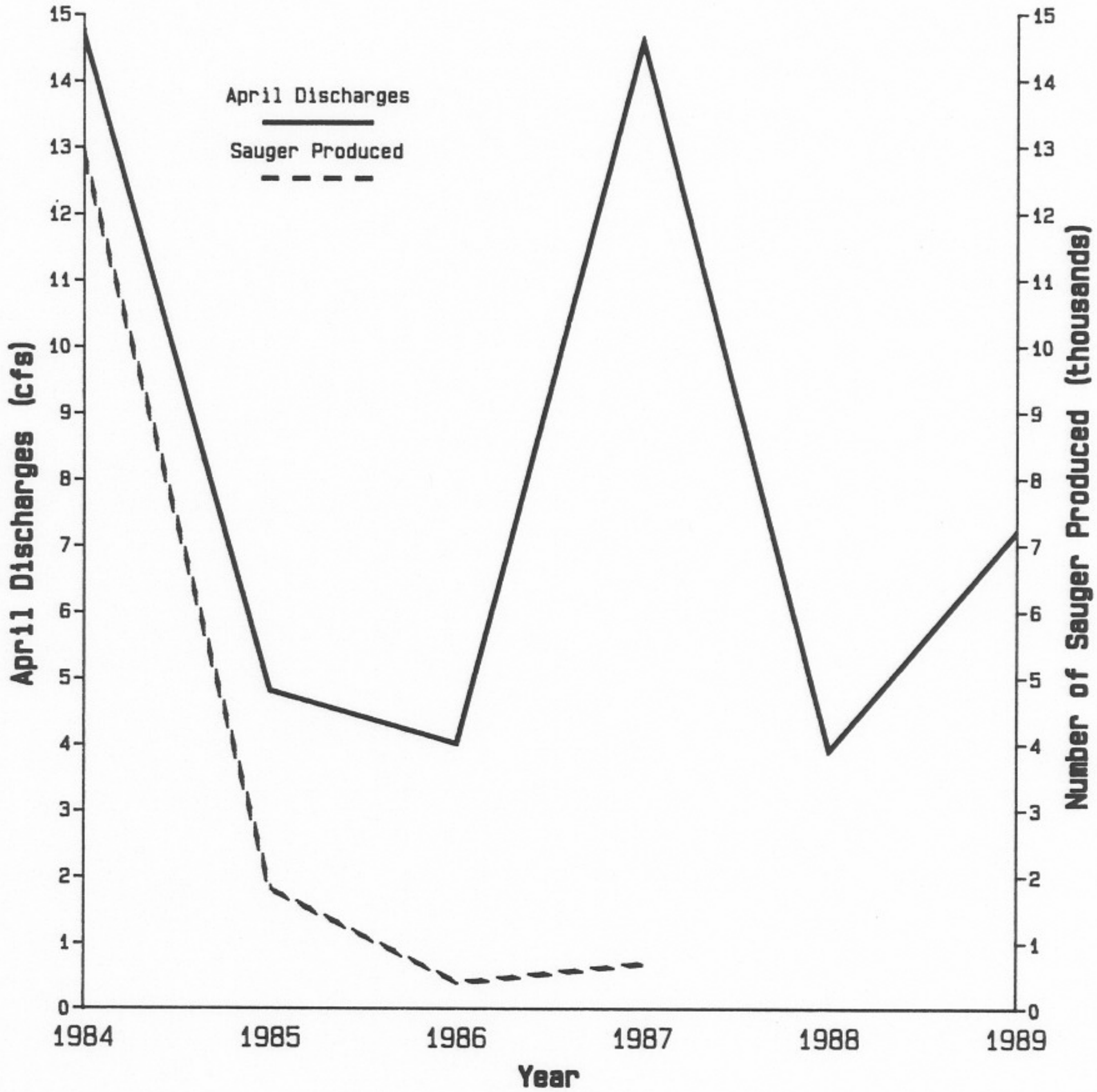

Figure 5. Average nighttime April discharges from Watts Bar Dam and estimates of sauger year class abundance (based upon age 2 sauger captured during sampling two years later).

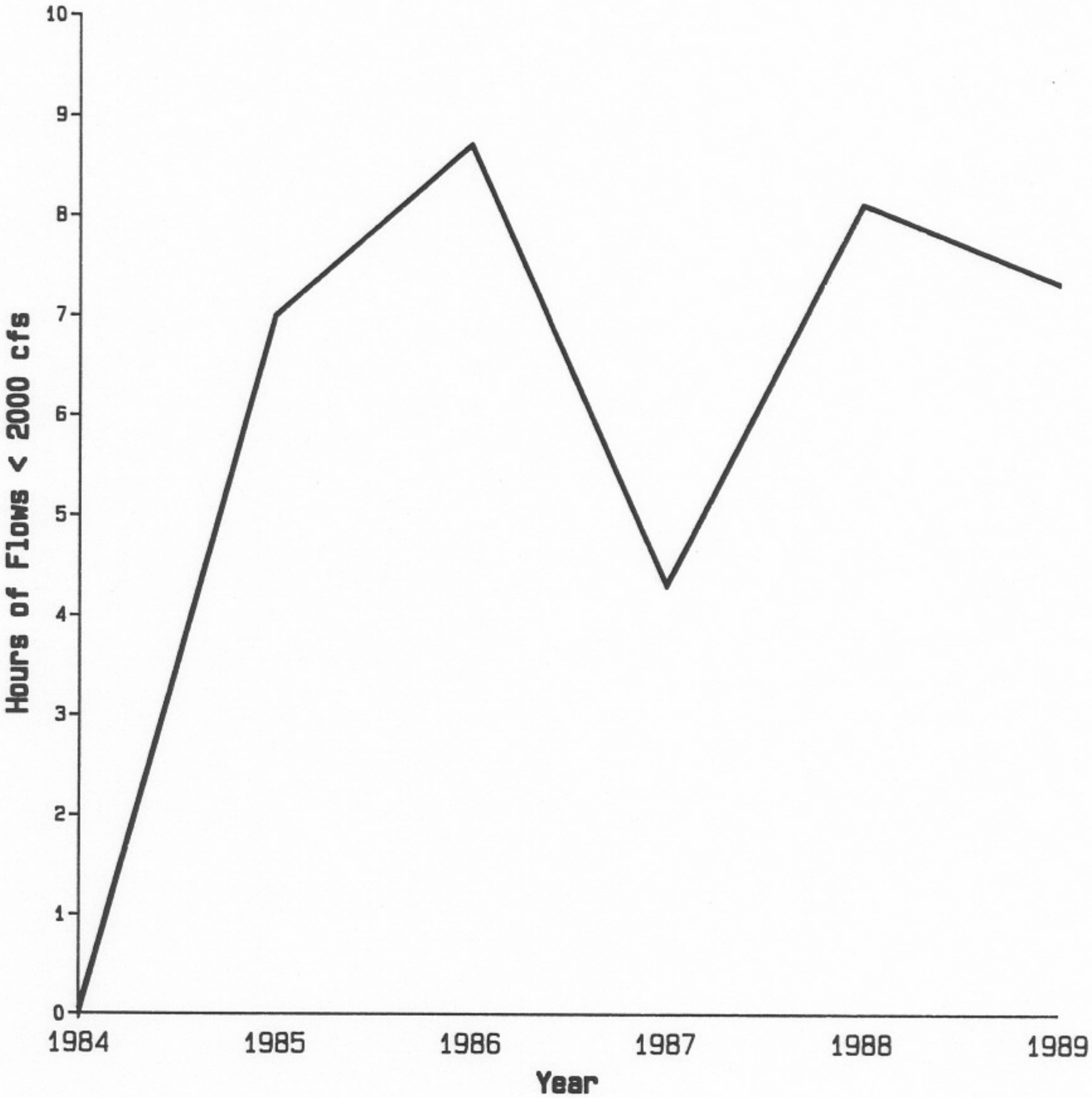

Figure 6. Average number of nighttime hours Watts Bar Dam discharges were <2000 cfs during April (1984-89).