fish - effects of water temperature control

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TEMPERATURE CONTROL OF RESERVOIR RELEASES INTO NOLIN AND BARREN TAILWATERS

Department of Fish and Wildlife Resources

Minor Clark, Commissioner

TEMPERATURE CONTROL OF RESERVOIR RELEASES INTO NOLIN AND BARREN TAILWATERS

By

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ABSTRACT

Investigations were conducted on Nolin Reservoir tailwater and Barren Reservoir tailwater to evaluate success in controlling tailwater temperatures through the utilization of multi-level releases, and to determine the fish population composition, and to measure fishing intensity, creel composition and fishing success on the tailwater.

The U. S. Army Corps of Engineers attempted to duplicate pre-impoundment temperatures in the tailwaters during the period April through August of 1965 and 1966, but reservoir water temperatures at the upper release levels were somewhat below the pre-impoundment temperatures during four out of five months of the temperature control period.

Gate-level releases were required during the temperature control period to control reservoir water levels and this contributed to lower tailwater temperatures. Mean monthly tailwater temperatures during the months of April, May, June and July ranged from 2 to 4 degrees below the scheduled mean whereas in August the scheduled mean was achieved.

Electrofishing studies revealed that substantial numbers of fishes emigrated from the reservoir into the tailwaters. Species dominance in the sections immediately below the dams fluctuated with the reservoir regulation period. During the seasonal pool period in the summer, game fishes and panfishes were most abundant; after drawdown in the fall threadfin shad was the dominant species; and prior to the seasonal pool period in early spring carp was the dominant species.

Creel surveys were based on a stratified sampling schedule and the fishing effort was estimated by the mean count method. The annual fishing effort ranged from 4,353 fisherman hours on Nolin tailwater (1,554 man-hours per acre) to 21,002 fisherman hours (4,880 man-hours per acre) on Barren tailwater. The catch rate fluctuated from a low of 0.33 fish per hour at Barren to a high of 1.47 fish per hour at Nolin. The estimated annual harvest ranged from 3,486 fishes at Nolin to 15,852 fishes at Barren. At Nolin the creel was numerically dominated by crappies the third year of impoundment and sunfishes the fourth year. At Barren the creel was numerically dominated by suckers, carp, and crappies, respectively, during the first three years of impoundment.

INTRODUCTION

Nolin Reservoir, impounded in 1963, and Barren Reservoir, impounded in 1964, were constructed by the U. S. Army Corps of Engineers under the Flood Control Act of 1938. The two reservoirs are unique in that both were designed with a multi-level release which permits the withdrawal of water from various reservoir depths. This release design was installed to control water quality in the tailwater.

This study was initiated in March, 1965 and was terminated in October, 1966 under Dingell-Johnson Project F-16-R, Pre- and Post-Impoundment Surveys. The objectives of the study were to evaluate techniques for controlling tailwater temperatures and to evaluate the tailwater fisheries. A more comprehensive study, designed to evaluate the effects of reservoir release location on reservoir productivity, was initiated in 1968 under Dingell-Johnson Project F-34.

ACKNOWLEDGEMENTS

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Dr. Don W. Hayne, North Carolina State University, provided technical assistance with the creel survey and Kenneth Merideth, Rex Brown, and Wendell Stephens, conservation officers of the Kentucky Department of Fish and Wildlife Resources, served as creel clerks.

Harry Hargis constructed the electrofishing unit and he, along with Larry Neal, William Caldwell and Mike Hearn, participated in each phase of the study.

The U. S. Army Corps of Engineers, Louisville District, cooperated with project personnel throughout the study by regulating reservoir releases and providing reservoir regulation data.

DESCRIPTION OF AREAS

Nolin River and Barren River are located in south central Kentucky and both are major tributaries of the Green River drainage.

Nolin River rises in Hardin County and flows in a general southwesterly direction for a distance of 122 miles to the mouth in Edmonson County. The drainage area is approximately 727 square miles, 24 square miles of which are located below Nolin Dam. The drainage area above the dam is located in the Pennyroyal physiographic region which is characterized by karst topography with underlying formations of limestone, some sandstone, shale and chert. Upland soils are mostly Westmoreland and Muskingum associations derived from acid siltstones, sandstones and shales. The tailwater is located in the Western Coalfield physiographic region. Underlying formations in this area are mainly sandstone and shale (U. S. Department of the Interior, 1960). A major portion of the tailwater lies within the western boundary of Mammoth Cave National Park. From Nolin Dam to the mouth of Nolin River, 7.8 miles downstream, the stream gradient averages two feet per mile. Stream flow is greatly influenced however, by backwater formed from Lock and Dam number 6, located 2.0 miles below the mouth on the Green River. Normal pool elevation at Lock 6 is 420.9 feet msl while the elevation at the Nolin Dam stilling basin is 419.0 msl.

Barren River rises in north-central Tennessee and Monroe County, Kentucky and follows a northwesterly course for a distance of 158 miles to the Green River. The drainage area is approximately 1900 square miles, 960 of which are located below Barren Reservoir Dam. Located in the Pennyroyal physiographic region, the watershed of the upper 125 miles of the river is characterized by hilly and karst topography. The underlying formations of this area are composed mainly of limestones, shales and siltstones. Soils in this area are mostly Dixon and Baxter associations which are derived from

geodic or cherty impure limestones, and soil fertility is considered medium to low (Agricultural and Industrial Development Board of Kentucky, 1953). The watershed of the lower 33 miles of the river is rolling and hilly with sandstones and shales being most prominent. From Barren Reservoir Dam to the mouth, 79.2 miles downstream, the stream gradient averages 1.8 feet per mile. An inactive navigation lock and dam is located on the river near Bowling Green.

A general description of the physical features of each reservoir is presented in Table 1. Barren is the larger reservoir encompassing 10,000 surface acres with a total volume of approximately 209,800 acre feet at seasonal pool. The surface area of Nolin is 5,800 acres with a total volume of 170,000 acre feet at seasonal pool. The reservoir outlet designs are essentially the same. The standard low-level release gates are supplemented by a multi-level bypass system. The bypass system basically consists of two vertical chambers with multi-level inlets and a common release valve at the bottom. Independently controlled slide-type structures regulate releases at both the bypass inlets and the low level gates. The bypass inlets are four feet square, are located on the upstream side of the control tower, and are paired at each elevation (Figure 1). At Nolin Reservoir there are six bypass inlets located at three elevations and at Barren Reservoir there are four bypass inlets at two elevations.

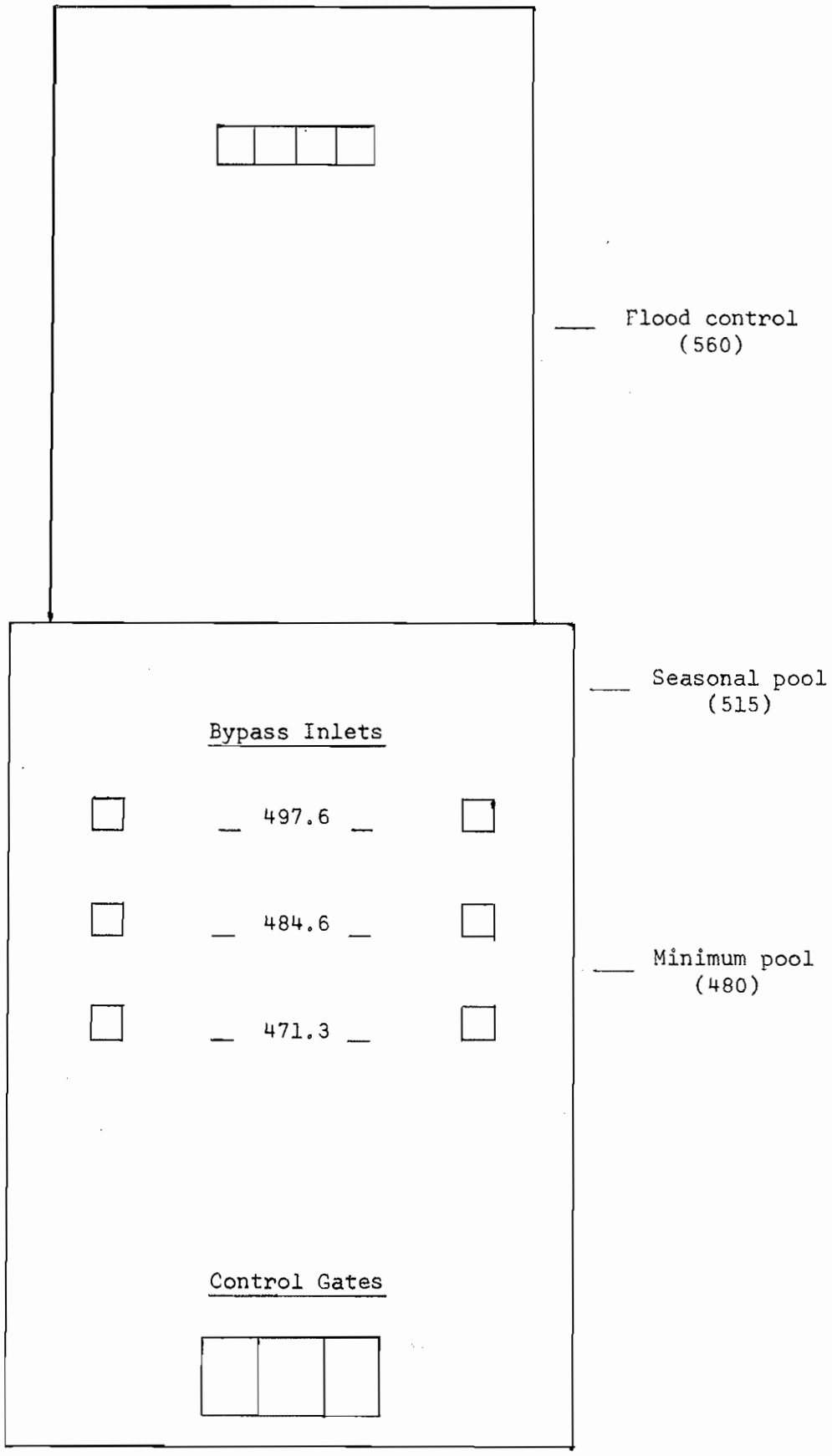
The U. S. Army Corps of Engineers installed continuous recording thermographs in the operating tower at each reservoir for recording water temperatures at the invert elevations of the bypass inlets; tailwater temperatures were monitored by U. S. Geological Survey thermographs located 0.3 mile below Nolin Dam and 0.5 mile below Barren Dam. Although the Geological Survey thermographs were installed for routine water quality surveillance, the Corps of Engineers thermographs were installed specifically for determining the desired level of withdrawal.

Table 1. Some physical features of Nolin Reservoir and Barren Reservoir.

	Nolin	Barren
Dam		
Type	Rock fill with earth core	Rolled earth with random rock
Height	174 feet	146 feet
Length	990 feet	3,970 feet
Outlet works		
Type	Reinforced concrete conduit	Reinforced concrete conduit
Gates	3 slide type 7.25 feet x 14 feet	3 slide type 6.5 feet x 14 feet
Invert elevations	426.0 msl	484.0 msl
Multilevel inlets	6 slide type, 4 feet square	4 slide type, 4 feet square
Invert elevations	497.6, 484.6, 471.3	531.0, 513.0
Seasonal pool discharge capacities		
Gates	12,000 cfs	10,300 cfs
Multilevel inlets	530 cfs	504 cfs
Volume		
Minimum pool	30,900 acre feet (480 msl)	46,600 acre feet (520 msl)
Seasonal pool	170,000 acre feet (515 msl)	209,800 acre feet (552 msl)
Maximum pool	570,000 acre feet (560 msl)	768,600 acre feet (590 msl)
Surface area		
Minimum pool	2,070 acres	3,440 acres
Seasonal pool	5,800 acres	10,000 acres
Maximum pool	14,530 acres	20,150 acres
Maximum depth (Seasonal pool)	93 feet	74 feet
Average depth	29 feet	26 feet

Seasonal operational schedules for the reservoirs were similar during the study period. Seasonal or summer pool was scheduled for May 1, and maintained through August. Drawdown began in early September and minimum or winter pool was generally reached by December 1. Under normal conditions the average rate

Figure 1. Upstream side of operating tower at Nolin Reservoir showing location of bypass inlets and various pool levels.



of drawdown was 725 cfs at Nolin Reservoir and 1162 cfs at Barren Reservoir. Minimum outflow during the seasonal pool period was 50 cfs.

TAILWATER TEMPERATURE CONTROL

With the cooperation of the U. S. Army Corps of Engineers, Louisville District, an effort was made to duplicate mean monthly pre-impoundment temperatures at both Nolin and Barren tailwaters during the seasonal pool periods of 1965 and 1966. We provided the monthly temperature schedules specifying the desired tailwater temperatures, while the Corps of Engineers accepted the responsibility of selecting withdrawal levels to conform to the schedule. A major part of this responsibility was left to the reservoir manager who periodically determined the water temperature at the level of withdrawal and compared that reading with the tailwater temperature.

The scheduled release temperatures for each tailwater are presented in Table 2. The Nolin tailwater temperature schedule was based on mean monthly pre-impoundment water temperatures derived from morning and evening recordings taken once a week at Wax, 20.2 miles upstream from the dam site, during the pre-impoundment period from 1951 - 1961. The Barren tailwater temperature schedule was based on mean monthly water temperatures derived from continuous thermograph records taken at Bowling Green, 43.0 miles below the dam site, for the same ten year period (U. S. Geological Survey, 1951 - 1961).

Table 2. Water temperature schedules (in Fahrenheit) for Nolin and Barren tailwaters during the seasonal pool periods April - August, 1965-1966.

Month	Nolin	Barren
	Pre-impoundment or scheduled mean	Pre-impoundment or scheduled mean
April	57	58
May	65	67
June	72	74
July	75	78
August	75	78

Mean monthly tailwater temperatures during the temperature control periods fell below the scheduled means for each month except August, in both tailwaters. During the first four months of the temperature control periods, mean tailwater temperatures ranged from 4 to 8 degrees below the scheduled or pre-impoundment mean in April; 1 to 5 degrees below in May; 2 to 4 degrees below in June; and 4 to 6 degrees below in July. In August, the scheduled mean was achieved (Table 3).

Table 3. Mean monthly tailwater temperatures and departures from scheduled means on Nolin tailwater in 1965-1966 and Barren tailwater in 1965.

	Nolin Tailwater					Barren Tailwater*		
MONTH	Scheduled mean	Mean tailwater temperature 1965	1966	Degrees differential 1965	1966	Scheduled mean	Mean tailwater temperature 1965	Degrees differential 1965
April	57	53	50	-4	-7	58	50	-8
May	65	64	60	-1	-5	67	63	-4
June	72	68	69	-4	-3	74	72	-2
July	75	71	70	-4	-5	78	72	-6
August	75	75	75	0	0	78	78	0

* The tailwater thermograph at Barren was not in operation during 1966.

Failure to achieve the scheduled mean during the first four months of the temperature control period was primarily attributed to low water temperatures at the level of the upper bypass inlets and secondly to gate level releases which were required for reservoir water level control.

During the first four months of the temperature control period, the mean maximum temperature at the invert elevation of the upper bypass inlets ranged from 4 to 6 degrees below the scheduled tailwater mean in April; 1 to 2 degrees below in May; 1 to 7 degrees below in June; and 1 to 4 degrees below in July (Table 4).

Table 4. The mean maximum temperature at the invert elevation of the uppermost bypass inlets and departures from the scheduled tailwater mean on Nolin and Barren Reservoirs, 1965-1966.

MONTH	Nolin Reservoir					Barren Reservoir				
	Scheduled mean	Mean maximum temperature at inlet		Degrees differential		Scheduled mean	Mean maximum temperature at inlet		Degrees differential	
		1965	1966	1965	1966		1965	1966	1965	1966
April	57	53	51	-4	-6	58	54	52	-4	-6
May	65	63	64	-2	-1	67	62	65	-5	-2
June	72	65	66	-7	-6	74	70	73	-4	-1
July	75	71	74	-4	-1	78	75	75	-3	-3
August	75	75	80	0	+5	78	78	78	0	0

Reservoir temperature profiles recorded 1,000 feet upstream from each dam revealed that scheduled tailwater temperatures could have been achieved during the period from May through July if the upper bypass inlets had been located at or above the ten foot depth instead of the eighteen foot depth at Nolin or the twenty-one foot depth at Barren. These studies showed that thermal stratification occurred in May and persisted throughout the remainder of the temperature control period. Reservoir releases at the level of the upper bypass inlets originated from the metalimnion during this three month period, and as indicated in Table 4, the temperature of this layer of water rarely equalled that of the scheduled tailwater temperature. Temperatures in the epilimnion generally exceeded the scheduled tailwater temperature during the period of thermal stratification but this warmer layer of water was not available for release until August when it descended to the level of the upper bypass inlets.

The temperature profile data for April showed that reservoir temperatures were generally below the scheduled tailwater temperature even at the ten foot depth. That month reservoir temperatures in the upper ten feet of the reservoir ranged from two to four degrees below the scheduled tailwater temperatures.

Occasional gate-level releases were made during the temperature control periods when the reservoir inflow increased to the magnitude that seasonal pool level could not be satisfactorily maintained through bypass releases. The bypass systems proved to have a rather limited discharge capacity in this respect (530 cfs maximum at Nolin and 504 cfs maximum at Barren) and this limitation contributed to lower tailwater temperatures.

During the 302-day temperature control periods at each reservoir, gate-level releases were made on 43 days at Nolin and 33 days at Barren (Table 5). Gate-level releases were made both years at Nolin Reservoir but only during 1965 at Barren Reservoir. Gate-level releases were not required at Barren Reservoir in 1966 because reservoir inflow was lower than normal.

Table 5. Total number and duration of gate-level releases plus the degree of temperature reduction at Nolin tailwater in 1965 and 1966 and Barren tailwater in 1965.

	Nolin 1965 and 1966 Combined			Barren 1965		
MONTH	Total no. days gates used	Max. duration (consecutive days)	Temp. reduction (°F)	Total no. days gates used	Max. duration (consecutive days)	Temp. reduction (°F)
April	11	11	8	20	20	5
May	11	11	8	7	5	10
June	6	3	5	1	1	3
July	14	3	16	5	3	14
August	1	1	10	0	0	0

Although tailwater temperature reductions resulting from gate-level releases were lessened by simultaneous warm water releases from the bypasses, normal tailwater temperatures were reduced by as much as 10 degrees as a result of gate-level releases during April, May, and June. During July and August, the surface to bottom temperature gradient in the reservoir was greater and the maximum reduction in tailwater temperature increased to 16 degrees.

DISCUSSION OF TEMPERATURE MANIPULATIONS

The reservoir thermographs with their thermistors located near the bypass inlets did not provide a satisfactory method of predicting the temperature of release water. Tailwater temperatures resulting from the mixing of releases from two or more levels were generally unpredictable and this required periodic trips to the tailrace to observe the temperatures derived from various outlet settings. Another disadvantage of the thermistor in-reservoir location was that the low level thermistors were inaccessible, making them inconvenient or even impossible to repair. A more satisfactory location for a thermistor would be in the concrete conduit tunnel just upstream from the stilling basin. Adequate information regarding the desired level of reservoir release may best be provided by simply recording the temperature profile of the reservoir with a telethermometer.

Although the temperature control periods of 1965 and 1966 contrasted in respect to temperature and precipitation, deviations from normal parameters were not considered significant enough to warrant speculation that substantially higher tailwater temperatures might be anticipated another year.

The inability to adequately control reservoir water levels with the bypasses may be a significant limitation to this particular outlet design. Although no definite conclusions can be drawn regarding the effects of water temperature reductions resulting from gate-level releases on the fish population of the tailwater, it seems obvious that the sudden temperature decreases which occurred during the spawning period may have reduced spawning success.

TAILWATER FISH POPULATIONS

The fish populations of both Nolin and Barren tailwaters were sampled with an electrofishing unit similar to that described by Stubbs (1965). The unit consisted of a 16-foot, square-end, aluminum boat, with a built-in live

well, remote-control steering, and an extra-large bow seat with a 40-inch guard rail. A 230-volt, 180-cycle AC, 110-volt DC, generator was used for a power supply and the output was regulated by means of a multitap transformer.

The boat was used as the negative while the positive electrode consisted of a 2-foot section of copper tubing mounted on the end of a 12-foot section of insulated aluminum rod. One man operated the positive electrode from the bow of the boat and controlled two safety switches; one switch was built into the electrode rod while the other was located on the bow seat. A second man, who also worked from the bow, netted stunned fish, and the third member of the crew operated the voltage regulator and outboard motor. The bow seat and guard rail were insulated with rubber mats and all crew members wore rubber electrician's gloves and rubber boots. Electrodes arranged on 10-foot booms extending horizontally from the bow were used on occasion, but the single aluminum rod electrode proved more satisfactory in that brushy areas could be sampled more efficiently.

Captured fishes were placed in the live well until they could be identified, weighed, and measured. After the fishes were processed they were released in the area from which they were captured.

Electrofishing was conducted in June and July during the seasonal pool period; soon after completion of drawdown in late November or early December; and in March, about one month prior to the attainment of seasonal pool. In 1965, electrofishing was conducted after dark. This was accomplished by mounting three 150-watt flood lamps on the guard rail. Nighttime electrofishing was considered a very satisfactory technique when water transparency was high, but when transparency was low it seemed to be no more efficient

than daytime electrofishing. Tailwater transparency was low throughout most of the summer of 1966 and that year electrofishing was conducted primarily during the daytime.

Nolin Tailwater

Five fish population sampling areas were established on Nolin tailwater (Figure 2). Each area was 0.5 mile in length; Nolin Dam formed the upstream boundary of Area I, whereas Area V was located 4.5 miles downstream.

In 1965, sampling was conducted at Area I in June, July, and December, whereas in 1966, all five areas were sampled in March and June. Twenty-five species of fishes were collected during the period (Table 6).

The 1965 samples are summarized in Table 1-A, Appendix. The size and species composition of the samples collected in June and July were comparable but there were substantial changes in both parameters after drawdown in December. The total sample numbered 109 fishes in June; 139 fishes in July; and 734 fishes in December. There were reductions in the total number of most species after drawdown. Only the threadfin shad, gizzard shad, white crappie, carp, and drum, increased in abundance from July to December.

Bluegill and longear sunfish comprised nearly one-half of the sample during the summer, whereas threadfin shad alone constituted 95% of the sample in December. Threadfin shad were so abundant in the stilling basin that efforts to capture all stunned specimens were abandoned. Threadfin shad abundance was only temporary, however, for in late December this species suffered an extensive winter kill which was witnessed by the local conservation officer.

The December sample was taken the night following completion of reservoir drawdown. Although the results of this study indicated that numerous game fishes and panfishes had emigrated from the 0.5 mile section immediately below the dam, there was evidence that substantial numbers of fishes re-entered

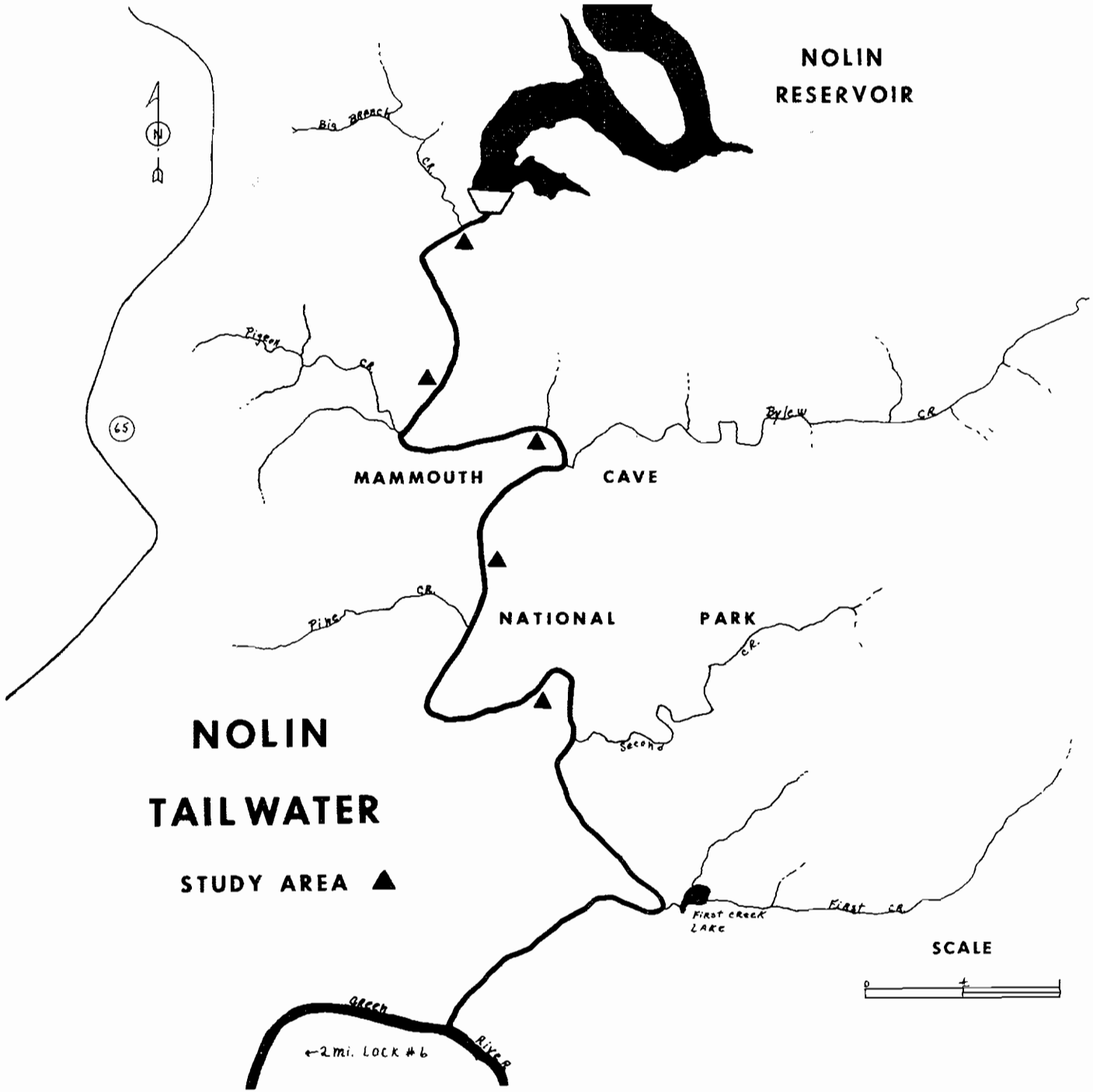

NOLIN
RESERVOIR
Big Branch
Pigeon
MAMMOUTH
CAVE
NATIONAL
PARK
Pine
Second
First
First Creek
Lake
65
N
NOLIN
TAILWATER
STUDY AREA
SCALE
Green
River
←2mi. Lock #6

Table 6. List of fishes collected from Nolin tailwater during 1965-1966.

LEPISOSTEIDAE	
Lepisosteus oculatus (Winchell)	Spotted gar
CLUPEIDAE	
Dorosoma cepedianum (Lesueur)	Gizzard shad
Dorosoma petenense (Gunther)	Threadfin shad
HIODONTIDAE	
Hiodon tergisus Lesueur	Mooneye
CYPRINIDAE	
Campostoma anomalum (Rafinesque)	Stoneroller
Carassius auratus (Linnaeus)	Goldfish
Cyprinus carpio Linnaeus	Carp
Notropis cornutus (Mitchill)	Common shiner
CATOSTOMIDAE	
Hypentelium nigricans (Lesueur)	Northern hog sucker
Minytrema melanops (Rafinesque)	Spotted sucker
Moxostoma anisurum (Rafinesque)	Silver redhorse
Moxostoma erythrurum (Rafinesque)	Golden redhorse
ICTALURIDAE	
Ictalurus melas (Rafinesque)	Black bullhead
Ictalurus natalis (Lesueur)	Yellow bullhead
Ictalurus punctatus (Rafinesque)	Channel catfish
Pylodictis olivaris (Rafinesque)	Flathead catfish
CENTRARCHIDAE	
Chaenobryttus gulosus (Cuvier)	Warmouth
Lepomis cyanellus Rafinesque	Green sunfish
Lepomis macrochirus Rafinesque	Bluegill
Lepomis megalotis (Rafinesque)	Longear sunfish
Lepomis sp. x sp.	Hybrid sunfish
Micropterus punctulatus (Rafinesque)	Spotted bass
Micropterus salmoides (Lacepede)	Largemouth bass
Pomoxis annularis Rafinesque	White crappie
Pomoxis nigromaculatus (Lesueur)	Black crappie
PERCIDAE	
Etheostoma maculatum Kirtland	Spotted darter
Stizostedion canadense (Smith)	Sauger
SCIAENIDAE	
Aplodinotus grunniens Rafinesque	Freshwater drum
ATHERINIDAE	
Labidesthes sicculus (Cope)	Brook silverside

the area later in the month. Both the reservoir manager and local conservation officer reported that tailwater fishermen were quite successful in late December.

In 1966, the combined sample from all five areas was 156 fishes in March, and 299 fishes in June (Table 2-A, Appendix).

Twelve species of fishes were recorded in March. Carp comprised 50% of the total sample and they were followed in order of decreasing abundance by brook silverside (16%), and white crappie (11%). The threadfin shad, which was so abundant in December 1965, was unrecorded in March and June, 1966.

In June, 1966, the species composition of the five areas combined was similar to the species composition of the samples in June and July, 1965. Bluegill and longear constituted over 50% of the total sample numerically and game fishes ranked second in order of abundance.

Barren Tailwater

In 1965, electrofishing studies were performed at Area I in June, July, and December, whereas in 1966, studies were conducted in March and June at two other areas in addition to Area I. Each study area was 0.5 mile in length; Barren Reservoir Dam formed the upstream boundary of Area I while Areas II and III were located 7.5 miles and 10.5 miles downstream, respectively (Figure 3).

A list of the common and scientific names of fishes recorded from Barren tailwater is presented in Table 7.

In 1965, the sample from Area I numbered 487 fishes in June, 458 fishes in July, and 425 fishes in November (Table 3-A, Appendix). Black crappie was the most abundant species in the sample during the summer and game fishes in the aggregate constituted 54% in June and 60% in July. Commercial fishes ranked second in order of abundance and comprised 32% of the sample in June

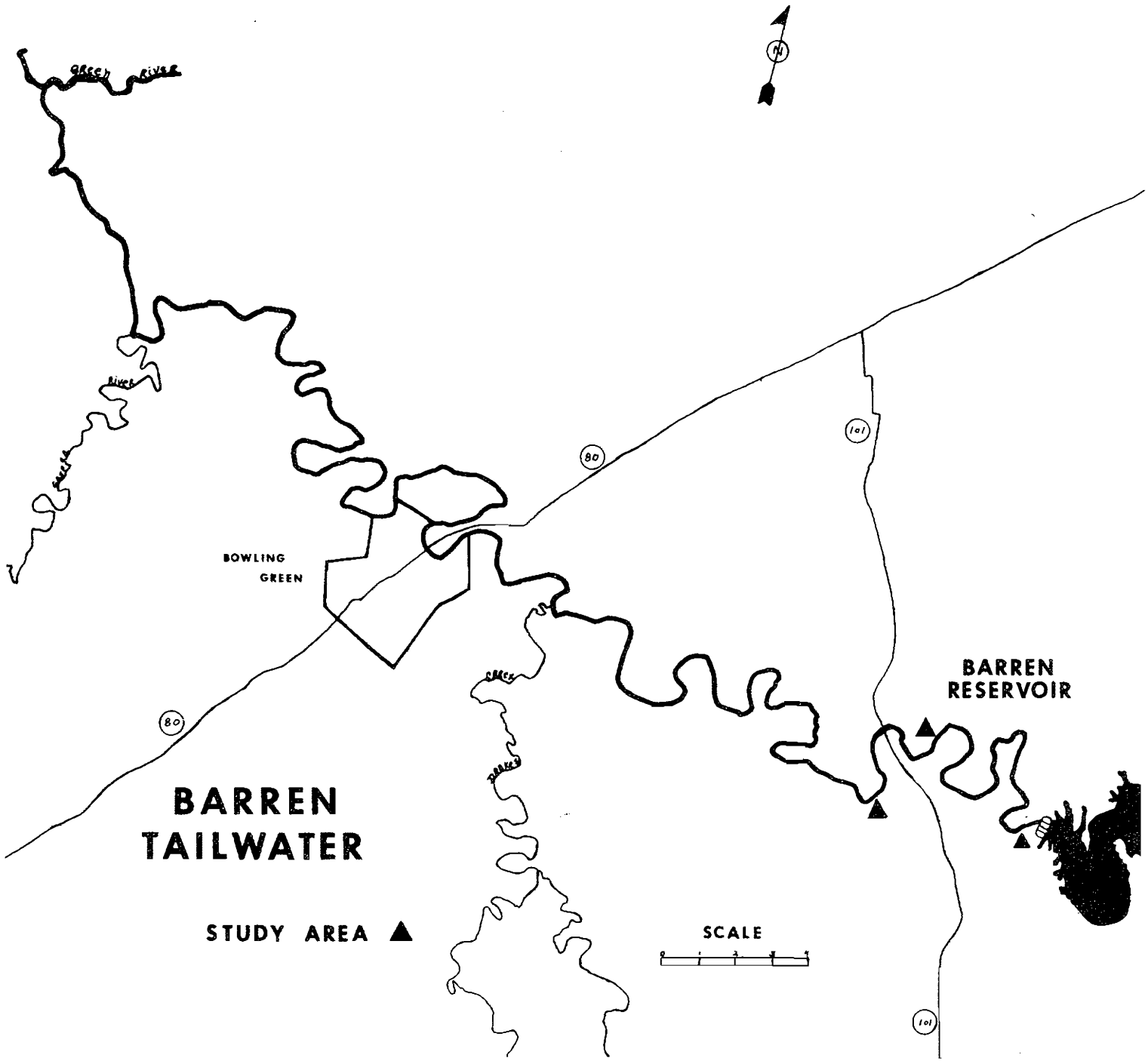

GREEN RIVER
BOWLING GREEN
80
101
BARREN RESERVOIR
BARREN TAILWATER
STUDY AREA
SCALE

Table 7. List of fishes collected from Barren tailwater in 1965-1966.

LEPISOSTEIDAE	
Lepisosteus osseus (Linnaeus)	Longnose gar
Lepisosteus platostomus Rafinesque	Shortnose gar
CLUPEIDAE	
Dorosoma cepedianum (Lesueur)	Gizzard shad
Dorosoma petenense (Gunther)	Threadfin shad
HIODONTIDAE	
Hiodon tergisus (Lesueur)	Mooneye
CYPRINIDAE	
Carassius auratus (Linnaeus)	Goldfish
Cyprinus carpio Linnaeus	Carp
Hybopsis dissimilis (Kirtland)	Streamline chub
Notropis atherinoides Rafinesque	Emerald shiner
Notropis cornutus (Mitchill)	Common shiner
Notropis photogenis (Cope)	Silver shiner
Notropis spilopterus (Cope)	Spotfin shiner
Pimephales notatus (Rafinesque)	Bluntnose minnow
CATOSTOMIDAE	
Minytrema melanops (Rafinesque)	Spotted sucker
Moxostoma anisurum (Rafinesque)	Silver redhorse
Moxostoma breviceps (Cope)	Shorthead redhorse
Moxostoma erythrurum (Rafinesque)	Golden redhorse
ICTALURIDAE	
Ictalurus melas (Rafinesque)	Black bullhead
Ictalurus natalis (Lesueur)	Yellow bullhead
Ictalurus punctatus (Rafinesque)	Channel catfish
Noturus miurus Jordan	Brindled madtom
Pylodictis olivaris (Rafinesque)	Flathead catfish
ANGUILLIDAE	
Anguilla rostrata (Lesueur)	American eel
SERRANIDAE	
Roccus chrysops (Rafinesque)	Rock bass
CENTRARCHIDAE	
Ambloplites rupestris (Rafinesque)	Rock bass
Chaenobryttus gulosus (Cuvier)	Warmouth
Lepomis cyanellus Rafinesque	Green sunfish
Lepomis humilis (Girard)	Orangespotted sunfish
Lepomis macrochirus Rafinesque	Bluegill
Lepomis megalotis (Rafinesque)	Longear sunfish
Micropterus dolomieui Lacepede	Smallmouth bass
Micropterus punctulatus (Rafinesque)	Spotted bass
Micropterus salmoides (Lacepede)	Largemouth bass
Pomoxis annularis Rafinesque	White crappie
Pomoxis nigromaculatus (Lesueur)	Black crappie

Table 7. (continued)

PERCIDAE	
Etheostoma blennioides Rafinesque	Greenside darter
Percina caprodes (Rafinesque)	Logperch
Percina phoxocephala (Nelson)	Slenderhead darter
Stizostedion vitreum vitreum (Mitchill)	Walleye
SCIAENIDAE	
Aplodinotus grunniens Rafinesque	Freshwater drum
COTTIDAE	
Cottus carolinae (Gill)	Banded sculpin
ATHERINIDAE	
Labidesthes sicculus (Cope)	Brook silverside

and 25% in July. The relative abundance of panfishes ranged from 11% in June to 13% in July.

Post-drawdown changes in the species composition at Area I were similar to those found on Nolin tailwater. The relative abundance of each fish group, excluding forage fishes, decreased after drawdown and threadfin shad replaced black crappie as the most abundant species. The only other species which increased in abundance after drawdown were gizzard shad, brook silverside, and bullheads.

During 1966, the combined sample from all three areas was 906 fishes in March and 639 fishes in June, Table 4-A, Appendix. Changes in the species composition from November to March and from March to June at Area I were also similar to the changes noted on Nolin tailwater during the period. Threadfin shad, which dominated the sample obtained in November, were absent from the samples obtained in March and June, 1966. Also, the relative abundance of carp and gizzard shad was greatest in March while game fishes dominated again in June.

The absence of threadfin shad from the 1966 studies on Barren tailwater is also attributed to a winter kill. The writer observed large numbers of dead shad in the tailwater in January, 1966.

DISCUSSION OF FISH POPULATIONS

During the summer of 1959, before the impoundment of Nolin and Barren Reservoirs, fish population studies were performed in both rivers at the same locations later designated as Area I in this study (Carter 1968, 1969). Results of these pre-impoundment studies cannot be critically compared with the findings of this study because rotenone was used for sampling before impoundment and electrofishing gear was employed after impoundment. Nevertheless, the fact that a more accurate sample was probably obtained before impoundment grants significance to some of the changes indicated in the fish population composition between periods.

Five species of fishes which were represented in the post-impoundment electrofishing studies (largemouth bass, brook silverside, black bullhead, yellow bullhead, and threadfin shad) were not even recorded by rotenone sampling in the same area before impoundment. Furthermore, bluegill and crappies were much more abundant in the same area after impoundment. Each of these species was well established in the reservoirs during the study period and their abundance in the tailwater is primarily attributed to their emigration through the dam.

The post-impoundment changes in the fish populations noted above compare with the findings of Hall (1951). He recorded substantial increases in the abundance of largemouth bass, crappies, and black bullhead in the stilling basin of Wister Reservoir, Oklahoma after impoundment and noted that these were among the dominant reservoir species.

Several factors in addition to water quality may influence the success of a tailwater fishery. One factor which is considered to be of primary

importance is fish movement from the upstream reservoir and/or from downstream sources. Some movement of fishes from each of these sources occurred during this study although it appeared that the movement of fishes from the reservoir was of greater consequence. The navigation dams previously mentioned undoubtedly prevented some degree of fish movement from the Green River into the tailwaters except during periods of flooding. As long as these structures exist the future of the tailwaters as warm water fisheries may largely depend on the emigration of fishes from the reservoirs.

CREEL SURVEYS

Creel surveys were conducted by Department conservation officers (subsequently referred to as creel clerks) who made direct contacts with fishermen. The creel clerks followed survey schedules which were designed to provide a stratified sample representative of each day of the week. This was accomplished by basing the survey on a 12-hour day (7:00 a.m. to 7:00 p.m.), dividing each day of the week into six, 2-hour periods, and sampling each period an equal number of times throughout the survey period. In this manner, creel samples were normally obtained on 63 days during the 214-day period from April 1 through October 31. The creel clerks made fisherman counts as well as interviews and the counts were used to compute the fishing pressure. This method was described by Lambou (1961):

$$f = c\bar{x}$$

where f = number of man-hours of fishing
c = number of hours in the population
$\bar{x}$ = mean number of fishermen per count.

The creel clerks interviewed as many fishermen as possible during the survey period and obtained information on the length of time fished, the number and species of fish harvested, the average length of each species, and the fishing method used.

After the catch rate and the average weight of fish harvested had been determined (the weight of fish in the creel was obtained from fish population study data) an estimate of the total harvest was made by multiplying the catch rate by the total fishing effort.

The creel survey areas were limited to the sections immediately below the dams and constituted 2.8 surface acres at Nolin and 4.3 surface acres at Barren.

Nolin Tailwater

At Nolin tailwater the fishing effort ranged from 9,926 fisherman hours in 1965, to 4,353 fisherman hours in 1966 (Table 8). This decrease in fishing effort was attributed to the closing of the tailwater access road in 1966. A corresponding decrease in the rate of harvest was noted during the period. Fishermen averaged 1.47 fish per hour (0.44 pound per hour) in 1965 and 0.81 fish per hour (0.29 pound per hour) in 1966. The percentage of successful fishermen decreased from 42 in 1965 to 29 in 1966.

Table 8. Creel data from Nolin tailwater during the third and fourth years of impoundment and from Barren tailwater during the first three years of impoundment.

	Nolin		Barren		
	1965	1966	1964	1965	1966
Survey period (days)	214	214	214	165	214
Survey area (surface acres)	2.8	2.8	4.3	4.3	4.3
Fisherman hours	9,926	4,353	21,002	7,012	13,321
fisherman hours/acre	3,545	1,554	4,680	1,630	3,097
Successful fishermen (%)	41.6	29.1	-	37.9	35.6
Rate of harvest					
fish/hour	1.47	0.81	0.33	0.63	1.19
pounds/hour	0.44	0.29	0.26	0.11	0.31
Average weight of fish harvested	0.20	0.36	0.80	0.16	0.20

Crappies dominated the creel both by number (54%) and by weight (49%) in 1965, whereas in 1966, panfishes dominated both by number (63%) and weight (32%), Table 9. Carp ranked second in order of abundance in 1965, whereas crappies ranked second in 1966.

The total estimated harvest decreased from 13,665 fishes (4,090 pounds) in 1965 to 3,486 fishes (1,262 pounds) in 1966.

Table 9. The estimated sport fishing harvest from Nolin tailwater during the third and fourth years of impoundment.

SPECIES	Numerical composition				Weight composition			
	1965		1966		1965		1966	
	No.	%	No.	%	Wt.	%	Wt.	%
Black basses	342	2.5	202	5.8	282	6.9	159	12.6
Crappies	7,365	53.9	446	12.8	1,992	48.7	215	17.0
Rock bass	123	0.9	42	1.2	20	0.5	20	1.6
Other sunfishes	1,899	13.9	2,210	63.4	131	3.2	400	31.7
Grass pickerel	-	-	21	0.6	-	-	6	0.5
Sauger	-	-	21	0.6	-	-	37	2.9
Catfishes	424	3.1	241	6.9	213	5.2	187	14.8
Drum	96	0.7	21	0.6	53	1.3	10	0.8
Suckers	14	0.1	122	3.5	16	0.4	98	7.8
Carp	3,402	24.9	143	4.1	1,383	33.8	101	8.0
Gar	-	-	17	0.5	-	-	29	2.3
TOTAL	13,665	100.0	3,486	100.0	4,090	100.0	1,262	100.0

Barren Tailwater

The fishing effort at Barren tailwater was an estimated 21,002 fisherman hours in 1964; 7,012 fisherman hours in 1965; and 13,321 fisherman hours in

1966 (Table 8). The decrease in fishing effort which occurred between 1964 and 1965 is partially attributed to a shorter survey period; the 1964 and 1966 surveys were both based on a 214 day survey period as opposed to a 165 day survey period in 1965.

The average rate of harvest increased from 0.33 fish per hour (0.26 pound per hour) in 1964, to 1.19 fish per hour (0.31 pound per hour) in 1966, while the average weight of fish in the creel decreased from 0.8 pound to 0.2 pound.

The total estimated harvest ranged from 6,931 fishes (5,461 pounds) in 1964, to 4,418 fishes (771 pounds) in 1965, to 15,582 fishes (4,219 pounds) in 1966 (Table 10).

There were marked changes in the creel composition during the study period. The first year of impoundment the creel composition was dominated by sunfishes, suckers, and catfishes — three species which were common in the creel before impoundment. The second and third years of impoundment the creel composition was dominated by crappies and carp — two species which were abundant in the reservoir.

Sunfishes comprised 21% of the harvest in 1964, and 2% in 1966. Suckers comprised 25% of the harvest in 1964 and less than 1% in 1966.

The numerical composition of crappies increased from 12% in 1964 to 69% in 1966, while the numerical composition of carp increased from 5% to 11% during the period.

In 1964, the weight composition of the harvest was chiefly comprised of suckers (21%), catfishes (20%), and carp (20%), whereas carp and crappies dominated the harvest during 1965 and 1966. Crappies comprised 6% of the harvest weight in 1964, 35% in 1965, and 45% in 1966. Carp comprised 20% of the harvest in 1964, 48% in 1965, and 29% in 1966.

Table 10. The estimated sport fishing harvest from Barren tailwater during the first three years of impoundment.

SPECIES	Numerical composition						Weight composition					
	1964		1965*		1966		1964		1965*		1966	
	No.	%	No.	%	No.	%	Wt.	%	Wt.	%	Wt.	%
Black basses	451	6.5	-	-	222	1.4	464	8.5	-	-	153	3.7
Crappies	825	11.9	1,811	41.0	10,954	69.1	333	6.1	273	35.4	1,858	45.0
White bass	520	7.5	-	-	888	5.6	339	6.2	-	-	636	15.4
Rock bass	76	1.1	115	2.6	-	-	11	0.2	26	3.4	-	-
Other sunfishes	1,442	20.8	1,074	24.3	317	2.0	333	6.1	84	10.9	33	0.8
Catfishes	1,379	19.9	115	2.6	1,585	10.0	1,071	19.6	18	2.3	178	4.3
Drum	166	2.4	-	-	16	0.1	158	2.9	-	-	25	0.6
Suckers	1,719	24.8	-	-	95	0.6	1,671	30.6	-	-	58	1.4
Carp	353	5.1	1,303	29.5	1,775	11.2	1,081	19.8	370	48.0	1,188	28.8
TOTAL	6,931	100.0	4,418	100.0	15,852	100.0	5,461	100.0	771	100.0	4,129	100.0

* The 1965 survey was based on a 165-day survey period as opposed to a 214-day period in 1964 and 1966.

DISCUSSION OF CREEL SURVEYS

The tailwater creel surveys did not provide an accurate measure of the total fishing pressure expended during the study period because many anglers frequented both tailwaters during the post-drawdown period from December through March and were not included in the creel surveys. Based on my own observations and those of the reservoir managers and local conservation officers, I believe that the fishing effort during the winter and early spring nearly equalled that of the survey period. In consideration of this, and the fact that Barren and Nolin Reservoirs dominated the local sport fishing scene during the period, the value of the tailwater fishery was considered more significant than the creel surveys indicated.

The popularity of the tailwaters may be attributed to access ease as well as fisherman success. Although the average number of fish harvested per hour was considered acceptable, the average size of the fish creeled was generally small.

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A P P E N D I X

Table 1-A. The fish population composition of Area I on Nolin tailwater during June, July, and December, 1965.

SPECIES	June				July				December			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Game Fishes												
Sauger	1	0.9	1.4	3.6								
Largemouth bass	6	5.5	3.4	8.8	13	9.4	14.4	30.5				
Spotted bass	21	19.3	11.4	29.5	22	15.8	12.6	26.7	2	0.3	0.6	2.8
White crappie	1	0.9	0.3	0.7	2	1.4	0.4	0.9	12	1.6	1.4	6.2
Sub total	29	26.6	16.5	42.6	37	26.6	27.4	58.1	14	1.9	2.0	9.0
Food Fishes												
Channel catfish	1	0.9	0.2	0.5	3	2.2	0.8	1.7				
Flathead catfish					1	0.7	0.2	0.5				
Sub total	1	0.9	0.2	0.5	4	2.9	1.0	2.2				
Predatory Fishes												
Mooneye	2	1.9	2.0	5.1								
Longnose gar	1	0.9	1.0	2.6								
Sub total	3	2.8	3.0	7.7								
Panfishes												
Bluegill	30	27.5	2.7	7.0	32	23.0	1.7	3.7	4	0.5	0.2	0.9
Longear sunfish	17	15.6	1.4	3.6	36	25.9	3.6	7.6	4	0.5	0.1	0.4
Warmouth					2	1.5	0.3	0.7				
Sub total	47	43.1	4.1	10.6	70	50.4	5.6	12.0	8	1.0	0.3	1.3

Table 1-A. (continued)

SPECIES	June				July				December			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Commercial Fishes												
Hog sucker					1	0.7	0.6	1.3				
Redhorses	10	9.2	6.9	17.8	16	11.5	8.3	17.7	2	0.3	1.0	4.3
Spotted sucker	5	4.6	1.5	3.9					1	0.1	0.2	0.7
Carp	9	8.2	4.0	10.4	3	2.2	1.4	2.9	9	1.2	4.2	19.0
Bullheads					1	0.7	0.2	0.3				
Drum	1	0.9	1.1	2.8					2	0.3	0.8	3.6
Sub total	25	22.9	13.5	34.9	21	15.1	10.5	22.2	14	1.9	6.2	27.6
Forage Fishes												
Gizzard shad	3	2.8	1.4	3.7	7	5.0	2.6	5.5	5	0.7	6.5	29.2
Threadfin shad	1	0.9	tr.	tr.					693	94.5	7.4	32.9
Sub total	4	3.7	1.4	3.7	7	5.0	2.6	5.5	698	95.2	13.9	62.1
GRAND TOTAL	109	100.0	38.7	100.0	139	100.0	47.1	100.0	734	100.0	22.4	100.0

Table 2-A. The fish population composition of Areas I - V on Nolin tailwater during March and June, 1966.

SPECIES	March				June			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Game Fishes								
Largemouth bass	1	0.6	2.4	5.5	23	7.7	19.1	21.6
Spotted bass	4	2.7	1.5	3.4	17	5.7	7.7	8.7
White crappie	17	10.9	2.4	5.5	15	5.0	2.8	3.2
Sub total	22	14.2	6.3	14.4	55	18.4	29.6	33.5
Food Fishes								
Channel catfish					2	0.7	0.8	0.9
Panfishes								
Bluegill	11	7.0	2.6	5.9	101	33.8	11.5	13.2
Longear sunfish	6	3.9	0.4	0.9	57	19.1	5.5	6.2
Warmouth					7	2.3	0.6	0.6
Green sunfish	1	0.6	tr.	tr.	1	0.3	tr.	0.1
Hybrid sunfish					1	0.3	tr.	tr.
Sub total	18	11.5	3.0	6.8	167	55.8	17.6	20.1
Commercial Fishes								
Redhorses	3	1.9	1.9	4.4	4	1.3	2.1	2.4
Spotted sucker	1	0.6	0.2	0.5	11	3.7	2.1	2.4
Carp	78	50.0	29.3	66.9	22	7.4	17.5	19.9
Sub total	82	52.5	31.4	71.8	37	12.4	21.7	24.7

Table 2-A. (continued)

SPECIES	March				June			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Forage Fishes								
Gizzard shad	7	4.4	2.9	6.6	37	12.4	18.3	20.8
Misc. cyprinids	3	1.9	0.1	0.2				
Brook silverside	24	15.5	0.1	0.2	1	0.3	tr.	tr.
Sub total	34	21.8	3.1	7.0	38	12.7	18.3	20.8
GRAND TOTAL	156	100.0	43.8	100.0	299	100.0	87.8	100.0

Table 3-A. The fish population composition of Area I on Barren tailwater during June, July, and November, 1965.

SPECIES	June 30				July 28				November 30			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.	Total no.	% wt.	Total wt.	% wt.
Game Fishes												
Walleye	1	0.2	1.2	1.5								
Largemouth bass	17	3.5	9.8	11.8	9	1.9	9.3	11.2	1	0.2	0.4	1.3
Smallmouth bass	1	0.2	0.1	0.1								
Spotted bass	12	2.5	6.4	7.7	25	5.5	17.1	20.6	2	0.5	1.0	3.8
Black crappie	214	43.9	12.2	14.7	240	52.4	13.2	15.8	14	3.3	2.4	8.9
White crappie	16	3.3	0.7	0.8					4	0.9	0.1	0.5
Sub total	261	53.6	30.4	36.6	274	59.8	39.6	47.6	21	4.9	3.9	14.5
Food Fishes												
Channel catfish					2	0.4	1.6	2.0				
Flathead catfish					2	0.4	2.4	2.8				
Sub total					4	0.8	4.0	4.8				
Predatory Fishes												
Longnose gar	6	1.2	5.8	7.0					1	0.2	0.4	1.0
Panfishes												
Rock bass					4	0.9	1.0	1.2				
Bluegill	35	7.2	2.5	3.0	28	6.1	2.0	2.4	1	0.2	tr.	tr.
Green sunfish	1	0.2	tr.	tr.								
Longear sunfish	17	3.5	1.2	1.4	25	5.5	0.5	0.6	1	0.2	tr.	0.2
Warmouth					1	0.2	0.2	0.2				
Sub total	53	10.9	3.7	4.4	58	12.7	3.7	4.4	2	0.4	tr.	0.2

Table 3-A. (continued)

SPECIES	June 30				July 28				November 30			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Commercial Fishes												
Hog sucker	1	0.2	0.7	0.9								
Redhorses	52	10.7	20.9	25.2	49	10.7	21.5	25.9	8	1.9	3.4	12.7
Spotted sucker	29	5.9	4.9	6.0	24	5.2	4.5	5.4	1	0.2	0.5	1.9
Carp	16	3.3	7.0	8.5	11	2.4	4.1	4.9	6	1.4	3.0	11.3
Bullheads	57	11.7	3.0	3.6	31	6.8	1.5	1.8	58	13.7	7.1	26.4
Sub total	155	31.8	36.5	44.2	115	25.1	31.6	38.0	73	17.2	14.0	52.3
Forage Fishes												
Gizzard shad	11	2.3	6.5	7.8	5	1.2	3.5	4.3	81	19.1	4.1	15.4
Threadfin shad									243	57.3	4.5	16.6
Notropis sp.	1	0.2	tr.	tr.								
Brook silverside									4	0.9	tr.	tr.
Goldfish					2	0.4	0.7	0.9				
Sub total	12	2.5	6.5	7.8	7	1.6	4.2	5.2	328	77.3	8.6	32.0
GRAND TOTAL	487	100.0	82.9	100.0	458	100.0	83.1	100.0	425	100.0	26.9	100.0

Table 4-A. The fish population composition of Areas I, II, and III combined on Barren tailwater during March and June, 1966.

SPECIES	March				June			
	Total no.	% no.	Total wt.	% wt.	Total no.	% no.	Total wt.	% wt.
Game Fishes								
Walleye	3	0.3	4.2	2.0				
Largemouth bass	4	0.4	0.9	0.5	10	1.6	7.9	2.6
Spotted bass	26	2.9	13.5	6.7	22	3.4	10.1	3.3
White bass					3	0.5	1.3	0.4
Black crappie	66	7.3	1.6	0.8	104	16.2	12.2	3.9
White crappie	46	5.1	4.9	2.4	7	1.1	3.0	1.0
Sub total	145	16.0	25.1	12.4	146	22.8	34.5	11.2
Food Fishes								
Channel catfish					2	0.3	3.6	1.2
Flathead catfish					4	0.6	10.0	3.2
Sub total					6	0.9	13.6	4.4
Predatory Fishes								
Longnose gar					4	0.6	3.8	1.2
Panfishes								
Rock bass	2	0.2	0.1	tr.	3	0.5	0.5	0.2
Bluegill	42	4.6	3.4	1.6	34	5.3	2.9	0.9
Longear sunfish	53	5.9	2.4	1.2	87	13.6	6.2	2.1
Green sunfish					2	0.3	0.1	tr.
Warmouth	1	0.1	0.3	0.2	2	0.3	0.5	0.2
Sub total	98	10.8	6.2	3.0	128	20.0	10.2	3.4

Table 4-A. (continued)

SPECIES	March Total no.	March % no.	March Total wt.	March % wt.	June Total no.	June % no.	June Total wt.	June % wt.
Commercial Fishes								
Hog sucker	4	0.4	2.4	1.2	3	0.5	1.1	0.3
Redhorses	56	6.1	34.9	17.2	74	11.6	51.6	16.6
Spotted sucker	6	0.7	1.0	0.5	50	7.8	15.7	5.0
Carp	238	26.3	108.8	53.6	127	19.8	143.9	46.3
Bullheads	132	13.6	8.5	4.1	3	0.6	0.8	0.3
Drum					2	0.3	10.3	3.3
Sub total	436	47.1	155.6	76.6	259	40.6	223.4	71.8
Forage Fishes								
Lampreys	1	0.1	0.1	0.1				
Gizzard shad	206	23.8	15.8	7.7	87	13.6	24.7	7.9
Misc. cyprinids	10	1.1	0.2	0.1	7	1.3	0.4	0.1
Darters	6	0.7	0.1	tr.				
Brook silverside	2	0.2	tr.	tr.	2	0.3	tr.	tr.
Sculpins	2	0.2	0.1	0.1				
Sub total	227	26.1	16.3	8.0	96	15.2	25.1	8.0
GRAND TOTAL	906	100.0	203.2	100.0	639	100.0	310.6	100.0