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An Ichtyhyofaunal Survey of Three Kentucky Tailwaters

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Western Kentucky University

Robison,

William Allen

1980

AN ICHTHYOFAUNAL SURVEY OF THREE KENTUCKY TAILWATERS

A Thesis

Presented to

the Faculty of the Department of Biology

Western Kentucky University

Bowling Green, Kentucky

In Partial Fulfilment

of the Requirements for the Degree

Master of Science

by

William Allen Robison

May 1980

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AN ICHTHYOFAUNAL SURVEY OF

THREE KENTUCKY TAILWATERS

Recommended April 16, 1980
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ACKNOWLEDGEMENTS

My most sincere thanks go to Dr. Robert D. Hoyt, chairman of my committee, for his advice, guidance, and patience throughout this entire study. I also express my appreciation for the suggestions and encouragement provided during the course of this study by the other members of my committee, Drs. Gary E. Dillard and Larry N. Gleason.

Financial support for this study was provided by the East Central Reservoir Investigations (ECRI) of the U.S. Fish and Wildlife Service, National Reservoir Research Program, and by the Department of Biology, Western Kentucky University. Members of the ECRI, Messers. Chuck Walburg, Jerry Novotny, Ken Jacobs, Terry Campbell, and Bill Swink, also helped with field and lab work.

I am grateful to Messers. Bonnie Laflin and Danny Richardson of the Kentucky Department of Fish and Wildlife Resources for their help with the rotenone samples and for the uses of their electroseine.

The assistance of fellow students with the field work is very much appreciated. These include Ben Del Tito, Greg Kindschi, Dennis Webb, Mike Cretella, and Stan Martin.

I would especially like to thank my parents, Mr. and Mrs. James W. Robison, for their spiritual and material support. I also thank Janet L. Rowlett for typing the drafts of this manuscript. The cooperative efforts of many other people too numerous to mention individually are both acknowledged and deeply appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

page

AN ICHTHYOFAUNAL SURVEY OF THREE
KENTUCKY TAILWATERS

William Allen Robison May 1980 45 pages
Directed by: R. Hoyt, G. Dillard, and L. Gleason
Department of Biology Western Kentucky University

Tailwater fishes of the Green, Barren, and Rough River Lakes, Kentucky, were sampled in the fall of 1978, spring 1979, and summer 1979. Fish per acre estimates were greatest in the fall and least in the spring, while standing crop estimates were similar in the fall and spring but markedly lower in the summer. Cyprinidae was the predominant family represented in the entire study. Rough species comprised the greatest component of biomass in each tailwater, while forage and/or game fish represented the majority of individuals.

Barren River tailwater fishes exhibited the greatest average standing crop estimates, while the greatest variety of species was observed in the Green River tailwater. Habitat differences were concluded to be responsible for the observed differences between the Green and Barren River tailwaters. The Rough River tailwater included a pool six miles in length and was considered an atypical tailwater.

Standing crop estimates were highest in the fall on Green and Rough River tailwaters and in the spring on Barren River tailwater. Numerically, the most abundant species in the Green River tailwater were the bluntnose minnow and white crappie. Longear sunfish and spotfin shiner predominated in the Barren, while white crappie and gizzard shad were most abundant in the Rough.

A decrease in average standing crop estimates was observed between the most upstream and downstream stations on Rough River tailwater, but, due to similarity of habitat between the stations, no explanation was available. Rainbow trout were generally found in close proximity to stocking points for each tailwater.

INTRODUCTION

The management of inland freshwater resources has increased throughout the world. Flow regulation of rivers and streams by man-made modifications has become so common that natural flow in waters in many countries is now the exception rather than the rule. This development, originally intended to be beneficial, has brought with it unforeseen problems that affect aquatic biota in both the impoundments and their tailwaters.

The location of reservoir discharges, surface versus bottom, has been reported to affect tailwater biota adversely due to the temperature and water chemistry of these releases (Martin and Stroud 1973, Charles and McLemore 1973). Increased discharge volume may also cause increased erosion downstream (Krumholz and Neff 1970). Keely et al. (1978) reported low dissolved oxygen concentrations, nutrient enrichment, heavy metals, pesticides, and fluctuations in flow and water levels to be major problems associated with reservoir releases.

Dams are constructed for a variety of purposes including power generation, flood control, navigation, recreation, and fish production. Many are designed to provide several of these services simultaneously. While water engineering authorities are responsible for providing flow releases from projects to insure the maintenance of downstream fisheries and aquatic habitat, present operational guidelines often do not allow them to do this while concurrently achieving other authorized project purposes (Keely et al. 1978).

Although much information has been compiled on cold-water tailwater fishes, few applications of this knowledge can be made on the complex fish populations characteristic of warm-water tailwaters (Carlander 1957, Keely et al. 1978, Marzolf 1978). Toward this end, the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers are working together through the National Reservoir Research Program to evaluate the effects of modified reservoir releases on both reservoir and tailwater fishes in warm-water areas.

The objective of the present study was to evaluate the seasonal community structure of fishes in the tailwaters of the Green, Barren, and Rough River Lake tailwaters during periods of minimal flow. Primary areas of concern included species composition, seasonal relative abundance of species and individuals, biomass estimates, and distribution of fish species.

STUDY AREA

Tailwaters originating from three small U.S. Army Corps of Engineer lakes in south-central Kentucky were selected for this study. All three lakes and the tailwater areas sampled lie within the Green River Basin and the Pennyroyal physiographic region. The Green River Basin, draining approximately 8,900 sq mi (23,013 sq km) in west-central Kentucky, is the largest of Kentucky's river basins. The Pennyroyal region is characterized by karst topography with underlying formations consisting primarily of limestone, chert, shale, and some sandstone.

Five collection stations were established on the Green River tailwater, Taylor and Green Counties, between the dam (River Mile 305, Kilometer 491) and Roachville Ford, approximately 14 miles (22.5 km) downstream (Figure 1, Table 1). The Barren River tailwater, Allen and Barren Counties, was likewise sampled at five stations between the dam (River Mile 79, Kilometer 127) and Kentucky Highway 101 bridge, about 13 miles (21 km) downstream (Figure 2, Table 2). Four areas were sampled on the Rough River tailwater, Breckinridge and Grayson Counties, between the dam (River Mile 89, Kilometer 143) and Falls of Rough, Kentucky, approximately six miles (9.5 km) downstream (Figure 3, Table 3). While the Green and Barren tailwaters provided a mixture of riffle and pool areas that could be sampled, the Rough River tailwater represented an atypical tailwater. A grist mill dam at Falls of Rough,

Figure 1. Map of the Green River Lake tailwater area showing the location of each sampling station.

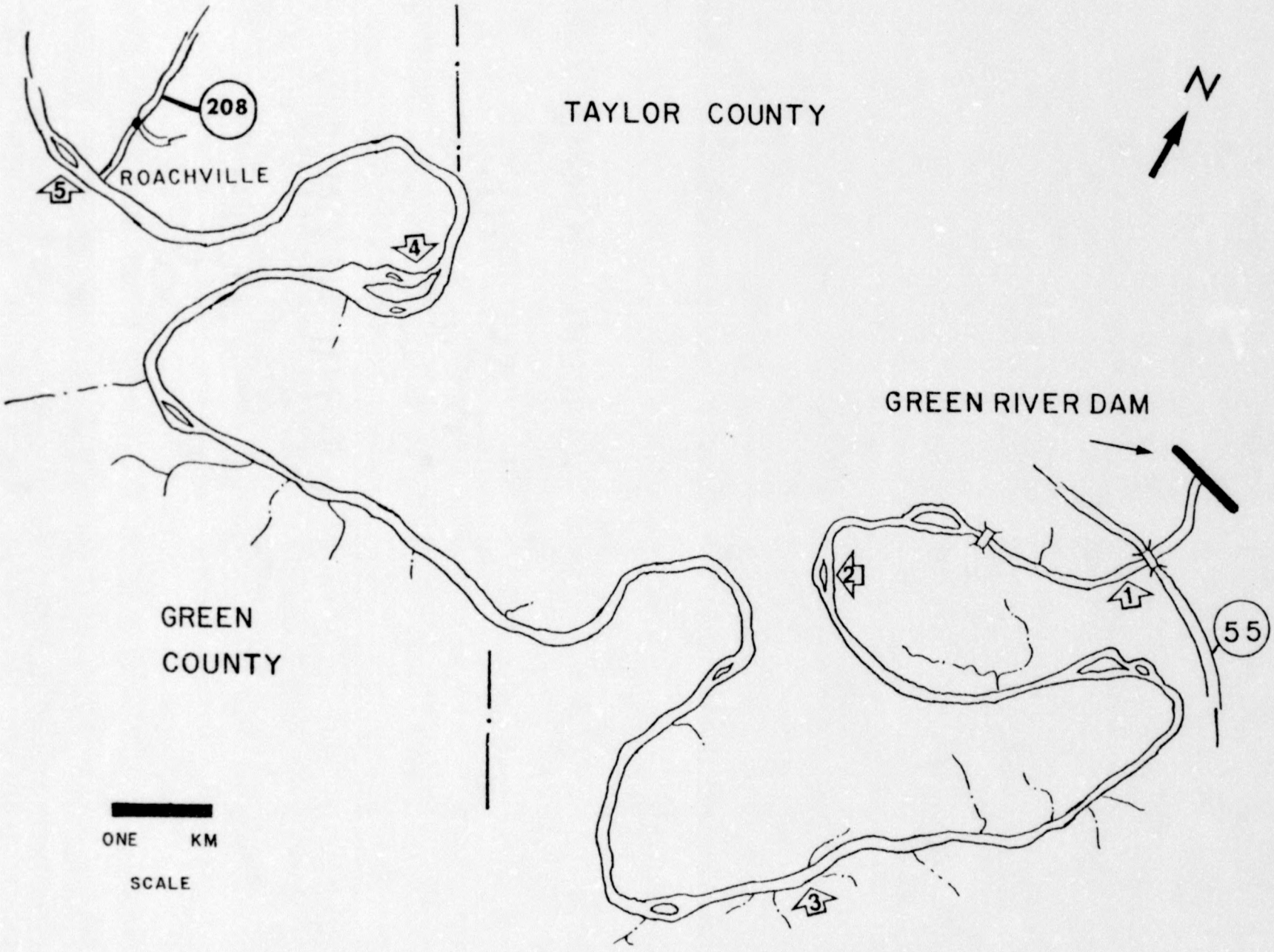

208
ROACHVILLE
5
4
TAYLOR COUNTY
N
GREEN RIVER DAM
2
1
55
GREEN
COUNTY
3
ONE KM
SCALE

Table 1. Description of collecting stations on the Green River Lake tailwater.

Station	Location	Surface Area of Station	Length X avg. Width	Physiography	Mean Depth Sampled	Substrate	Habitat
I	Tailwater Mile 0.5 (0.8 km)	0.77 acres (0.31 ha)	430 X 78 feet (131 X 24 m)	Shallow riffle at head of station, pool at lower end	3.5 feet 1.1 m	gravel in riffle to bedrock pool	sunken logs and some large rocks in pool
II	Tailwater Mile 2.5 (0.4 km)	0.49 acres (0.20 ha)	385 X 55 feet (117 X 17 m)	riffle at head of station, pool at lower end	2.0 feet 0.6 m	gravel to rubble in riffle, bedrock in pool	large rocks in riffle, submerged bank vegetation
III	Tailwater Mile 6 (9.7 km)	0.44 acres (0.18 ha)	289 X 66 feet (88 X 20 m)	station all riffle, upper end deep, lower end split around small island	2.0 feet 0.6 m	gravel to very large rocks	large rocks and submerged bank vegetation
IV	Tailwater Mile 11 (17.7 km)	0.35 acres (0.14 ha)	289 X 53 feet (88 X 16 m)	short, narrow pool	3.0 feet 0.9 m	mud-clay to coarse gravel	large log down center of pool, tree stumps and submerged vegetation along banks
V	Tailwater Mile 14 (22.5 km)	0.14 acres (0.06 ha)	185 X 33 feet (56 X 10 m)	riffle at upper end, pool at lower end	3.0 feet 0.9 m	mud-clay to gravel	water willow in upper station riffle area

Figure 2. Map of the Barren River Lake tailwater area showing the location of each sampling station.

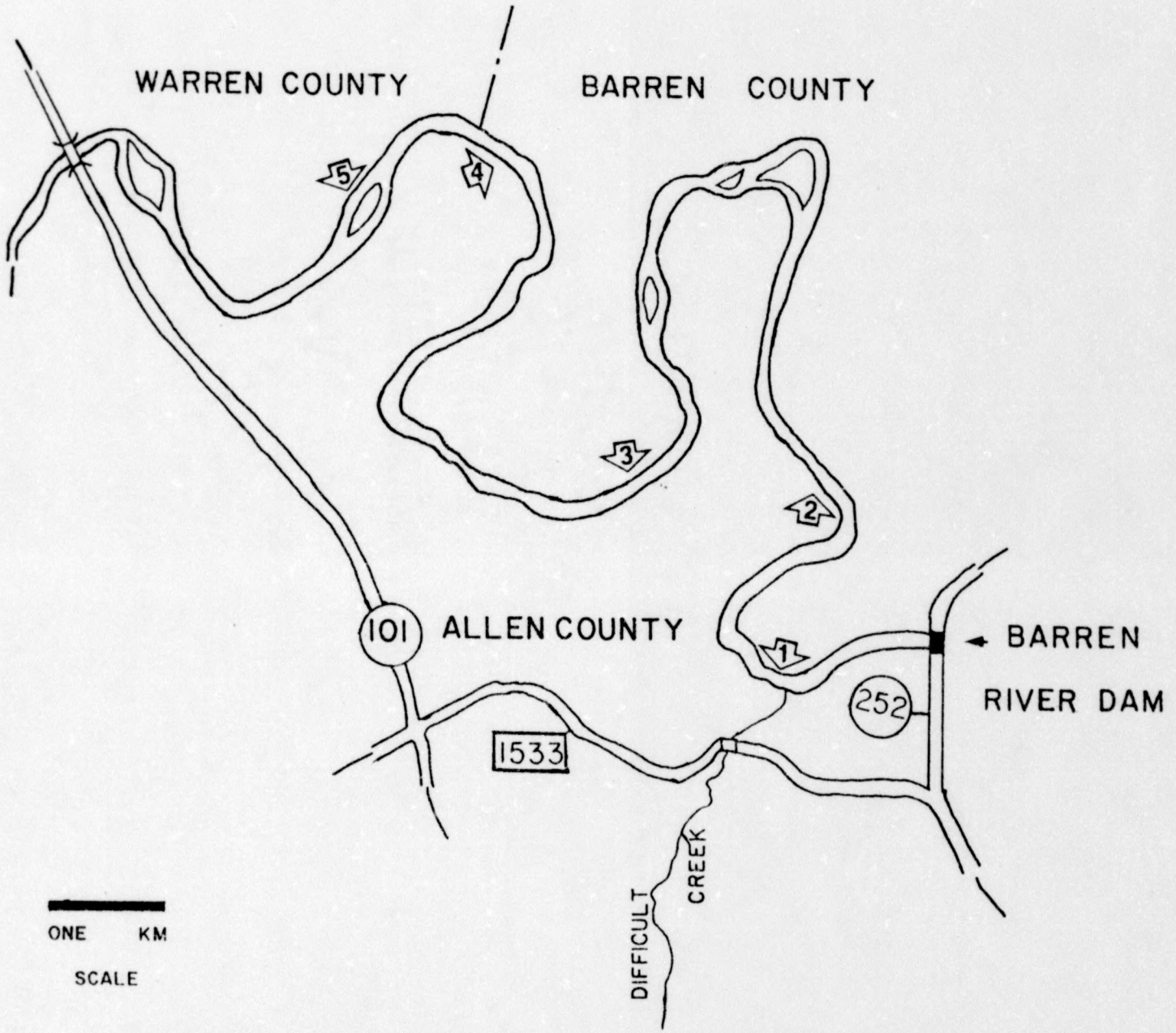

WARREN COUNTY
BARREN COUNTY
5
4
3
2
1
N
101
ALLEN COUNTY
BARREN
RIVER DAM
252
1533
DIFFICULT
CREEK
ONE KM
SCALE

Table 2. Description of collecting stations on the Barren River Lake tailwater.

Station	Location	Surface Area of Station	Length X Avg. Width	Physiography	Mean Depth Sampled	Substrate	Habitat
I	Tailwater Mile 0.8 (1.3 km)	0.15 acres (0.06 ha)	151 X 78 feet (46 X 13 m)	long narrow riffle and wide pool	2.5 feet 0.75 m	mud-silt to coarse gravel	submerged tree limbs and large stump
II	Tailwater Mile 2 (3.2 km)	0.34 acres (0.14 ha)	185 X 79 feet (56 X 24 m)	riffle-chute with deep side pool	3.0 feet 0.9 m	rubble to large rocks in riffle, mud-silt in pool	large rocks
III	Tailwater Mile 6.5 (10.5 km)	0.28 acres (0.11 ha)	302 X 46 feet (92 X 14 m)	long, narrow riffle	1.0 foot 0.3 m	gravel to rubble	submerged trees, stumps, and roots roots along an undercut bank
IV	Tailwater Mile 11 (17.7 km)	0.34 acres (0.14 ha)	268 X 56 feet (82 X 17 m)	wide, shallow shoal-riffle area with a narrow trench along one bank	10 inches 0.25 m	fine to coarse gravel	large, embedded long, submerged tree limbs
V	Tailwater Mile 12 (19 km)	0.15 acres (0.06 ha)	215 X 30 feet (66 X 9 m)	riffle at upper end, 2 large pools at lower end	3.0 feet 0.9 m	mud-clay to gravel	extensive sunken logs, limbs, and undercut banks

Figure 3. Map of the Rough River Lake tailwater area showing the location of each sampling station.

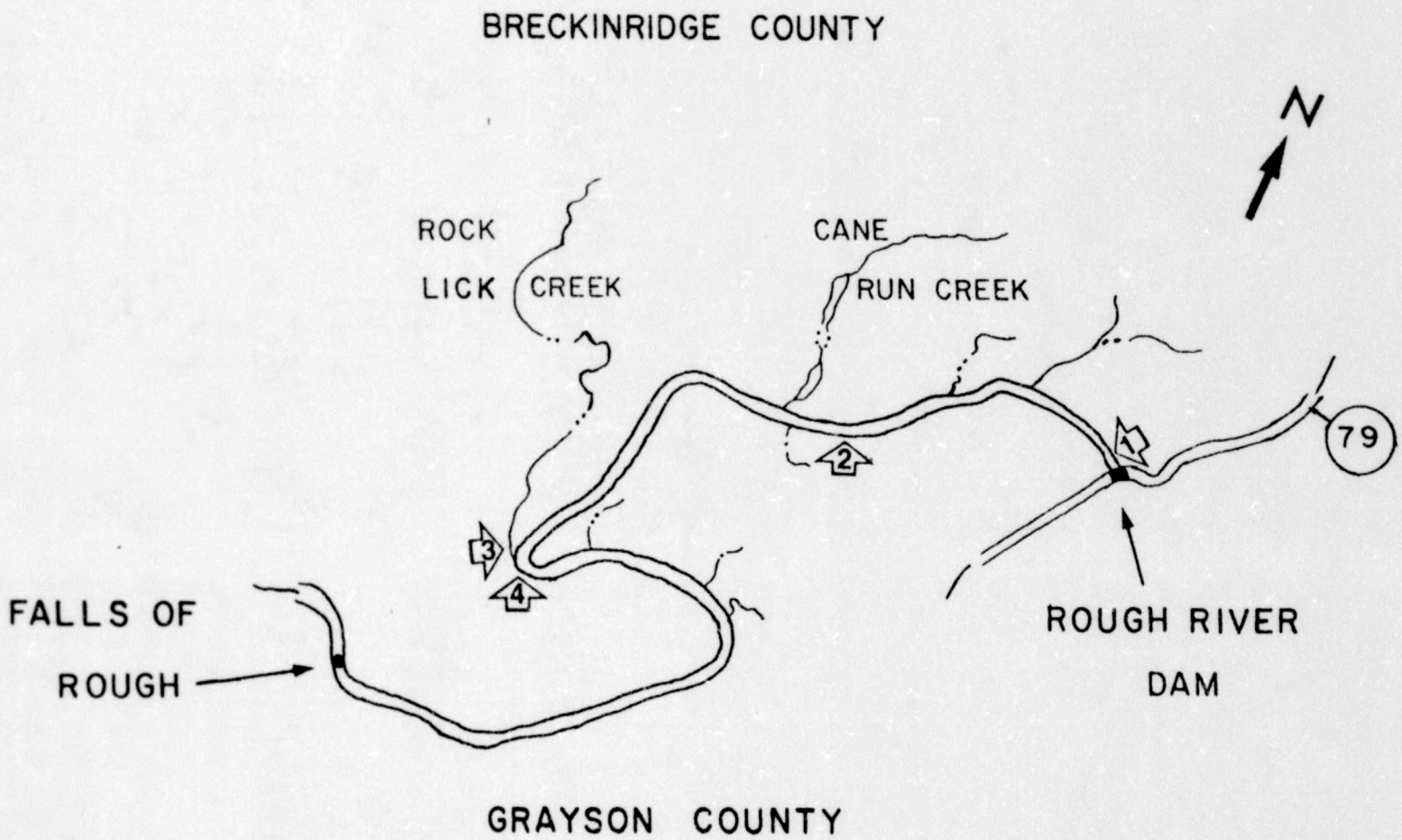

BRECKINRIDGE COUNTY
N
ROCK
LICK CREEK
CANE
RUN CREEK
79
1
2
3
4
FALLS OF
ROUGH
ROUGH RIVER
DAM
GRAYSON COUNTY
ONE KM
SCALE

Table 3. Description of collecting stations on the Rough River Lake tailwater.

Station	Location	Surface Area of Station	Length X Avg. Width	Physiography	Mean Depth Sampled	Substrate	Habitat
I	Tailwater Mile 0 (0.0 km)	0.46 acres (0.18 ha)	200 X 100 feet (62 X 31 m)	large spill pool below dam raceway, riffle area to deep pool	6.0 feet 1.8 m	mud-silt to large rocks	large rocks, buck bushes in lower end of pool
II	Tailwater Mile 1.25 (2 km)	0.41 acres (0.16 ha)	300 X 60 feet (91 X 18 m)	large pool	7.0 feet 2.0 m	mud-silt	undercut banks, submerged trees and limbs
III	Mouth of Rock Lick Creek at Tailwater Mile 4 (6.4 km)	0.46 acres (0.18 ha)	400 X 50 feet (122 X 15 m)	long, narrow pool	5.0 feet 1.5 m	mud-silt	undercut banks, roots, submerged logs and limbs
IV	Tailwater Mile 4, at mouth of Rock Lick Creek (6.4 km)	0.92 acres (0.37 ha)	400 X 100 feet (122 X 30 m)	large, mainstream pool	5.0 feet 1.5 m	mud-silt	fallen trees, submerged limbs, logs, tires, etc.

Kentucky, produced a six mile (9.5 km) pool below the dam on Rough River that showed little change in physical conditions or habitat at the collection stations.

Temperature measurements identified each stream as a warm-water tailwater (Tables 4-6). Temperatures ranged from 13 C (55 F) in the spring to 26 C (78.5 F) in the summer. While most physico-chemical measurements taken showed little or no fluctuation from the most upstream station to the most downstream station, the total alkalinity measurement on Green River tailwater (Table 4) during the spring sampling period increased from 51.3 mg/l at Station 1 to 102.6 mg/l at Station 5. No explanation was available to account for this increase.

Table 4. Physico-chemical measurements taken at Station 1 and Station 5 on the Green River Lake tailwater September, 1978 through August, 1979.

Station 1	September 23, 1978	May 14, 1979	August 23, 1979
Temperature °Celsius	25	13	26
pH	7.5	7.5	7.5
Dissolved Oxygen	7 mg/1	7 mg/1	7 mg/1
Total Alkalinity	68.4 mg/1	51.3 mg/1	119.7 mg/1
Total Hardness	85.5 mg/1	102.6 mg/1	85.5 mg/1

Station 5	September 23, 1978	May 14, 1979	August 23, 1979
Temperature °Celsius	22	13	25
pH	7.5	7.5	7.5
Dissolved Oxygen	7 mg/1	8 mg/1	7 mg/1
Total Alkalinity	68.4 mg/1	102.6 mg/1	119.7 mg/1
Total Hardness	85.5 mg/1	119.7 mg/1	85.5 mg/1

Table 5. Physico-chemical measurements taken at Station 1 and Station 5 on the Barren River Lake tailwater September, 1978 through August, 1979.

Station 1	September 30, 1978	June 16, 1979	August 4, 1979
Temperature °Celsius	24	20	24
pH	8	7.5	7.5
Dissolved Oxygen	5 mg/1	7 mg/1	8 mg/1
Total Alkalinity	102.6 mg/1	102.6 mg/1	85.5 mg/1
Total Hardness	136.8 mg/1	119.7 mg/1	138.6 mg/1

Station 5	September 30, 1978	June 16, 1979	August 4, 1979
Temperature °Celsius	23	20	26
pH	7.5	7.5	8
Dissolved Oxygen	6 mg/1	7 mg/1	7 mg/1
Total Alkalinity	102.6 mg/1	102.6 mg/1	119.7 mg/1
Total Hardness	136.8 mg/1	119.7 mg/1	119.7 mg/1

Table 6. Physico-chemical measurements taken at Station 1 and Station 4 on the Rough River Lake tailwater October, 1978 through August, 1979.

Station 1	October 1978	June 1979	August 1979
Temperature °Celsius	20	17	24
pH	7	8	7.5
Dissolved Oxygen	4 mg/1	7 mg/1	6 mg/1
Total Alkalinity	119.7 mg/1	68.4 mg/1	119.7 mg/1
Total Hardness	136.8 mg/1	119.7 mg/1	171.0 mg/1

Station 4	October 1978	June 1979	August 1979
Temperature °Celsius	20	17	No Data
pH	7	7.5	No Data
Dissolved Oxygen	4 mg/1	7 mg/1	No Data
Total Alkalinity	119.7 mg/1	119.7 mg/1	No Data
Total Hardness	136.8 mg/1	119.7 mg/1	No Data

MATERIALS AND METHODS

Sampling of the Green, Barren, and Rough River Lake tailwaters was conducted in the fall of 1978 and spring and summer of 1979. The Green River tailwater was sampled August 31 and September 23, 1978, and May 14, August 6, and August 13, 1979; Barren River tailwater, September 14 and 30, 1978, and June 16, August 1, and August 4, 1979; Rough River tailwater, October 13, 1978, and June 11, June 29, and August 17, 1979. All collections were made at approximate minimum lake discharges which, during periods when greater than minimal flows were encountered, were begun twelve hours before the first station was sampled. Minimum flows ranged from 85 cfs on the Green River tailwater to 75 and 70 cfs on the Barren and Rough River tailwaters, respectively.

Electroseining, electrofishing with hand-held probes and shockerboat, and rotenone application were the primary sampling methods used. Hand seining of several riffle areas on Green and Barren tailwaters was also conducted for qualitative collections. The electroseine used was a "Kentucky seine" as described in Carlander (1957). The seine was 53 feet (15.1 m) long and charged by a Sears 2560 watt alternator at 230 volts. Current and voltage were regulated by a Coffelt PV-10 power box control unit. The electroseine was used in collections taken on Green and Barren tailwaters in the fall of 1978 with good results. Subsequent use of the electroseine was prevented by a malfunction of the power box.

Two pairs of hand-held probes powered by the above described

alternator were utilized on Green and Barren tailwaters for the spring and summer collections. Current at 130 volts was uncontrolled and run direct from alternator to electrodes.

Prior to sampling each station on the Green and Barren tailwaters block seines of 3/16 inch (5 mm) mesh were placed above and below the collection stations. Electrofishing involved shocking through the station to the lower block seine, then returning upstream to the upper block net, covering the entire station. Seven people made up the sampling team: two working the electroseine, three using dip nets and two manipulating a twelve foot john boat carrying the alternator and control box. When probe shocking was used, four people held probes and dip nets, one person dip netted, and two people controlled the boat. Collections were made during daylight hours with field personnel wearing rubber gloves and waders in all electrofishing operations.

Establishment of sampling stations was made on the basis of accessibility to electro-shocking sampling techniques, availability of habitat, and physiographic features such as riffle-pool composition.

Because of the deep, pool nature of the Rough River tailwater, a conventional boom-type shockerboat was used. Alternating current supplied by an Onan TR series alternator varying from 3 to 6 amperes at 120 volts and controlled by a Smith-Root Type 6 power box was used in all but two collections. Due to failure in the Smith-Root power box, shocking with hand-held probes from a john boat was used as an alternate sampling technique on Stations 3 and 4 during the spring collections.

Rotenone samples at Station 5 on the Green and Barren tailwaters were made in the fall of 1978 and summer of 1979 in cooperation with biologists of the Kentucky Department of Fish and Wildlife Resources.

A five percent liquid rotenone solution was applied at a rate of approximately one ppm for about 15 minutes with potassium permanganate crystals added to the downstream flow during the rotenone application.

Multiple representatives of harvestable game fish were measured, weighed, and released alive. All other fish collected were retained and fixed in 10 percent formalin. Total weights, length, and identifications were recorded for all fish taken in the study. Fish specimens were separated into three catagories: rough fishes or those which may or may not be of commercial value; forage fishes or small fishes that serve as prey throughout most of their lives, and game fishes or those sought by anglers (Lagler 1956, Appendix F). Common and scientific names of fishes follow Bailey et al. (1970).

Physico-chemical parameters were recorded at the extreme upstream and downstream station for each of the three seasons of the study. Temperature was recorded with a standard Celsius thermometer; pH, dissolved oxygen, total alkalinity, and total hardness were determined using standard solutions and field methods applicable to the A136-WR Hach field chemical kit (Tables 4-6).

RESULTS

During the study, a total of 3,444 fish representing 60 species and 2 hybrids, 33 genera, and 15 families weighing a total of 574 pounds (260.5 kg) was collected (Table 7). An average of 325 fish per acre (862 fish/ha) weighing 43.3 pounds per acre (47.0 kg/ha) was observed during the study. Fish per acre estimates were highest in the fall and lowest in spring, while biomass estimates were similar in the fall and spring but markedly lower in summer (Figure 4).

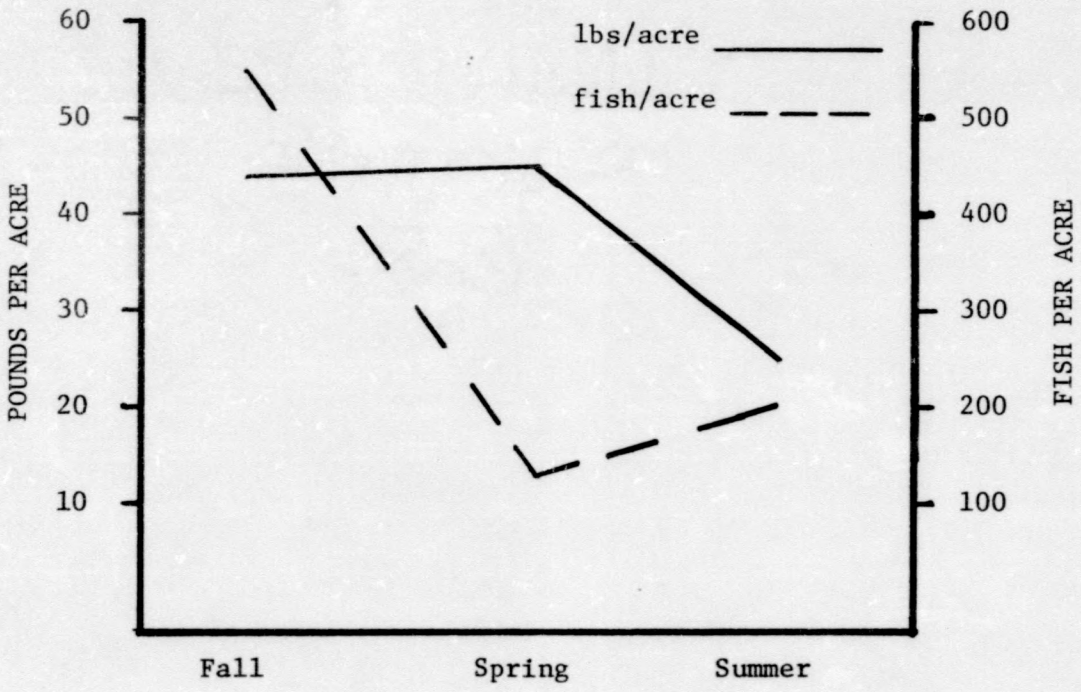
The minnow family, Cyprinidae, was the predominant family represented in the study with a total of 1,143 specimens. The bluntnose minnow, Pimephales notatus, was the most abundant minnow species collected (539) and the second most abundant species taken in the entire study. Other common minnow species included the stoneroller, Campostoma anomalum (244), spotfin shiner, Notropis spilopterus (144), and carp, Cyprinus carpio (67), and rosyface shiner, Notropis rubellus (50). The remaining ten minnow species had a combined total of 99 specimens.

The sunfish family, Centrarchidae, was the second most abundant family represented, with 1,053 specimens. White crappie, Pomoxis annularis, was the most common sunfish species (549) and the most abundant species taken in the entire study. Other predominant sunfish species included longear sunfish, Lepomis megalotis (188), bluegill, Lepomis macrochirus (180), spotted bass, Micropterus punctulatus (62), and rock bass, Ambloplites rupestris (56). The remaining six sunfish species had a combined total of only 18 individuals.

Table 7. Total number and weight (kg) of specimens collected in each tailwater during each season of the study.

	Number of Specimens				Biomass (kg)			
	Fall	Spring	Summer	Total	Fall	Spring	Summer	Total
Green River	1261	574	434	2269	33.5	36.4	20.2	90.1
Barren River	285	142	199	626	20.7	33.7	15.6	70.0
Rough River	180	149	220	549	53.3	17.2	29.9	100.4
Total	1726	865	853	3444	107.5	87.3	65.7	260.5

Figure 4. Average biomass estimates, in pounds per acre, and average fish per acre estimates for each season of the study.


60
50
40
30
20
10
POUNDS PER ACRE
lbs/acre
fish/acre
600
500
400
300
200
100
FISH PER ACRE
Fall
Spring
Summer

The perch family, Percidae, ranked third in the study with 573 specimens. The rainbow darter, Etheostoma caeruleum (99), and fantail darter, Etheostoma flaballare (94), were the predominat species.

The herring family, Clupeidae, represented by 257 gizzard shad, Dorosoma cepedianum, and the sucker family, Catostomidae, with 219 specimens, were the fourth and fifth most abundant families observed, respectively. The northern hogsucker, Hypentelium nigricans (89), and black redhorse, Moxostoma duquesnei (54), comprised the majority of the sucker specimens. The remaining six catostomid species had a combined total of only 76 specimens.

The trout family, Salmonidae, and the silverside family, Atherinidae, represented by 68 rainbow trout, Salmo gairdneri, and 52 brook silverside, Labidesthes sicculus, respectively, were the next most common families.

The seven families presented above represented 98 percent of the total number and 95 percent of the total weight of all fish taken in the study. The remaining eight families had a total of 79 specimens of which the catfish family, Ictaluridae (35), and the sculpin family, Cottidae (22), comprised the majority.

Twelve of the sixty species observed were collected in all three tailwaters, six of which were taken during all three seasons (Table 8). These six species were likewise the most frequently encountered representatives in the study, ranging from 40 percent (white crappie) to 64 percent (bluegill) of all collections.

Fifteen species collected in this study were categorized as rough species, thirty-four as forage species and eleven as game species. Rough species represented 61 percent of total weight but only 9 percent

Table 8. Species collected in all three tailwaters and those species taken during all three seasons (*)

Gizzard Shad *
Rainbow trout
Common stoneroller
Common carp *
Bluntnose minnow *
Golden redhorse
Channel catfish
Brook silverside
Bluegill *
Longear sunfish
Spotted bass *
White crappie *

of total number, while forage species comprised 58 percent of total number and only 10 percent of total weight (Figure 5). Game species provided 29 percent of total weight and 33 percent of total number. Forage species comprised the majority of specimens on the Green and Barren River tailwaters while game species predominated on the Rough River tailwater (Figures 6-8).

Green River Tailwater- The number of fish collected was highest in the fall, 1,261, and lowest in the summer, 434, (Table 9) as were seasonal average biomass estimates, 41.8 lbs/acre (46.8 kg/ha) in the fall and 19.0 lbs/acre (21.3 kg/ha) in the summer (Table 10). The number of species taken was greatest in the fall (40) and fewest in spring (30). Likewise, the number of fish per acre was also greatest in the fall, 1,139 (2,812 fish/ha) and least in the spring, 226 (558 fish/ha) (Figure 9). The greatest estimated number of fish and biomass per acre, 5,700 fish and 102 pounds (14,073 fish and 114.2 kg/ha), respectively, were observed at Station 5 during the fall. The 5,700 fish/acre also represented the highest estimated number of individuals in the entire study. The Green River tailwater had the greatest average estimated number of individuals, 595 fish/acre (1,470 fish/ha), the most species taken (46), and the lowest average biomass estimate, 32.0 lbs/acre (36 kg/ha), of the three tailwaters.

Thirty-one species collected were categorized as forage species and represented the majority of specimens collected (65%), while the six species considered as rough species yielded only 8 percent of the total number. However, rough species comprised 59 percent, game species 32 percent, and forage species 9 percent of the total weight (Figure 6).

Figure 5. Composition of tailwater fishes on the basis of percent of biomass and individuals represented by rough, forage and game species during each season of the study.

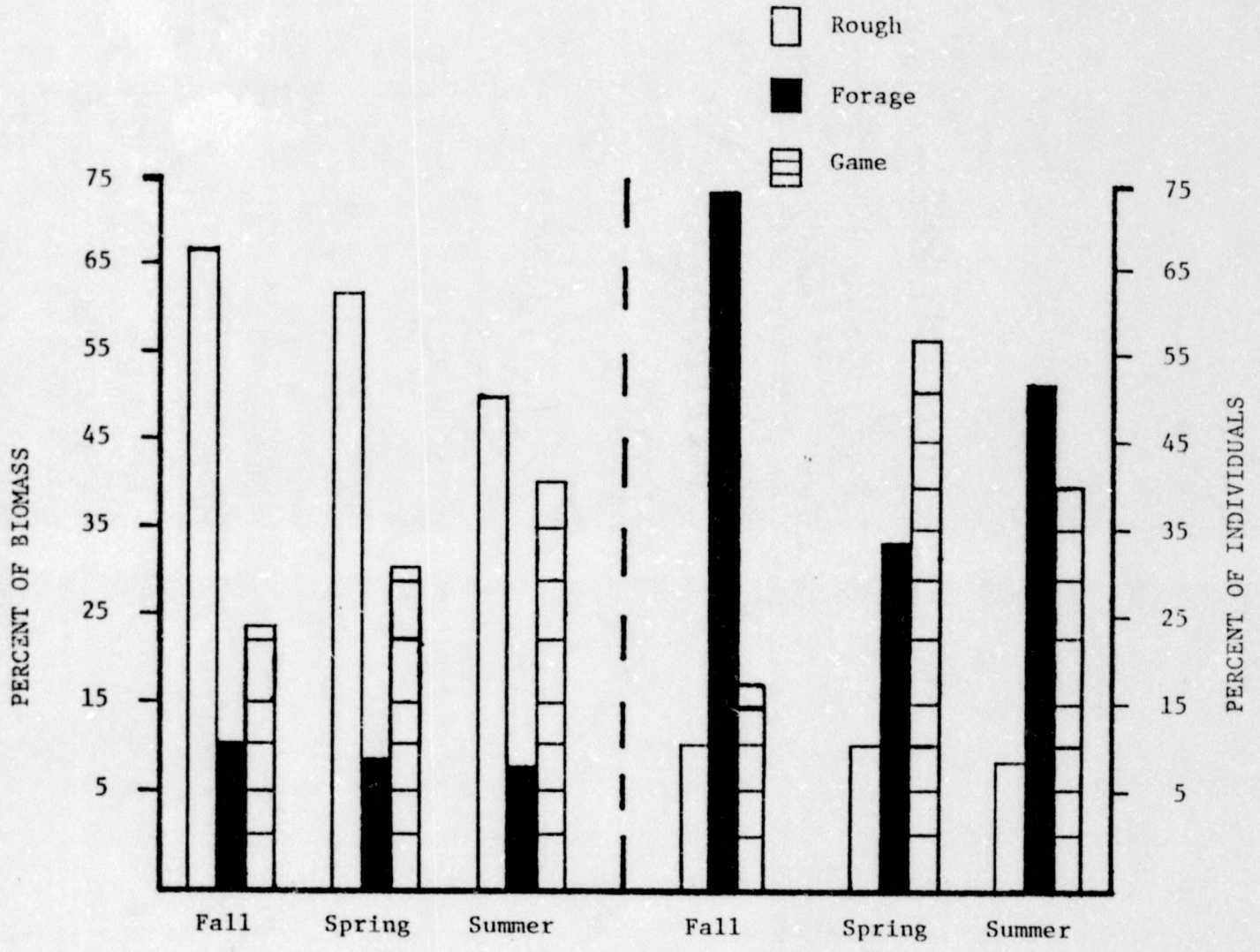

Rough
Forage
Game
75
65
55
45
35
25
15
5
PERCENT OF BIOMASS
PERCENT OF INDIVIDUALS
Fall
Spring
Summer
Fall
Spring
Summer

Figure 6. Seasonal composition of the fish community in the Green River Lake tailwater on the basis of percent of biomass and individuals represented by rough, forage, and game species during each season of the study.

Figure 7. Seasonal composition of the fish community in the Barren River Lake tailwater on the basis of percent of biomass and individuals represented by rough, forage, and game species during each season of the study.

Figure 8. Seasonal composition of the fish community in the Rough River Lake tailwater on the basis of percent of biomass and individuals represented by rough, forage, and game species during each season of the study.

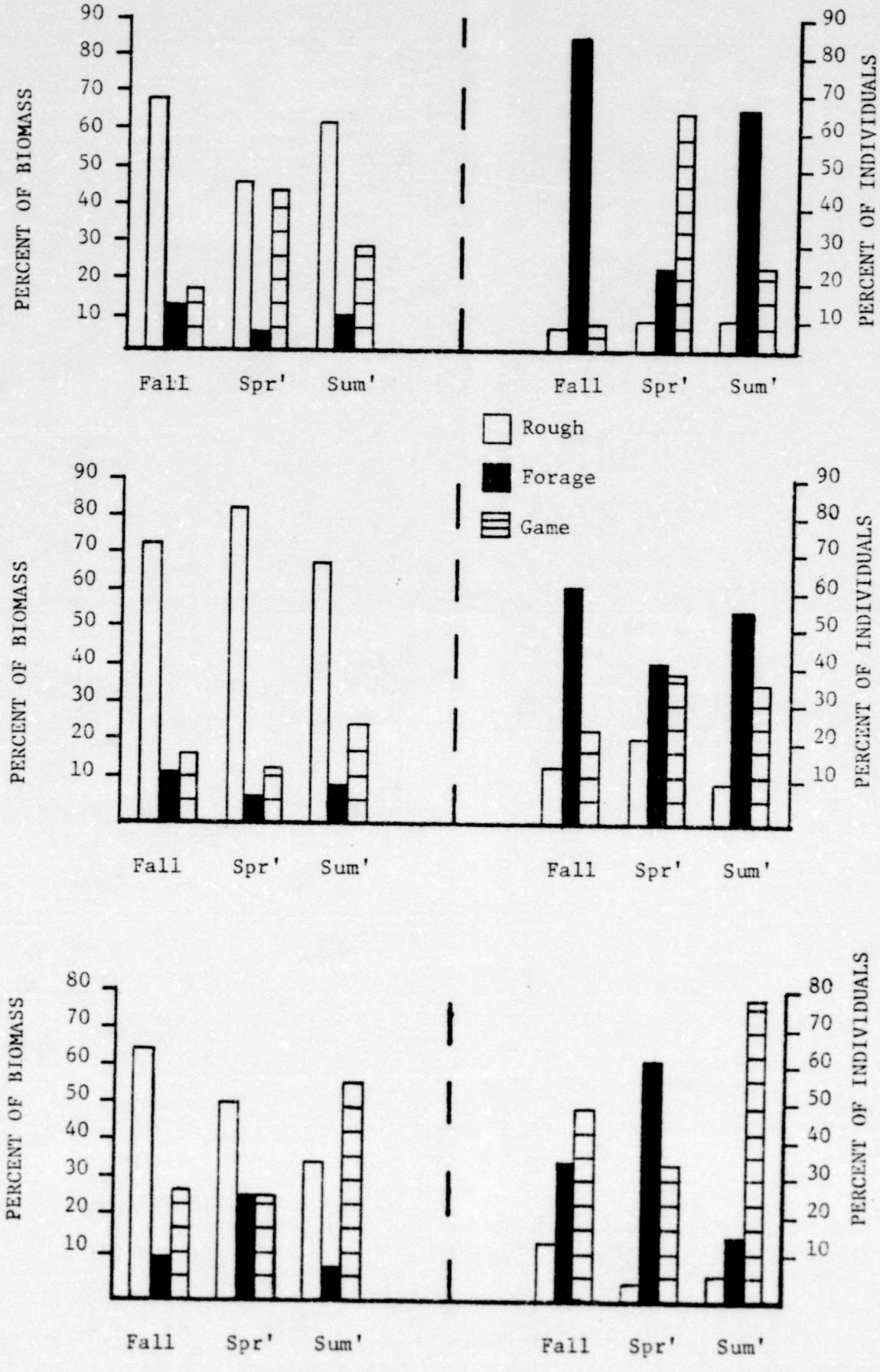

PERCENT OF BIOMASS
PERCENT OF INDIVIDUALS
90
80
70
60
50
40
30
20
10
Fall
Spr'
Sum'
Rough
Forage
Game

Table 9. Species list, number of individuals, weight (g), and designation of rough, forage, and game species for fish collected in Green River Lake tailwater September, 1978 through August, 1979.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Ichthyomyzon bdellium (F)			7	235		
Lepisosteus osseus (R)	1	350			4	1595
Dorsoma cepedianum (F)	12	1051	35	982	10	1235
Salmo gairdneri (G)	10	1155	2	428	28	3823
Campostoma anomalum (F)	150	1596	21	278	20	127
Cyprinus carpio (R)	12	7418	3	3486	3	3300
Hybopsis amblops (F)	1	6				
Hybopsis dissimilis (F)					1	6
Notropis ardens (F)	1	2				
Notropis ariommus (F)	14	86			1	4
Notropis cornutus (F)	11	222	7	333	1	56
Notropis photogenis (F)	24	225	2	32		
Notropis rubellus (F)	30	34	2	2	5	4
Notropis spilopterus (F)	36	102	2	16	8	39
Phenacobius mirabilis (F)			1	10	2	4
Pimphales notatus (F)	446	290	6	22	72	72
Hypentelium nigricans (R)	40	5563	11	1244	14	1206
Moxostoma duquesnei (R)	15	5345	26	7565	13	4324
Moxostoma erythrurum (R)	7	284	9	3291	3	467
Moxostoma macrolepidotum (R)	12	4217	4	1500	3	1401

Table 9. continued.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Ictalurus punctatus (R)			1	250		
Noturus elegans (F)	6	4			8	10
Labidesthes sicculus (F)	7	1	2	10	1	2
Morone chrysops (G)			1	17		
Ambloplites rupestris (G)	18	1457	13	2211	4	725
Lepomis macrochirus (G)	29	98	9	743	29	160
Lepomis megalotis (G)	39	1181	20	1034	33	961
Micropterus dolmieui (G)	2	154				
Micropterus punctulatus (G)	6	920	7	924	2	31
Micropterus salmoides (G)	6	234				
Pomoxis annularis (G)	26	953	330	11568	6	260
Etheostoma bellum (F)	17	55	3	4	16	30
Etheostoma blennioides (F)	24	148	12	66	11	50
Etheostoma caeruleum (F)	54	55	14	19	25	31
Etheostoma flabellare (F)	64	29			30	36
Etheostoma kennicotti (F)	66	24				
Etheostoma stigmaeum (F)	21	10				
Etheostoma maculatum (F)	3	0				
Etheostoma zonale (F)	14	13	13	13	12	24
Percina caprodes (F)	13	196	8	79	11	172
Percina copelandi (F)	9	10	1	0	34	36
Percina evides (F)	12	50			19	25

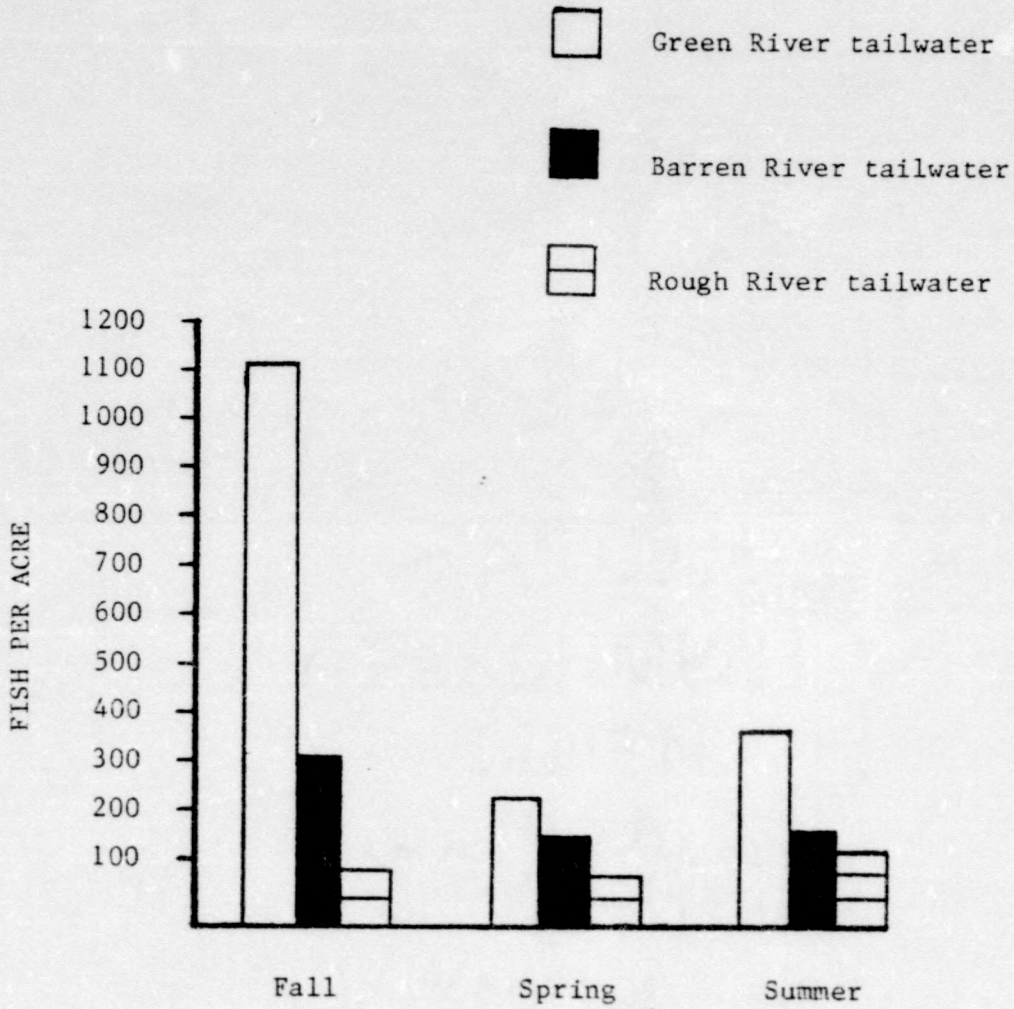
Table 9. continued.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Percina macrocephala (F)	1	6				
Percina phoxocephala (F)	1	0				
Percina sciera (F)					1	8
Cottus carolinae (F)	1	3	2	75	4	16
TOTALS	1261	33547	574	36437	434	20240

Table 10. Number of individuals taken at each station, biomass estimates (lbs/acre) for each station, and seasonal average biomass estimates for the Green, Barren, and Rough River Lake tailwaters during September, 1978 through August, 1979. 5R denotes rotenone samples.

	Fall 1978						Spring 1979					Summer 1979					
Station	1	2	3	4	5	5R	1	2	3	4	5	1	2	3	4	5	5R
Green River																	
Number of Specimens	155	58	149	63	42	798	374	19	76	74	31	26	44	100	21	20	223
Standing Crop lbs/acre	20	43	21	24	40	102	43	41	15	43	37	10	39	10	28	9	18
Season Mean	41.7 lbs/acre						35.8 lbs.acre					19 lbs/acre					
Barren River																	
Number of Specimens	58	35	44	18		130	50	41	10	3	38	44	26	31	19	15	64
Standing Crop lbs/acre	63	31	20	20		88	168	19	59	23	121	32	6	33	13	27	66
Season Mean	44.4 lbs/acre						78 lbs/acre					29.5 lbs/acre					
Rough River																	
Number of Specimens	116	7	23	34			83	48	11	7		179	4	13	24		
Standing Crop lbs/acre	128	25	23	41			20	53	9	3		92	9	14	14		
Season Mean	54.3 lbs/acre						21.3 lbs.acre					32.3 lbs/acre					

Figure 9. Average seasonal fish per acre estimates for the Green, Barren, and Rough River Lake tailwaters.


Green River tailwater
Barren River tailwater
Rough River tailwater
FISH PER ACRE
1200
1100
1000
900
800
700
600
500
400
300
200
100
Fall
Spring
Summer

The most abundant species in the tailwater were the bluntnose minnow, 23 percent of the total, the white crappie (16%) and the stoneroller (8%). Species comprising the greatest component of biomass were the black redhorse, 19 percent of the total, carp (16%), and white crappie (14%).

The species composition of the tailwater varied seasonally with forage species dominating in the fall (82%) and summer (67%) and game species being most abundant in the spring (67%). Rough species consistently dominated biomass with 69 percent in the fall, 61 percent in the spring, and 48 percent in the summer. Game species comprised a considerable portion of the total weight in spring and summer representing 46 percent and 30 percent, respectively (Figure 6).

Twenty-five of the 46 species collected were common to all three seasons of the study. Of these, the northern hogsucker was the most frequently observed species, occurring in 94 percent of all samples. Twelve other species were commonly encountered, occurring in more than 50 percent of the collections.

No consistent trend was observed in standing crop estimates from upstream to downstream in the Green River tailwater stations. Station 2 (upstream) and 5 (downstream) had the highest average biomass estimates, each having 41 lbs/acre (45.9 kg/ha). Station 3, a mid-stream station, provided the lowest average biomass estimate, 15.3 lbs/acre (17.2 kg/ha).

Rainbow trout, Salmo gairdneri, was never collected at Stations 4 or 5, the most downstream stations, while the elegant madtom, Noturus elegans, was never collected at Stations 1, 2, or 3. Black redhorse,

present in 65 percent of all samples, was collected only at Stations 1, 2, and 3 in the fall and summer yet was taken at all stations in the spring.

Barren River Tailwater- The number of fish collected was highest in the fall, 285, and lowest in the summer, 199, (Table 11). The average estimated number of individuals was also greatest in the fall, 313 fish/acre (773 fish/ha), but was least in the spring, 150 fish/acre (371 fish/ha), (Figure 9). The greatest number of species was also observed in the fall (28) and the least in the spring (17). Biomass estimates however, were highest in the spring, 78 lbs/acre (87.4 kg/ha), and lowest in the summer, 30 lbs/acre (33.6 kg/ha) (Table 10). Barren River tailwater had the greatest average biomass estimate of the three tailwaters studied, 49 lbs/acre (54.9 kg/ha).

Seventeen forage species and seven game species were collected in the tailwater and comprised the majority of individuals, 44 and 43 percent, respectively. Rough fish, although few in number, represented 75 percent of the total weight ranging from 67 percent in the summer to 81 percent in the spring. Forage species were most numerous in the fall and in the summer, 62 and 55 percent respectively, while game species (67%) were predominant in the spring (Figure 7).

The most abundant species taken in the tailwater were the longear sunfish (23%), spotfin shiner (14%), and gizzard shad (9%). Carp represented the major biomass component (57%) followed by longear sunfish (7%) and northern hogsucker (6%).

Fourteen of the thirty-one species collected were taken in all three seasons of the study. The spotfin shiner and the longear sunfish

Table 11. Species list, number of individuals, weight (g), and designation of rough, forage, and game species for fish collected in Barren River Lake tailwater September, 1978 through August, 1979.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Anguilla rostrata (R)	2	926	2	771	1	907
Dorsoma cepedianum (F)	13	1121	39	2038	10	353
Salmo giardneri (G)			2	452	10	1167
Campostoma anomalum (F)	33	546	4	63	15	328
Cyprinus carpio	15	10388	18	24448	7	4951
Hybopsis dissimilis (F)	3	37			2	22
Notropis cornutus (F)			1	3		
Notropis rubellus (F)	8	35			5	19
Notropis leuciodus (F)	6	4				
Notropis spilopterus (F)	53	243	11	71	34	209
Notropis stramineus (F)	5	10				
Phenacobius mirabilis (F)	4	30			10	81
Pimphales notatus (F)	7	5	1	1	4	3
Hypentelium nigricans (R)	10	1796	8	1458	6	1035
Minytrema melanops (R)					1	570
Moxostoma erythrurum (R)	2	1324	1	625		
Ictalurus punctatus (R)	3	472	1	80	1	61
Pylodictis olivaris (R)	9	4			1	2976
Labidesthes sicculus (F)	2	2				
Ambloplites rupestris (G)	13	662	1	129	7	664
Lepomis cyanellus (G)	1	4				

Table 11. continued.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Lepomis macrochirus (G)	3	129	15	1049	21	300
Lepomis megalotis (G)	34	1470	22	1783	24	1328
Micropterus punctulatus (G)	16	1183	3	110	9	418
Pomoxis annularis (G)	1	31	11	600	1	15
Etheostoma caeruleum (F)	3	2			3	2
Etheostoma zonale (F)	7	11	2	3	4	5
Percina caprodes (F)	9	184			9	177
Percina phoxocephala (F)	2	4			10	15
Percina sciera (F)	8	71			2	9
Cottus carolinae (F)	13	22			2	16
TOTALS	285	20676	142	33684	199	15631

were the most frequently taken species, each occurring in 81 percent of all collections, followed by carp and longear sunfish, each present in 69 percent of the collections, and spotted bass (63%).

No consistent trends in standing crop estimates from upstream to downstream stations were observed. Both the most upstream and downstream stations, Station 1 (87 lbs/acre, 98.3 kg/ha) and Station 5 (75.5 lbs/acre, 84.6 kg.ha), respectively, had the greatest average standing crop estimates. The lowest average standing crop, 18.7 lbs/acre (20.9 kg/ha), was observed at both stations 2 and 4. Rainbow trout were collected only at Station 1 while three of the five darter species taken were observed only at Station 5.

Rough River Tailwater- The number of individuals collected was greatest in the summer, 220, and least in the spring, 149 (Table 12). Likewise, the number of fish per acre was also greatest, 113 (279 fish/ha), in the summer and least, 82 (203 fish/ha), in the spring (Figure 9). Biomass estimates were lowest, 17 lbs/acre (23.8 kg/ha), in the spring but were highest, 54.2 lbs/acre (60.8 kg/ha), in the fall (Table 10). The number of species taken declined during each season of the study with 21 collected in the fall, 16 in the spring, and 14 in the summer. Rough River tailwater had the lowest average estimated number of individuals, 95 fish/acre (235 fish/ha), and an average biomass estimate of 35.9 lbs/acre (40.2 kg/ha).

Game and forage species represented the most abundant specimens taken in the tailwater, 51 and 36 percent respectively. Rough species comprised the major component of biomass (41%) followed by game species (36%).

Table 12. Species list, number of individuals, weight (g), and designation of rough, forage, and game species for fish collected in Rough River Lake tailwater September, 1978 through August, 1979.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Anguilla rostrata (R)	1	1078				
Dorsoma cepedianum (F)	58	4991	49	4054	31	2420
Salmo giardneri (G)			2	397	14	1540
Esox americanus (G)	1	62				
Campostoma anomalum (F)					1	16
Cyprinus carpio (R)	5	11833	2	4026	2	3798
Notemigonus crysoleucas (F)	2	49				
Pimphales notatus (F)	1	2	1	2	1	4
Erimyson sucetta (F)			2	118		
Ictiobus bubalus (R)	9	11676	1	124	6	5187
Ictiobus cyprinellus (R)			1	1673		
Minytrema melanops (R)	6	5153	2	1985		
Moxostoma erythrurum (R)	1	993	1	790	5	1080
Ictalurus punctatus (R)	2	964			1	584
Pylodictis olivaris (R)	2	1350				
Labidesthes sicculus (F)			39	112	1	4
Morone chrysops (G)	1	111				
Lepomis cyanellus (G)	1	28				
Lepomis gulosus (G)			1	45		
Lepomis macrochirus (G)	19	677	27	1598	28	1889
Lepomis macrochirus X cyanellus	2	55				

Table 12. continued.

Species	Fall 1978		Spring 1979		Summer 1979	
	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
Lepomis macrochirus X *megalotis*			1	162		
Lepomis megalotis (G)	8	1009			8	378
Micropterus punctulatus (G)	8	1324	2	124	9	1066
Micropterus salmoides (G)	1	290	3	1036		
Pomoxis annularis (G)	47	3620	15	920	112	7353
Stizostedion vitreum (G)	4	7264			1	4535
Ambloplites grunniens (R)	1	755				
TOTALS	180	53284	149	17166	220	29854

The most common species taken in the tailwater was the white crappie, 32 percent of specimens, followed by the gizzard shad (25%), and bluegill (14%). Carp represented 20 percent of biomass and smallmouth buffalo 17 percent. Gizzard shad, white crappie, and walleye each represented 12 percent of biomass.

The species composition of the tailwater varied noticeably during the study with game fish being most abundant in the fall and summer, 57 and 78 percent, respectively, while forage specimens (61%) were most common in the spring. Although rough fish were the greatest component of biomass in the fall and spring, 41 and 50 percent, respectively, game species represented 55 percent of biomass in the summer (Figure 8). White crappie replaced carp and sucker species in the summer sampling period.

Eight species were taken in all three seasons of the study. The bluegill was the most frequently encountered species, occurring in 90 percent of all collections. Gizzard shad were taken in 83 percent of the samples followed by smallmouth buffalo and spotted bass, each in 67 percent of the samples, and carp (50%).

Average standing crop estimates decreased from the most upstream to the most downstream station, Station 1 (80 lbs/acre, 89.7 kg/ha) and Station 4 (19.3 lbs/acre, 27.6 kg/ha), respectively. While no darters were collected in the Rough River tailwater, rainbow trout were taken in four samples extending to approximately 4 miles (6.4 km) downstream of the dam.

DISCUSSION

The ichthyofauna of the three tailwaters sampled in this study may generally be regarded as rich in both variety and number of specimens. With the exception of rainbow trout, all species taken in this study were considered to be native inhabitants of the streams studied (Clay 1975). Rainbow trout were present as the result of the post impoundment stocking program in each tailwater by the Kentucky Department of Fish and Wildlife Resources.

The predominant families represented and the most commonly observed species in this study generally correlated with prior studies conducted in the respective drainages and tailwater areas. Bell (1977) reported the Cyprinidae, Centrarchidae, and Percidae to be the dominant families in a diversity study on Drake's Creek, a major tributary of the Barren River. Carter (1968, 1969) found cyprinids to be the most commonly represented specimens in the tailwaters of the Barren and Nolin Rivers, both major tributaries of the Green River. Turner (1963) reported cyprinids to be the predominant mainstream species in both the Green and Cumberland Rivers, while Bacon et al. (1968) observed cyprinids dominating the fish population of Beaver Reservoir tailwater in Arkansas.

The observation of centrarchids as the most abundant specimens taken in Rough River tailwater was also reported by Turner (1960) in post-impoundment studies on Rough River. These observed differences between Rough River tailwater and the other two tailwaters sampled were

most likely due to the greater average depth, lentic type habitat, and silt substrate of Rough River tailwater. Likewise, Rough River tailwater did not lend itself well to electrofishing techniques.

The observation of greater standing crop estimates in the Barren River tailwater than in the Green or Rough River tailwaters was consistent with previous studies. Carter (1969) and Turner (1959, 1960, 1961, 1963) reported similar trends for these rivers in a series of pre- and post-impoundment studies. Griswold et al. (1978) and Marzolf (1978) have reported the importance of stream debris in the form of brush, logs, fallen trees, and stumps for the support of aquatic invertebrate populations which in turn help support fish populations. Since the Barren River tailwater included diverse bank habitats and many more midstream obstructions that the other two tailwaters, this may account for the greater standing crop estimates observed in the Barren River tailwater.

While seasonal trends were observed with regard to numbers of individuals, species diversity, and changes in community composition, no one or combination of environmental factors could be determined as being soley responsible for these trends. As summarized by Bell and Hoyt (1980), structural features of the habitat and depth (Sheldon 1968), gradient, temperature, marl (Minckley 1963), and available resources in the general environment (Smith and Powell 1971) may affect the distribution and composition of stream fishes. Spawning activity as mentioned by Walburg et al. (1971) and the adaptations of stream organisms to the physical and chemical characteristics of the stream (Krumholz and Neff 1970) also may affect stream fish populations. The above factors, except for marl, appeared to be affecting the stream fish community in this study.

The presence of a resident group of species in each tailwater that was observed in all seasons of the study was typical of stream fishes (Larimore 1952, Gerking 1953, 1957; Funk 1957, Bell and Hoyt 1980). This stability of a nucleus of species has been described by Gerking (1957) to be a function of homing instincts, recognition of home range, and social behavior. The presence of adequate habitat is a requirement for this stability. The observation of six species common to all three tailwaters that were collected during each season sampled probably identified part of the resident population of those streams.

The composition of the tailwater community by rough, forage, and game species in the three tailwaters studied was generally supported in the literaure. Previous studies on these tailwaters (Carter 1965, 1966; Turner 1959, 1960, 1961, 1963) also reported rough species comprising the major component of biomass and forage or game species as being numerically dominant in number. Differences between this study and earlier studies were attributed to the use of rotenone in earlier studies, whereas electrofishing techniques were used primarily in this study.

The number of species observed in the present study was similar to that reported in the literature for the Barren River, but differed for that of the Green and Rough Rivers. Turner (1959), in a pre-impoundment study, and Carter (1966), in a post-impoundment study on the Barren River, reported 38 and 32 species, respectively, from the tailwater area while 31 species were observed in this study. The apparent response of the Barren River fish community to impoundment was that of species replacement. While darter and sniner species, characteristic of free flowing streams, declined following damming, species characteristic of

impoundments and deep pools increased. In a 1960-1962 pre-impoundment study on the Green River, 57 species were identified in the future tailwater (Charles 1964, Stations -21.1 and -34.7), while 46 were taken in this study. Many of the species identified by earlier workers (Turner 1959, Charles 1964, Carter 1966) but not observed in this study are known to still be present in the drainage (ECRI personal communication). This feature identified one of the problems of comparative fish studies, e. g. that of matching all previously observed species. Although flow variations (Jones et al. 1974) and hypolimnion discharges (Charles and McLemore 1973, Edwards 1978) may have been responsible for the disappearance of some tailwater species, it is unlikely that impoundment conditions would account for the disappearance of so many. These differences most likely resulted from different collecting techniques, unit efforts, and a greater tailwater study area in the present study.

The observation of high standing crop estimates at the most upstream and downstream stations on the Barren River tailwater was most likely due to the use of rotenone in sampling Station 5 for two of the seasons and to the possible influence of Difficult Creek immediately upstream of Station 1. Hoyt et al. (1979) reported highest standing crop estimates with toxicants, while Laflin and Richardson (1977) reported 22 species in the lower region of Difficult Creek, 11 of which were observed at Station 1 during this study.

No explanation was available for the decrease in standing crop estimates from the most upstream to the most downstream station on the Rough River tailwater. Habitat and physical conditions were very similar between the stations.

The longitudinal zonation of rainbow trout observed in this study most likely resulted from the location of stocking places in each tailwater used by the Kentucky Department of Fish and Wildlife Resources. Gerking (1957) reported that rainbow trout have been found to remain in the same area for extended periods of time. This may explain why all rainbow trout observed, except one, were in close proximity to locations where the Kentucky Department of Fish and Wildlife Resources stock trout into those streams.

LITERATURE CITED

Bacon, E.J., Jr., S.H. Newton, R.V. Kilambi, and C.W. Hoffman. 1968. Changes in the ichthyofauna in the Beaver Reservoir tailwaters. Proc. S. E. Game and Fish Comm. 22:245-248.

Bailey, R.M., J.E. Fitch, E.S. Herald, E.A. Lachner, C.C. Lindsey, C.R. Robins, and W.B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd Ed. Amer. Fish. Soc. Spec. Publ. No. 6. 150 p.

Bell, D.E. 1977. Seasonal abundance and diversity of fishes at three stations on the middle fork of Drake's Creek, Warren and Allen Counties, Kentucky. Unpubl. M.S. Thesis. Western Kentucky Univ. 59 p.

Bell, D.E., and R.D. Hoyt. 1980. Temporal and spatial abundance and diversity of fishes in a Kentucky stream. Trans. Ky. Acad. Sci. In Press.

Carlander, K.D. 1957. Symposium on evaluation of fish populations in warm-water streams. Iowa State College, Ames, Iowa. 118 p.

Carter, J.P. 1965. Pre- and post-impoundment surveys. Progress Report for Investigation Project F-16-R-6. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 46 p.

_____. 1966. Pre- and post-impoundment surveys. Progress Report for Investigation Project F-16-R-7. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 71 p.

_____. 1968. Temperature and control of reservoir releases into the Nolin and Barren tailwater. Ky. Fish. Bull. No. 49. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 36 p.

_____. 1969. Pre- and post-impoundment surveys on Barren River. Ky. Fish. Bull. No. 50. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 33 p.

Clay, W.M. 1975. The fishes of Kentucky. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 416 p.

Charles, J.R. 1964. Effects of oilfield brines. Proc. S. E. Assoc. Game and Fish Comm. 18:371-403.

Charles, J.R., and W.N. McLemore. 1973. Reservoir discharge investigations at Barren and Nolin Reservoirs. Ky. Fish. Bull. No. 59, Part I, Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 94 p.

Edwards, R.J. 1978. The effect of hypolimnion reservoir releases on fish distribution and species diversity. Trans. Amer. Fish. Soc. 107:71-77.

Funk, J.L. 1957. Movements of stream fishes in Missouri. Trans. Amer. Fish. Soc. 85:39-57.

Gerking, S.D. 1953. Evidence for the concept of home range and territory in stream fishes. Ecology 34:347-365.

_____. 1957. Fish behavior as related to stable stream populations. In Carlander, K.D., Ed. Symposium on evaluation of fish populations in warm-water streams, Iowa State College, Ames, Iowa. pp. 3-11.

Griswold, B.L., C. Edwards, L. Woods, and E. Weber. 1978. Some effects of stream channelization on fish populations, macroinvertebrates, and fishing in Ohio and Indiana. U. S. F. W. S./O. B. S. Bull. 77/46, Co-op. Fish. Res. Unit, Ohio State Univ. 36 p.

Hoyt, R.D., S.E. Neff, and V.H. Resh. 1979. Distribution, abundance, and diversity of fishes of the Upper Salt River drainage, Kentucky. Trans. Ky. Acad. Sci. 40:1-20.

Jones, D.R., J.W. Kiceniuk, and O.S. Bamford. 1974. Evaluation of swimming performance of several fish species from MacKenzie River. J. Fish. Res. Board Can. 31:1641-1647.

Keely, J.W., J.L. Mahlock, J.W. Barko, D. Gunnison, and J.D. Westhoff. 1978. Reservoirs and waterways; identification and assessment of enviromental quality problems and research program development. Tech. Report E-78-1, U. S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss. 152 p.

Krumholz, L.A., and S.E. Neff. 1970. The freshwater stream, a complex ecosystem. Water Res. Bull. 6:163-174.

Laflin, B.D., and D. Richardson. 1977. Annual Performance Report for Midwestern Fishery Investigation. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. pp. 65-79.

Lagler, K.F. 1956. Freshwater Fishery Biology, 2nd Ed. W.C. Brown Co., Dubuque, Iowa. 421 p.

Larimore, R.W. 1952. Home pools and homing behavior of smallmouth black bass in Jordan Creek. Ill. Nat. Hist. Surv. Div., Biol. Notes 28:3-12.

Martin, R.G., and R.H. Stroud. 1973. Influence of reservoir discharge location on water quality, biology, and sport fisheries of reservoirs and tailwaters, 1969-1971. U. S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss. 128 p.

Marzolf, G.R. 1978. The potential effects of clearing and snagging on stream ecosystems. U. S. F. W. S./O. B. S. Bull. 78/14. National Stream Alternation Team, Columbia, Mo. 31 p.

Minckley, W.L. 1963. The ecolgoy of a spring stream, Doe Run, Meade County, Kentucky. Wildlife Monographs 11:1-124.

Sheldon, A.L. 1968. Species diversity and longitudnal succession in stream fishes. Ecology 49:193-198.

Smith, C.L., and C.R. Powell. 1971. The summer fish communities of Brier Creek, Marshall County, Okalahoma. Amer. Museum Novitates 2458:1-30.

Turner, W.R. 1959. Pre-impoundment surveys of six Kentucky streams. Final Report for Investigation Project F-10-R. Ky. Fish. Bull. No. 24. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 43 p.

_____. 1960. Pre- and post-impoundment surveys. Progress Report for Investigation Project F-16-R-1. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 43 p.

_____. 1961. Pre- and post-impoundment surveys. Progress Report for Investigation Project F-16-R-2. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 75 p.

_____. 1963. Pre- and post-impoundment surveys. Progress Report for Investigation Project F-16-R-4. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky. 64 p.

Walburg, C.H., G.L. Kaiser, and P.L. Hudson. 1971. Lewis and Clark tailwater biota and some relations of the tailwater and reservoir fish populations. In Hall, G.E., Ed. Reservoir Fisheries and Limnology. Spec. Publ. No. 8, Amer. Fish. Soc. pp. 449-467.