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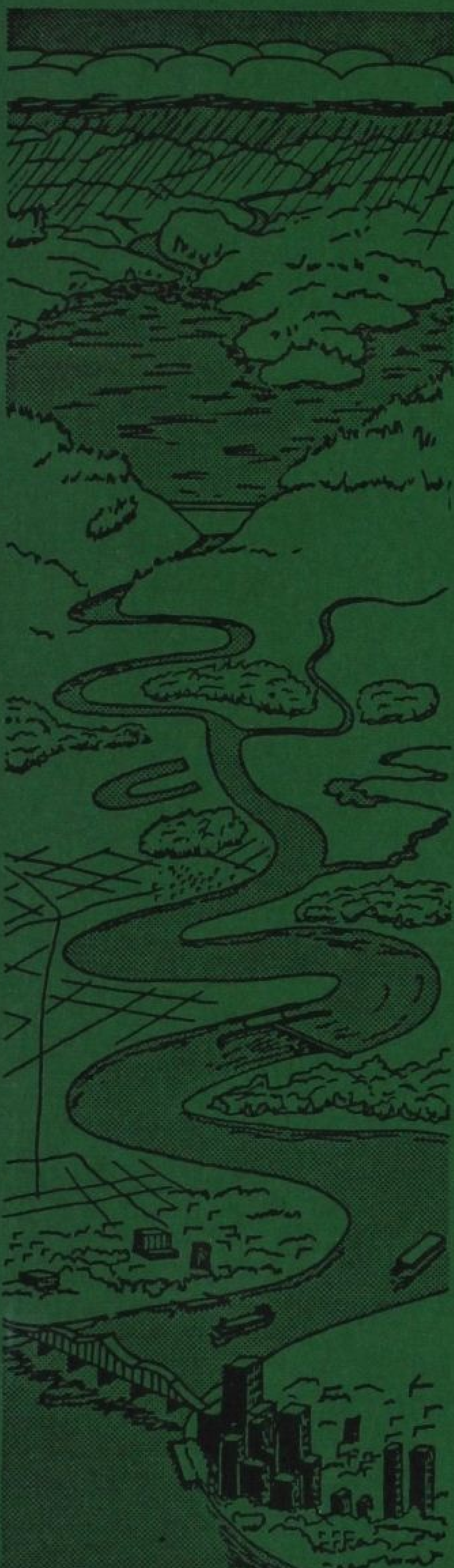

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TECHNICAL REPORT E-85-15

FISH RECRUITMENT AND MOVEMENT IN A FLOOD CONTROL RESERVOIR AND TAILWATER

by

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This report identifies factors that alter the relative abundance of tailwater fishes. Specifically, the objectives of this study were to determine the significance of fish recruitment from the reservoir into the tailwater, determine which species are recruited from the reservoir, identify conditions in the tailwater that foster the concentration of fish, identify the season of recruitment, and describe the direction and season of movement of tailwater

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fishes. To meet these objectives, fish were intensively sampled, marked, and recaptured in the immediate tailwater of Barren River Lake, Ky., for 1 year. Analyses of the resulting data indicated that the reservoir may be the source of recruitment for the most abundant fish in the tailwater of deep-release, flood control reservoirs; the passage of fish from the reservoir into the tailwater exhibits pronounced seasonality; the seasonality of fish passage can be related to conditions in the reservoir relative to the behavior of certain common fishes; and project operation can have substantial effects on the tailwater fishery by altering conditions that foster the movement of reservoir fish into the tailwater.

PREFACE

This study comprises part of the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit IIB, entitled Guidelines for Determining Reservoir Releases to Meet Environmental Quality Objectives. The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the management of the Environmental Laboratory (EL). The OCE Technical Monitors for EWQOS were Mr. Earl E. Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

This report was prepared in draft form by the East Central Reservoir Investigations (ECRI), National Reservoir Research Program (NRRP), US Fish and Wildlife Service, Bowling Green, Ky., with the assistance of the EL, WES. The report was completed under Contract No. DACW39-83-M-0631 by the EL because the NRRP was disbanded before the study was finished.

This report was written by Messrs. Kenneth E. Jacobs and William D. Swink, formerly of the ECRI, and by Dr. John M. Nestler and Ms. Lillian T. Curtis of the WES. Mr. Charles Walburg was Chief of ECRI and Mr. Robert M. Jenkins was Director of the NRRP. This report was prepared under the direct supervision of Dr. John M. Nestler, EL, WES, and under the general supervision of Mr. Mark Dortch, Chief, Water Quality Modeling Group; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division; and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager, EWQOS. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division.

This report is intended for use by Corps of Engineers biologists as an aid in understanding the complex fishery dynamics that may occur in the tailwaters of flood control projects. The information presented on factors that control the seasonal abundance of common tailwater fishes can be used to predict the effects of reservoir operation on the tailwater fishery.

Director of WES was COL Allen F. Grum, USA. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

FISH RECRUITMENT AND MOVEMENT IN A FLOOD CONTROL RESERVOIR AND TAILWATER

PART I: INTRODUCTION

Background

1. River reaches immediately downstream from reservoirs may support productive fisheries, provide valuable recreational opportunities, and enhance the downstream habitat for aquatic organisms. Successful management of tailwaters requires a firm understanding of factors affecting tailwater ecosystems, particularly those factors that alter the size and species composition of the fish community. Currently, cause-effect relations are poorly understood, and the relative importance of different hydrologic events to fish recruitment in tailwaters has not been quantified. Walburg et al. (1981, 1983) and Jacobs and Swink (1983) have observed that the abundance of fish in tailwaters is generally related to the quantity, quality, and timing of discharges from the reservoir. The results of both studies also suggest that certain reservoir operations, such as fall drawdown, may be critical in determining the composition and abundance of warmwater fishes in tailwaters of flood control projects. Additional detailed information is required to document the precise relationship between reservoir operations and fish movement and recruitment in tailwaters.

2. At present, a number of conflicting hypotheses are available to explain fish recruitment to the tailwater. Fish may be concentrated in the tailwater because of the blockage of upstream migration (Eschmeyer and Manges 1945, Pfitzer 1962, Sharnov 1963). Alternatively, resident populations of fish that recruited from natural reproduction in the tailwater may persist year-round in the tailwater (Wirth et al. 1970, Cavender and Crunkilton 1974), or fish may pass through the outlet structure of the project (Hall 1949, Parsons 1957, Hanson 1977) and concentrate in the immediate tailwater. The relative importance of these

different mechanisms may be site specific and vary in importance according to unknown factors.

3. This study relates hydrologic conditions to the relative abundance, recruitment, and movement of fish in and between Barren River Lake, Ky., and its tailwater. Specifically, the objectives of this study are to:

a. Determine the significance of fish recruitment to the tailwater from the reservoir.

b. Determine which species are recruited into the tailwater from the reservoir.

c. Identify conditions in the tailwater that foster the concentration of fish.

d. Identify the season of recruitment.

e. Describe the direction and season of movement of fish in the tailwater.

f. Determine the generality of the findings by comparing trends observed in the electrofishing data for Barren River Lake to trends observed in similar data from tailwaters downstream from other Corps of Engineers (CE) reservoir projects.

Study Area

4. Barren River Lake is a flood control reservoir in south-central Kentucky (Figure 1). Maximum and mean depths are 24 and 8 m, respectively. The surface area is 4,047 ha at summer pool (April-October) and 1,758 ha at winter pool (December-March). Summer and winter pool elevations are 168 and 160 m above mean sea level (msl), respectively. Reservoir closure occurred in March 1964.

5. The reservoir pool is stabilized during the summer for recreational purposes, and is drawn down in the fall to provide storage capacity for winter and spring runoff. Although short-term flood discharges can occur during any season, prolonged discharges occur mainly in the fall, during drawdown, when about 75 percent of the reservoir volume is evacuated. During 1981 and 1982, discharges from Barren River Lake ranged from 1.5 to 291 m^3/sec and reflected general seasonal trends observed in other years (Figure 2).

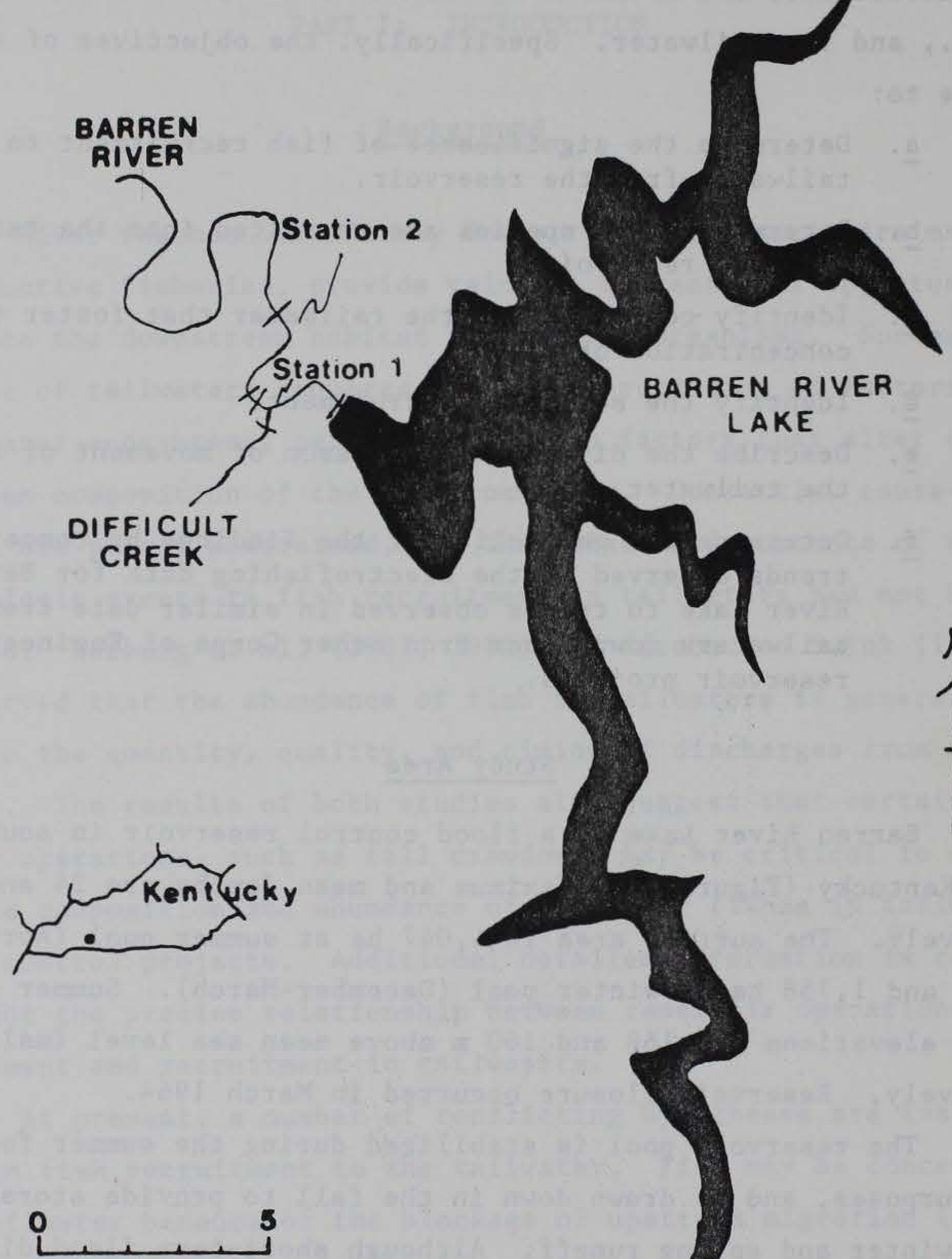

Figure 1. Barren River Lake and tailwater, Kentucky

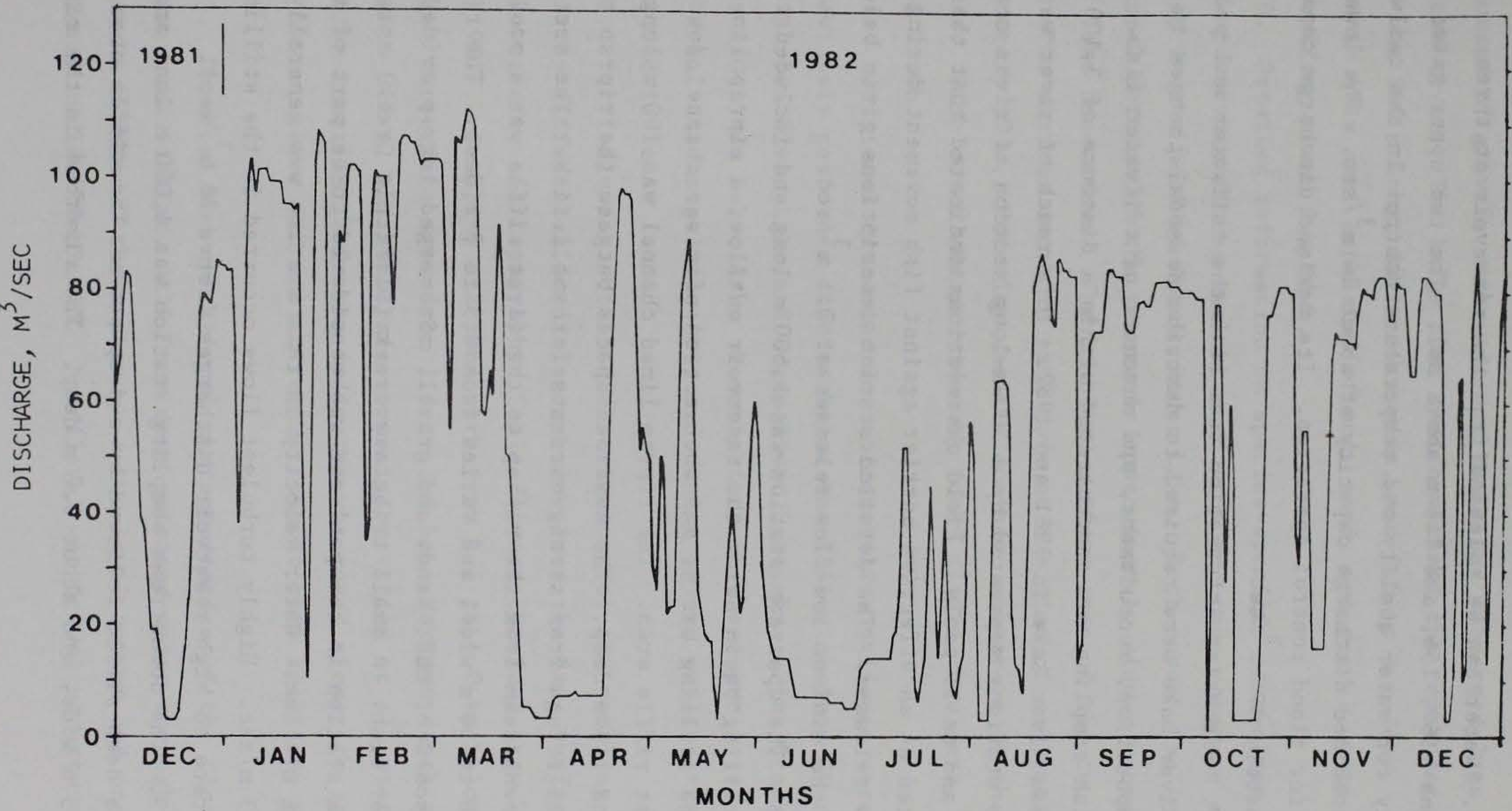

Figure 2. Average daily flows (m^3/sec) in Barren River Lake tailwater during December 1981 through December 1982. Data from US Geological Survey, Louisville, Ky.

6. Water can be released from the reservoir at three elevations--162, 156, and 146 m above msl. The two upper gates, used primarily for water quality and temperature control in the tailwater, have a combined discharge capacity of about 14 m^3/sec. The lowest gate is used for flood control operation. Its maximum discharge capacity is approximately 374 m^3/sec.

7. Fisheries information from both the tailwater and pool of Barren River Lake were required to describe seasonal changes in the species composition, recruitment, and movement of tailwater fish. Tailwater fish sampling was concentrated within a distance of 3,100 m below the Barren River Lake in 1981 and 1982. This reach of river was divided into two stations separated by a 500-m-long section of river composed of riffles and small pools. Field observations indicated that these riffles acted as an effective barrier against fish movement during minimum low-flow releases. The detailed station descriptions given below were made at the minimum low-flow releases of 2.1 m^3/sec.

8. The upstream station was 1,600 m long and included the concrete stilling basin below the reservoir outflow, a riprap lined channel below the stilling basin, and the section of river channel downstream to the first riffle area. The riprap lined channel was 100 m long, 15 m wide, and 1.5 m deep. The numerous spaces between the riprap provided cover and refuge from strong currents for small fish. The section of river downstream from the riprap to the first riffle was a pool 1,480 m long, 20 to 50 m wide, and varied from 0.3 to 3 m deep. The riverbed was composed of mud, sand, and gravel. Submerged logs provided abundant cover for fish. A small tributary creek (Difficult Creek) entered the upstream station in the pool and was considered to be part of the sampling station. Water velocity in this station was generally less than 0.3 m/sec. Highly turbulent flows occurred in the stilling basin at moderate to high reservoir discharges (above 28 m^3/sec).

9. The downstream sampling station was 1,000 m long and comprised a deep riffle followed by a deep pool. The riffle area was 60 m long, 15 m wide, and about 0.7 m deep. The riverbed in the riffle area

was composed of gravel, with undercut banks and submerged logs providing ample fish cover. The large pool that comprised the remainder of the station was 940 m long, 20 to 60 m wide, and 0.3 to 3 m deep. The riverbed in this pool consisted of mud, sand, and gravel, with submerged logs providing cover for fish.

10. Detailed information on species-specific size-class composition for reservoir fishes was obtained from two cove rotenone samples collected in the pool of Barren River Lake. Both coves were located in the central portion of the reservoir approximately midway between the dam and lake headwaters. The combined surface area of the two coves was 2.3 ha. The maximum depth in each cove at the time of collection was approximately 10 m. Mud-clay was the dominant substrate in the collection area. Fish cover was provided by rocky cliffs, boulders, and some logs and brush.

11. Additional data used for corroborative evidence were obtained from previously performed studies below the following from CE reservoirs: Barren River Lake and Green River Lake, Ky.; Pine Creek Lake, Okla.; and Gillham Lake, Ark. Descriptions of these projects, including surface area, discharge capacity, and design of the outlet structure, are provided in Table 1.

12. The following detailed descriptions of the sampling stations illustrating differences in distance below from the dam, surface area, depth, substrate, and topography (Table 2) were obtained from Walburg et al. (1983). Sampling stations were from 1.5 to 4.0 km below the dam and varied in surface area from 1.1 to 3.4 ha. Maximum depth ranged from 1.8 to 3.2 m, and substrate composition varied at all stations. The station location in Barren tailwater was moved closer to the dam in 1980; however, cover and habitat conditions at both locations were similar.

13. Physical and operational characteristics of the flood control reservoirs were similar. All four dams released water through multilevel intake bypasses, three through a two-level outlet and one through a nine-level outlet (Table 1). Multilevel withdrawal structures were

operated to maintain water quality and coldwater temperatures at Barren River Lake and Green River Lake. At Pine Creek Lake and Gillham Lake, the multilevel intakes were operated to maintain warmwater temperatures in the summer. Large-volume releases, which were associated with heavy rainfall, occurred during all seasons, and lasted from a few days to over a month. Flows greater than the maximum capacity of the bypasses at all projects (Table 1) were released through floodgates located near the bottom of the dam.

14. In summer and early fall, all of these projects ordinarily stratify both thermally and chemically (Walburg et al. 1983). Consequently, a layer of anoxic water will prevent fish from concentrating in the vicinity of the floodgate intakes. Operation of the four flood control reservoirs during the years when the corroborative data were obtained was similar to the operation of Barren River Lake in 1981 and 1982. In the fall, a large part of the volume of each reservoir was discharged during drawdown to provide storage for winter and spring runoff. The reduced water levels and destratified conditions during the winter and spring would probably increase the access of fish to the floodgate intake area. In late spring, reservoir discharges were reduced to raise the reservoir to summer pool levels. Minimum low flows in the tailwaters of the four projects ranged from 0.8 to 2.4 m^3/sec.

Methods

15. Samples were collected in both the tailwater and reservoir to provide information on abundance, recruitment, size distribution, and movement of the most important fish species.

Fish collection

16. Fish were sampled in Barren River Lake tailwater in December 1981 and March, May, August, October, and December 1982 (Table 3). Barren River Lake Reservoir was chemically and thermally destratified during the December and March samplings. Figure 3 illustrates typical seasonal stratification patterns observed in Barren River Lake. Table 4

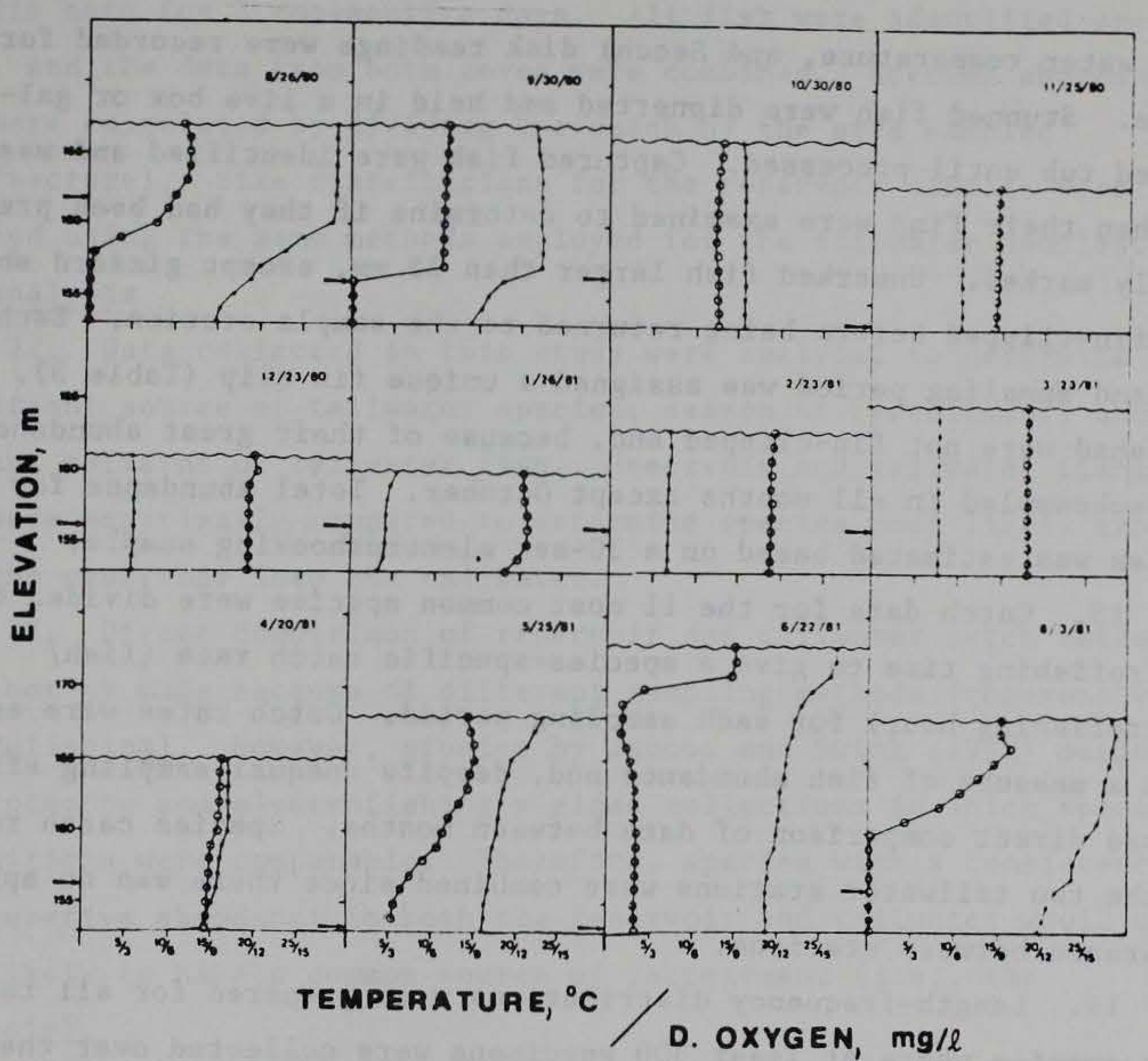

Figure 3. Monthly temperature (●—●) and dissolved oxygen (o—o) profiles taken in Barren River Lake, August 1980-August 1981. Arrows indicate depth of reservoir discharge, except that discharges depicted as 153 m above mean sea level (25 Nov 1980 and 25 May and 22 June 1981) were actually from the 147-m level

presents typical water quality conditions in the tailwater of Barren River Lake.

17. In the tailwater, fish were collected with two boat-mounted Smith-Root Type VI electrofishers powered by 240-V, 3000-W generators. All sampling was conducted at or near the minimum established discharge of 2.1 m^3/sec during daylight hours. Each set of samples was collected over a 5-day period--3 days at the upstream station and 2 days at the downstream station. Each station was completely sampled, and areas providing fish cover were intensively sampled. Elapsed electrofishing

time, water temperature, and Secchi disk readings were recorded for each sample. Stunned fish were dipnetted and held in a live box or galvanized tub until processed. Captured fish were identified and measured, and then their fins were examined to determine if they had been previously marked. Unmarked fish larger than 25 mm, except gizzard shad, were fin-clipped before being returned to the sample station. Each station and sampling period was assigned a unique fin clip (Table 3). Gizzard shad were not fin-clipped and, because of their great abundance, were subsampled in all months except October. Total abundance for this species was estimated based on a 30-sec electroshocking sample.

18. Catch data for the 11 most common species were divided by the electrofishing time to give a species-specific catch rate (fish/electrofishing hour) for each sampling period. Catch rates were assumed to be a measure of fish abundance and, despite unequal sampling effort, allowed direct comparison of data between months. Species catch rates for the two tailwater stations were combined since there was no apparent difference between stations.

19. Length-frequency distributions were prepared for all tailwater species where at least 300 specimens were collected over the course of the study. Distribution data were compiled using 25-mm size groups for all species except channel catfish and common carp, where 50-mm size groups were used. Size distribution data from the two tailwater stations were combined since there was no discernible difference between stations.

20. Fish movement within the tailwater was determined from the recapture of marked fish. Species with ten or more recaptures were analyzed for direction and seasonality of movement. Fish recaptured at the same location as originally marked were not considered to have moved, even though they may have moved and then returned.

<u>Reservoir samples</u>

21. Fish samples were collected in Barren River Lake in August of both 1981 and 1982. Two coves of the lake were blocked with a small-mesh net, and rotenone was applied at the rate of 1 mg/ℓ as described by Grinstead et al. (1977). Dead and dying fish in the cove were collected

with dip nets for 3 consecutive days. All fish were identified and measured, and the data from both coves were combined. Species abundance data were calculated by dividing the catch by the area sampled (fish/hectare). Size distributions for the reservoir samples were compiled using the same methods employed for the tailwater samples.

Data analysis

22. Data collected in this study were analyzed to determine the recruitment source of tailwater species, season of recruitment, and movement patterns of tailwater fish. Reservoir and tailwater fishery data were empirically compared to determine species most likely exported from the reservoir into the tailwater.

23. Direct comparison of reservoir and tailwater catch rates could not be made because of different sampling methods (rotenone versus electrofishing). However, studies by Jacobs and Swink (1982) suggested that rotenone and electrofishing yielded collections in which species compositions were comparable. Therefore, species with a consistently high relative abundance in both the reservoir and tailwater would appear most likely to have a common source of recruitment (i.e., the reservoir).

24. Comparisons were also made between the size distribution of species captured in both the reservoir and tailwater. Similarity in the size distribution between the two groups of fish would provide further evidence of a common source of recruitment.

25. Comparisons among tailwater fish catch and size distribution data were used to determine both the occurrence and season(s) of recruitment into or out of the tailwater. Major changes in catch or size distribution from one sampling period to the next would indicate periods of recruitment or emigration. Although fish can enter the tailwater from both the reservoir and downstream, out-migration can occur only in a downstream direction. The design of the outlet works makes it virtually impossible for fish to enter the reservoir from the tailwater. In addition, fin-clip information was examined to determine which species tended to move upstream, downstream, or remain concentrated in the immediate tailwater.

26. Changes in fish abundance were also correlated with hydrologic conditions in the reservoir and tailwater to determine which species were most influenced by reservoir operations. Data on reservoir elevation, reservoir volume, change in volume 30 days prior to sampling, tailwater temperature, and tailwater Secchi disk reading (Table 5) were obtained from the US Geological Survey, Louisville, Ky., and correlated with species catch rates using Spearman's Rank Correlation (Elliot 1971).

Corroborative information

27. Electrofishing data collected in 1979 and 1980 below Barren River Lake, Ky., Green River Lake, Ky., Gillham Lake, Ark., and Pine Creek Lake, Okla., were reevaluated for seasonal changes in abundance of selected species. Samples were taken on a similar schedule in all four tailwaters (Table 6). Collection methods were similar to those used in this study and are described fully by Walburg et al. (1983). The results of these previous studies were then analyzed to determine if trends discovered in the current Barren River Lake study were also observed at the other sites.

PART II: RESULTS

Detailed Studies at Barren River Lake

28. The following paragraphs detail the abundance, size distribution, direction, and seasonality of movement of fish in Barren River tailwater and relate hydrologic conditions to the abundance of individual fish species common in the tailwater of Barren River Lake. The results are then evaluated to determine the origin of fishes in the tailwater. The following information is provided for each fish species:

- a. Relative abundance estimates (Table 7) for Barren River Lake tailwater fishes were developed from the collection of 17,523 fish of 36 species and 1 hybrid. These estimates obtained by electrofishing were compared to the abundance of reservoir fishes obtained by cove rotenone samples to determine if the relative abundance of the tailwater fish community was similar to the reservoir fish community.
- b. Abundance estimates were evaluated for large increases in abundance to identify likely times when fish may recruit from the reservoir. Particular attention was paid to changes in tailwater fish abundance in December and reservoir fish abundance in August, because conditions in the reservoir would be most conducive to fish passage through the outlet works of a project in the time period represented by the December tailwater sample. During this time, the reservoir would be destratified (allowing fish access to the vicinity of the floodgate) and the high-volume discharges occurring during fall drawdown would more likely entrain reservoir fish.
- c. Size distributions of nine common fishes of the Barren River Lake and tailwater were developed from the collection of over 100,000 specimens. The size distributions of tailwater fishes collected in December were compared to the size distributions of reservoir fishes collected in August reservoir cove rotenone samples to determine the similarity of the two groups of fishes.
- d. Size distributions of tailwater fish were examined for substantial changes or shifts over seasonal samples to identify time periods of fish movement or recruitment.

e. Fish movement within the tailwater, both in terms of seasonality and net movement, was described on the basis of 510 recaptures of over 13,000 marked fish (Tables 8 and 9).

f. Results from the correlation analysis were used to relate tailwater fish abundance to reservoir and tailwater conditions.

Gizzard shad (*Dorosoma cepedianum*)

29. Gizzard shad was the most abundant fish species in the tailwater and reservoir (Table 7). Over 77,000 gizzard shad were collected in cove rotenone samples from Barren River Lake, accounting for 71 percent of all fish collected. Over 15,000 gizzard shad were collected in the tailwater electrofishing samples, which accounted for 46 percent of all fish electrofished.

30. Gizzard shad exhibited pronounced changes in abundance over the course of the tailwater studies (Table 10). Gizzard shad were most abundant in the December 1981 tailwater electrofishing sample and declined in the following months until they substantially increased in December 1982. Seasonal changes in the abundance of gizzard shad showed a strong inverse correlation with reservoir elevation, reservoir volume, and tailwater temperature (Table 11).

31. The size distributions of gizzard shad were similar in the reservoir and tailwater in 1981 and, to a lesser extent, in 1982 (Figure 4). In 1981, both reservoir and tailwater size distributions had peaks at the 75- and 175-mm size classes. The smaller size groups contained 62 and 57 percent of the reservoir and tailwater gizzard shad catch, respectively. In 1982, the numbers of fish in the August reservoir size distribution peaked at 125 mm, with progressively fewer fish in the 175- and 225-mm size groups. A similar size distribution was observed in the tailwater in December, but peak abundance was at 175 mm with progressively fewer fish in the 225-, 275-, and 325-mm groups. Assuming growth of the gizzard shad occurred in the reservoir between August and December, the tailwater fish may have been recruited from the reservoir.

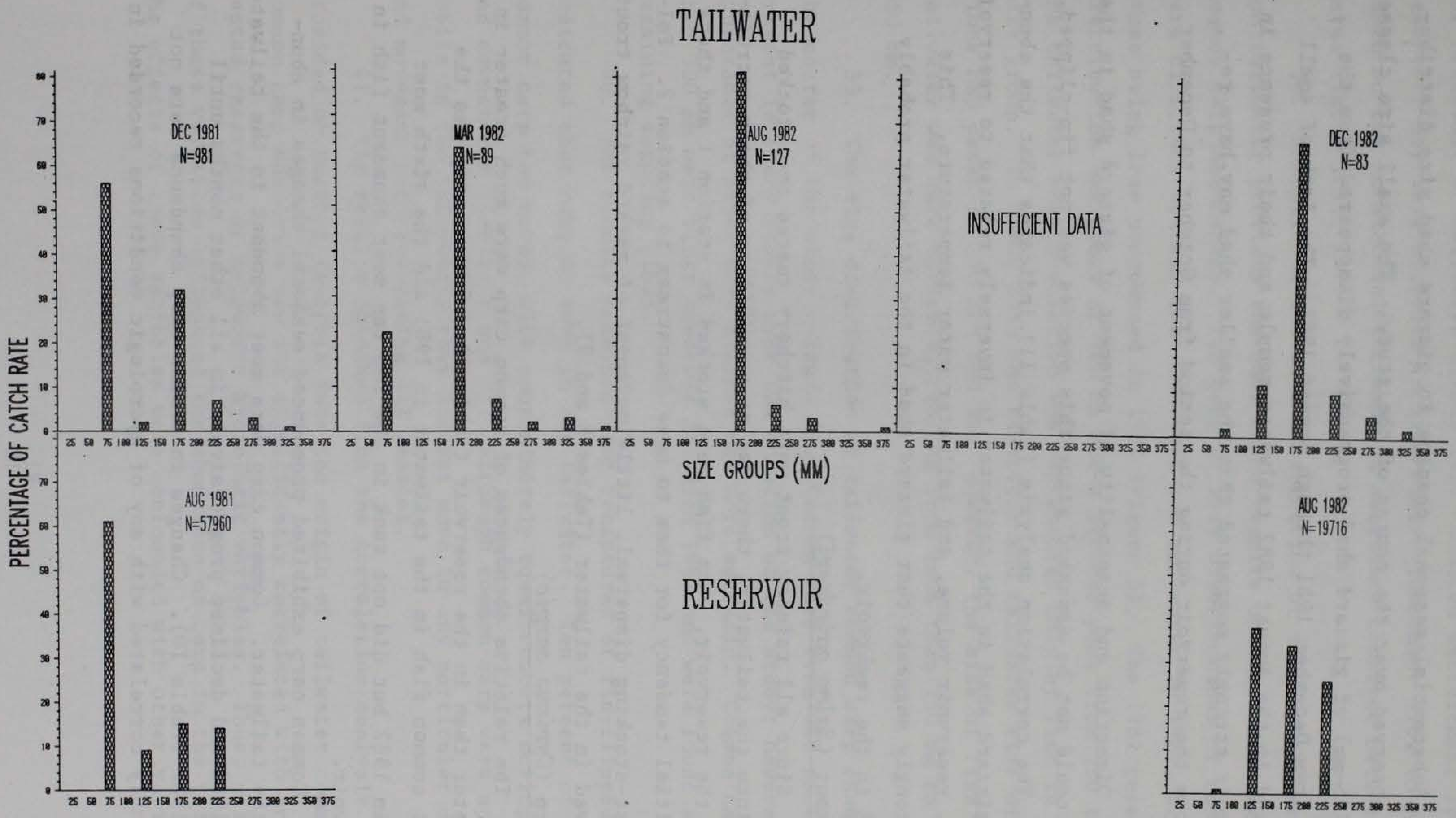

Figure 4. Size distributions of gizzard shad captured in Barren River Lake and tailwater (N = number of fish used to generate the length-frequency distributions)

32. Substantial seasonal changes in gizzard shad size distribution were observed over the course of the study. The small size classes (75- and 125-mm) of gizzard shad progressively disappeared from the tailwater from December 1981 through August 1982. The lack of small gizzard shad in the August 1982 tailwater sample and their presence in the reservoir strongly suggested that the smaller shad may have recruited from the reservoir during the period from October to December 1982.

33. Direction and seasonality of movement of gizzard shad in the tailwater could not be assessed since this species was not fin-clipped.

34. The correlation analysis (Table 11) indicates that the abundance of gizzard shad in the tailwater is inversely related to reservoir elevation, reservoir volume, and tailwater water temperature. This result strongly suggests that gizzard shad in the tailwater probably originated in the reservoir.

Rainbow trout (*Salmo gairdneri*)

35. Since all rainbow trout were hatchery reared and stocked directly into the tailwater, there was no possibility of their recruitment from the reservoir. The fish were stocked in station 1 and there was an initial tendency for them to move downstream to station 2. Following post-stocking dispersal, little movement of marked rainbow trout was observed in the tailwater (Tables 8 and 9).

Common carp (*Cyrinus carpio*)

36. The relative abundances of common carp were much greater in the tailwater than in the reservoir (Table 7). Common carp was the fifth most common fish in the tailwater in 1981 and the sixth most abundant in 1982 but did not rank in the top ten most abundant fish in the reservoir.

37. Common carp exhibited pronounced seasonal changes in abundance in the tailwater. Common carp were most abundant in the tailwater in March 1982 and declined progressively in all other months until December 1982 (Table 10). Changes in common carp abundance were not significantly correlated with any of hydrologic conditions recorded in

the reservoir or tailwater (Table 11). Limited recruitment from the reservoir may have occurred in late winter (December 1981 to March 1982) based on the substantial increase in abundance observed between these dates (Table 10).

38. Analysis of the size distribution of carp in the reservoir and tailwater provides the same mixed results obtained from examining common carp abundances. The general size distributions of common carp were different between the reservoir and tailwater in 1981, with differences being less pronounced in 1982 (Figure 5). The 1981 reservoir size distribution had peaks at 200 mm and a broader peak from 350 to 450 mm; the tailwater carp population was represented only by fish in the larger size group. In 1982, both the reservoir and tailwater size distributions had peaks at 250 and 400 mm. However, the size of fish in the tailwater was more variable, ranging from less than 150 mm to over 650 mm.

39. The size distribution of tailwater common carp changed during the course of the study (Figure 5). Common carp from 400 to 450 mm were present in every sample over the duration of the study; however, the appearance of other size classes was more sporadic. Common carp smaller than 300 mm were first observed in March 1982 and were found at all remaining sampling times.

40. The results obtained from recaptures of fin-clipped carp indicated that carp do move in the tailwater. Ten percent of the marked common carp had moved, with approximately equal numbers moving upstream and downstream (Tables 8 and 9). Although common carp were apparently mobile in the tailwater, they did not move in any particular direction and movement occurred during all seasons.

41. The results obtained from the correlation analysis (Table 7) provided no further insights into the origin of tailwater common carp. Common carp abundance was not significantly correlated with any of the tested reservoir or tailwater hydrologic variables. Thus, either none of these variables influenced the abundance of carp in the tailwater or the effects of these variables were confounded with other variables.

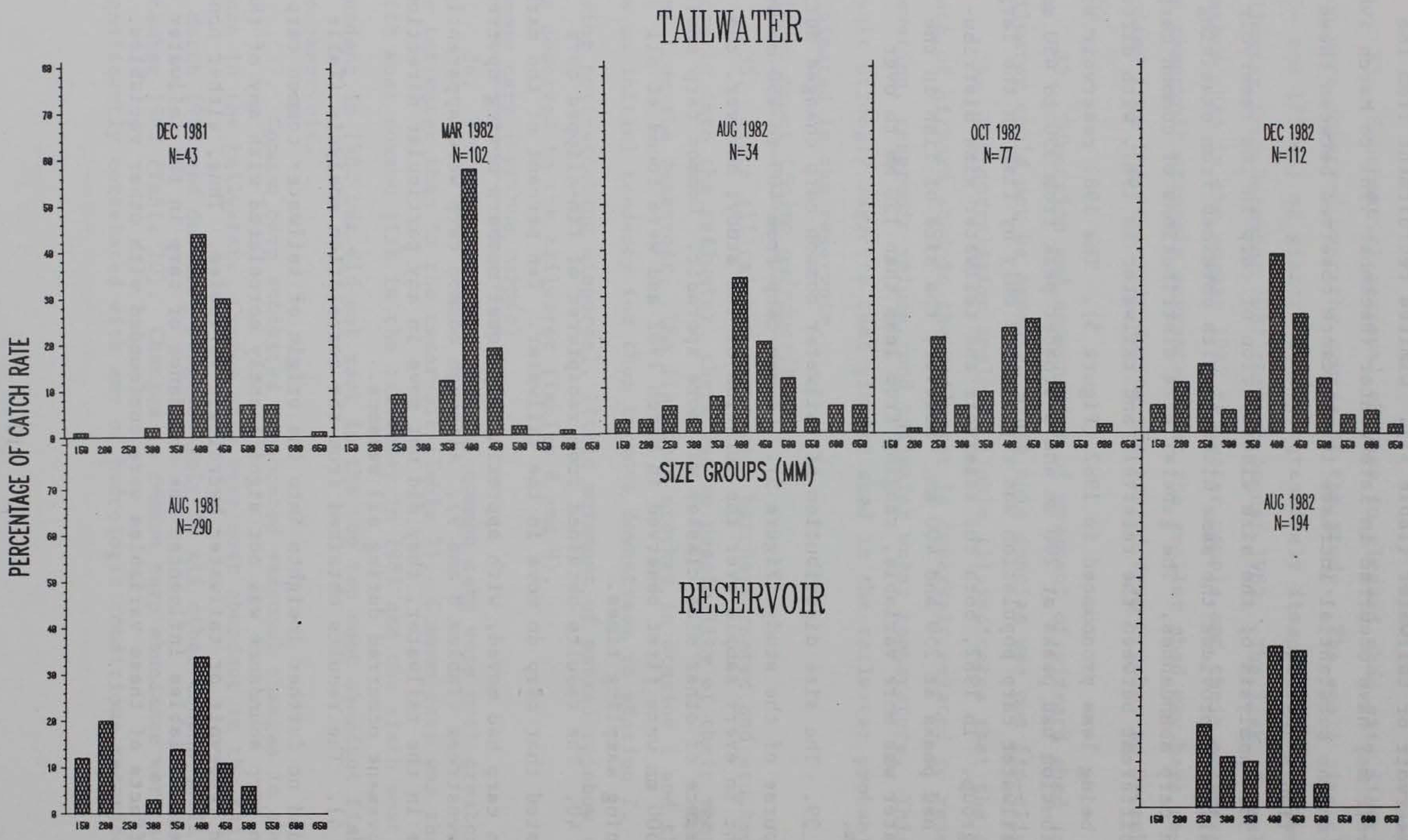

Figure 5. Size distributions of common carp captured in Barren River Lake and tailwater

Spotted sucker (*Minytrema melanops*)

42. Spotted suckers were not a large part of either the reservoir or tailwater fish communities (Table 7), although they were the most abundant sucker in both the reservoir and tailwater. In terms of relative abundance, spotted suckers were the ninth most abundant fish in the tailwater in 1982 and did not rank in the top ten in the reservoir.

43. Spotted sucker abundance exhibited inconsistent seasonal changes in the tailwater. Tailwater abundance was largest in May 1982 (Table 10). Spring gathering for reproduction could account for the May catch rate. Catch rates did not change substantially in other months, and recruitment from the reservoir was not indicated.

44. Small catches of spotted suckers in the December 1981 and May 1982 tailwater samples precluded development of size distribution data and prevented comparison with the 1981 reservoir data (Figure 6). In 1982, the reservoir sample had one peak, at 275 mm, whereas this size group was absent from the tailwater sample. The tailwater size distribution had two peaks, one at 225 mm and another at 300 mm. The large discrepancy in size distribution between the tailwater and reservoir fish indicated these fish were not from a common origin.

45. Recruitment was not indicated by radical changes in size distributions (Figure 6). In fact, size distributions of spotted suckers were similar for August, October, and December 1982, further indicating no large influx of fish from the reservoir. Growth of this species in the tailwater could be observed from August to December as the 175-mm peak shifted to 225 mm and the 275-mm peak shifted to 300 mm.

46. Results of the movement portion of the study indicated that the spotted suckers moved considerably within the tailwater (Tables 8 and 9). A total of 30 percent of the recaptured fish (7 out of a total of 23 recaptured fish) had moved, with most of the movement occurring during the summer and fall in a downstream direction. Downstream movement may have been in response to poor tailwater water quality conditions or may have reflected slow dispersal after spring reproductive gathering.

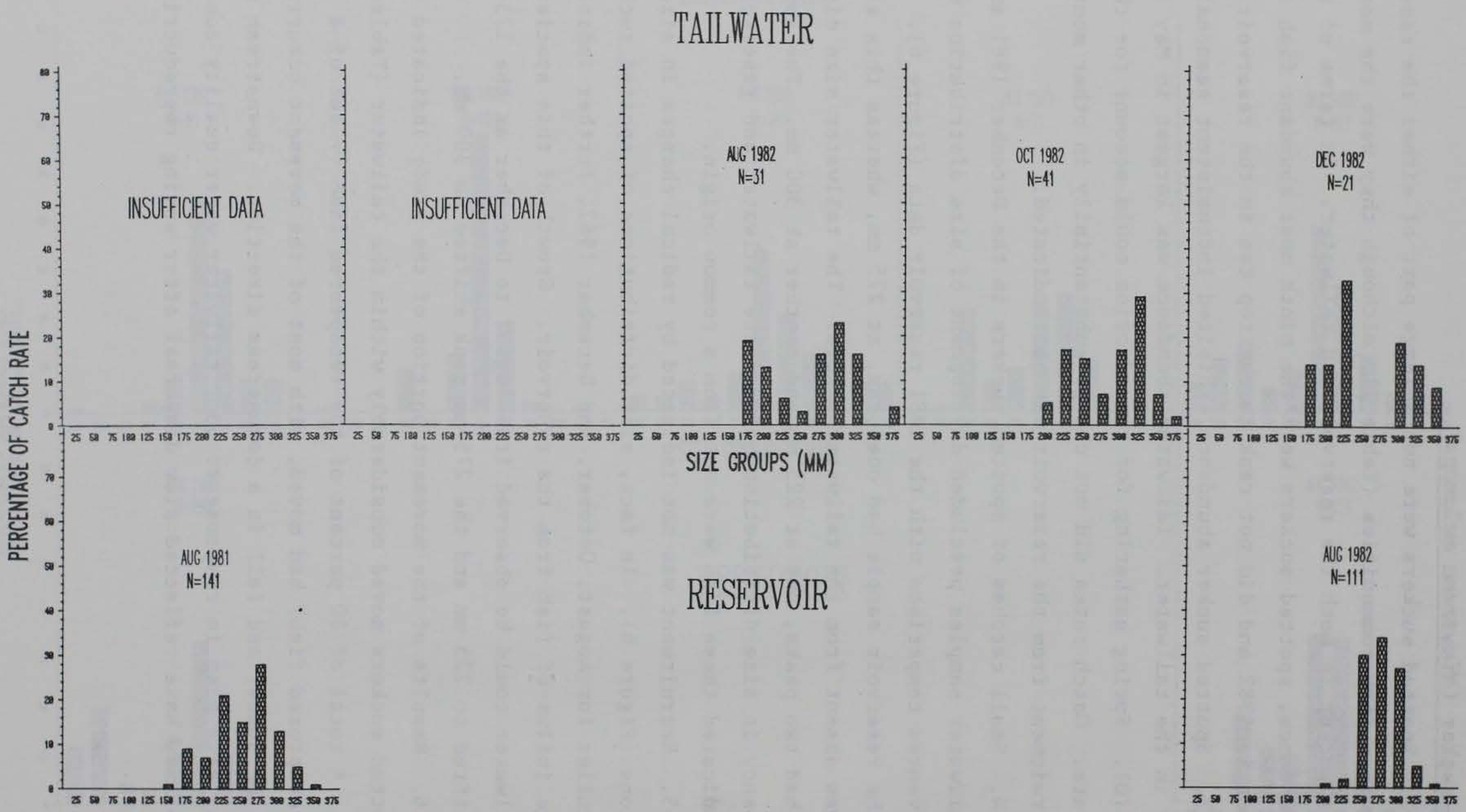

Figure 6. Size distributions of spotted sucker captured in Barren River Lake and tailwater

47. The results of the correlation analysis (Table 11) provided no additional insights to the observations made in the relative abundance and size-distribution portion of this study. Correlation analysis of spotted sucker abundance with reservoir and tailwater variables did not indicate any significant correlations. Apparently, their abundance was not related to these factors.

Channel catfish (*Ictalurus punctatus*)

48. Channel catfish were not a large part of the reservoir or tailwater community (Table 7), ranking only as the sixth most abundant fish in the tailwater in 1981 and not ranking in the top ten in terms of abundance in the reservoir.

49. Seasonally, channel catfish were most abundant in December 1981, with smaller numbers collected in succeeding months (Table 10). The high abundance of channel catfish in December 1981 suggests that these fish could have originated from the reservoir; however, the low number of channel catfish collected in the tailwater in December 1982 suggests that recruitment from the reservoir may be sporadic.

50. Comparison of the size distribution of channel catfish in the reservoir with that of fish in the tailwater was generally inconclusive because too few fish were captured in some months (Figure 7). The only size distribution comparisons possible were between the 1981 reservoir and tailwater samples. Although the reservoir was dominated by 225-mm fish, the tailwater had almost no fish in this size group. The dissimilarity in the size distribution between the tailwater and reservoir suggests that the channel catfish were not from the same stock.

51. Seasonal changes in the size distribution of channel catfish could not be assessed since sample sizes were too small.

52. Movement of channel catfish in the tailwater could not be analyzed since only three channel catfish were recaptured after being fin-clipped (Table 8).

53. Correlation analysis of tailwater channel catfish abundance with reservoir and tailwater conditions indicated either that channel catfish probably did not originate from the reservoir or that movement

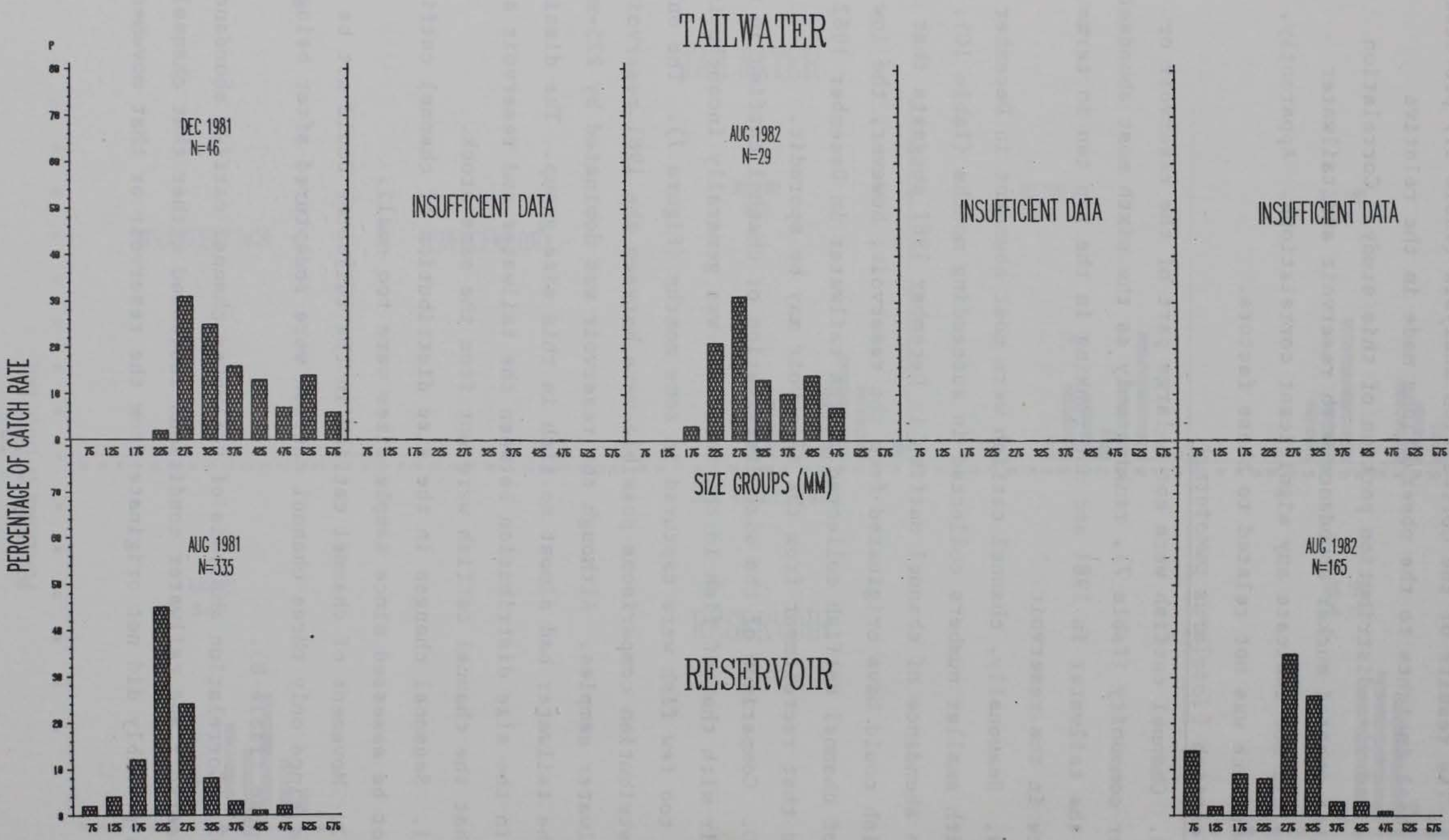

Figure 7. Size distributions of channel catfish captured in Barren River Lake and tailwater

out of the reservoir was confounded with upstream movement since no significant correlations were observed (Table 11).

White bass (*Morone chrysops*)

54. Analysis of the relative abundances of white bass in the tailwater and reservoir indicated similarities in 1982 but not in 1981 (Table 7). White bass in 1982 were the sixth most abundant fish in the reservoir and the seventh most abundant fish in the tailwater.

55. Seasonally, white bass abundance in the tailwater was highest in March 1982 and substantially lower in the other months (Table 10). Recruitment from the reservoir may have occurred from December 1981 to March 1982. However, the peak of white bass abundance in March may also represent blockage of upstream migration by the dam since white bass migrate upstream to spawn. Between October and December 1982, a smaller increase in abundance occurred that cannot be accounted for by spawning migration.

56. The 1981 reservoir and tailwater size distributions were not similar. The August reservoir size distribution had a peak at 175 mm and the December tailwater size distribution peaked at 150 mm (Figure 8). In 1982, reservoir and tailwater size distributions were similar, indicating that these fish may have come from the same origin. The shift of the dominant 225-mm size class in the reservoir in August to the 250-mm size class in the tailwater in December can be accounted for by growth.

57. Size distributions for tailwater white bass varied considerably from sample to sample (Figure 8). The December 1981 sample was composed only of fish from 100 to 150 mm. In March, fish were grouped into two size ranges, 100 to 200 mm and 300 to 350 mm. In December 1982, the tailwater population was dominated by the 250-mm size group. Fish of this size were not captured in the earlier samples and may have been recruited from the reservoir. Alternatively, the tailwater white bass population may consist of a very large and diverse group of fish that move over a long reach of river.

58. The results of the movement portion of the study provided the same enigmatic results produced by the analysis of seasonal size

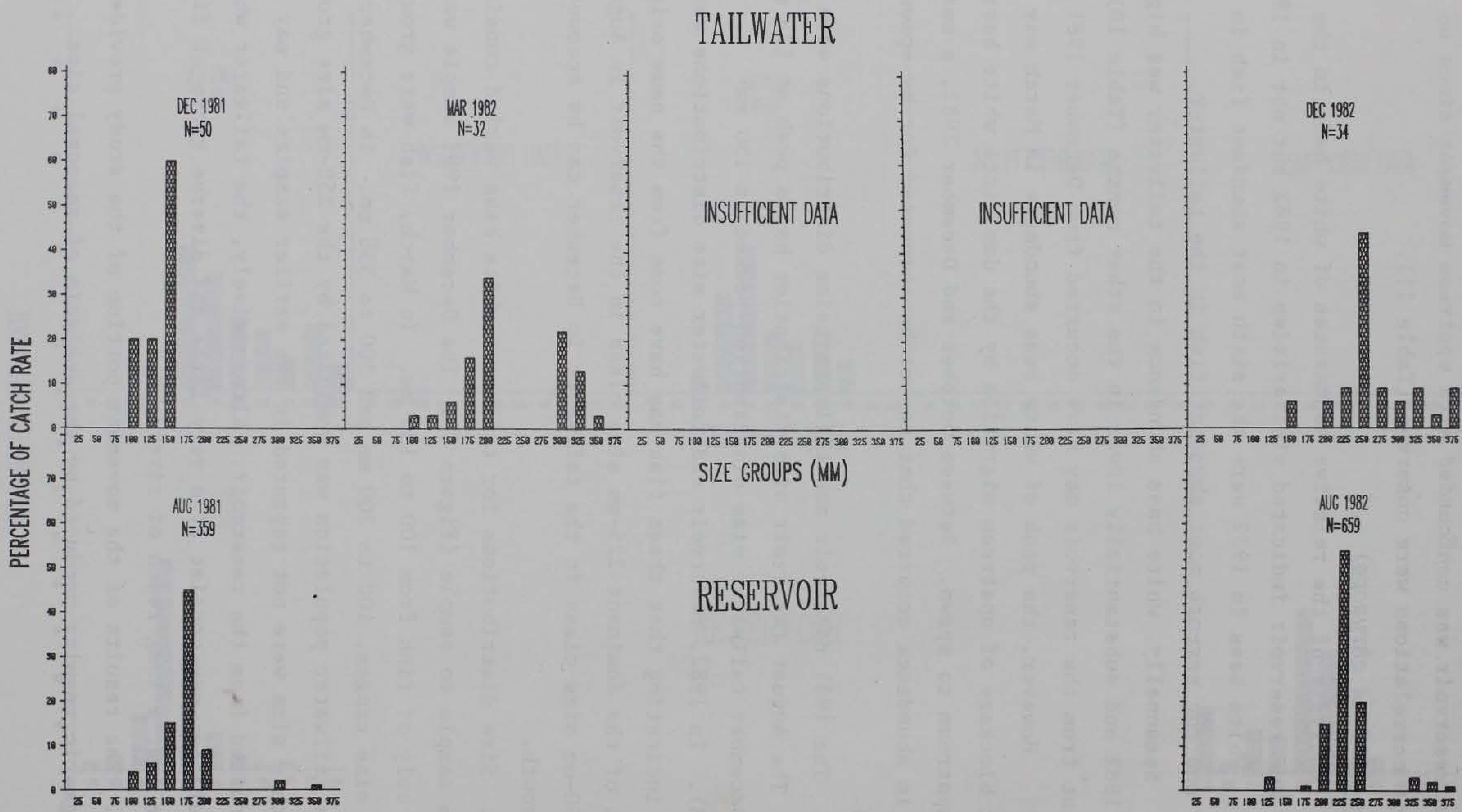

Figure 8. Size distributions of white bass captured in Barren River Lake and tailwater

distributions. None of the 686 fin-clipped white bass in the tailwater were recaptured, so no information on movement was developed (Table 8). The lack of returns would seem to indicate that the movement patterns of white bass in the tailwater were complex and may have been heavily influenced by both upstream and downstream movement in the tailwater as well as by passage through the dam.

59. White bass abundance was not significantly correlated with any reservoir or tailwater characteristics (Table 11).

Bluegills (*Lepomis macrochirus*)

60. Bluegills were consistently abundant in the tailwater and reservoir, ranking as the second or third most abundant fish in both systems (Table 7).

61. Seasonally, bluegills were most abundant in the tailwater in March 1982 and December 1982 (Table 10). Abundances gradually declined from March 1982 to October 1982, until they peaked again in December 1982 (Table 10). Seasonal increases in abundance corresponded with the incidence of high fall discharges associated with drawdown.

62. Bluegill size distributions from the reservoir and tailwater were similar in 1981, but dissimilar in 1982 (Figure 9). The 1981 reservoir size distribution was centered at the 100-mm size group; the tailwater sample was centered at the 125-mm size group. Assuming a growth of 25 mm from August to December, the two populations could have recruited from the same source. The 1982 reservoir size distribution contained many small-sized fish in the 25- and 50-mm size classes, whereas the tailwater was dominated by larger bluegills (in the 125- and 150-mm size classes). The substantial difference between the 1982 reservoir and tailwater size distributions made recruitment from the reservoir to the tailwater less likely for this species.

63. The tailwater size distributions appeared similar during all samples, with a slight shift (to larger size groups) accounted for by growth over the year (Figure 9). All samples had one peak located around the 125- to 150-mm groups. A large influx of bluegills was not indicated by substantial changes in the size distributions.

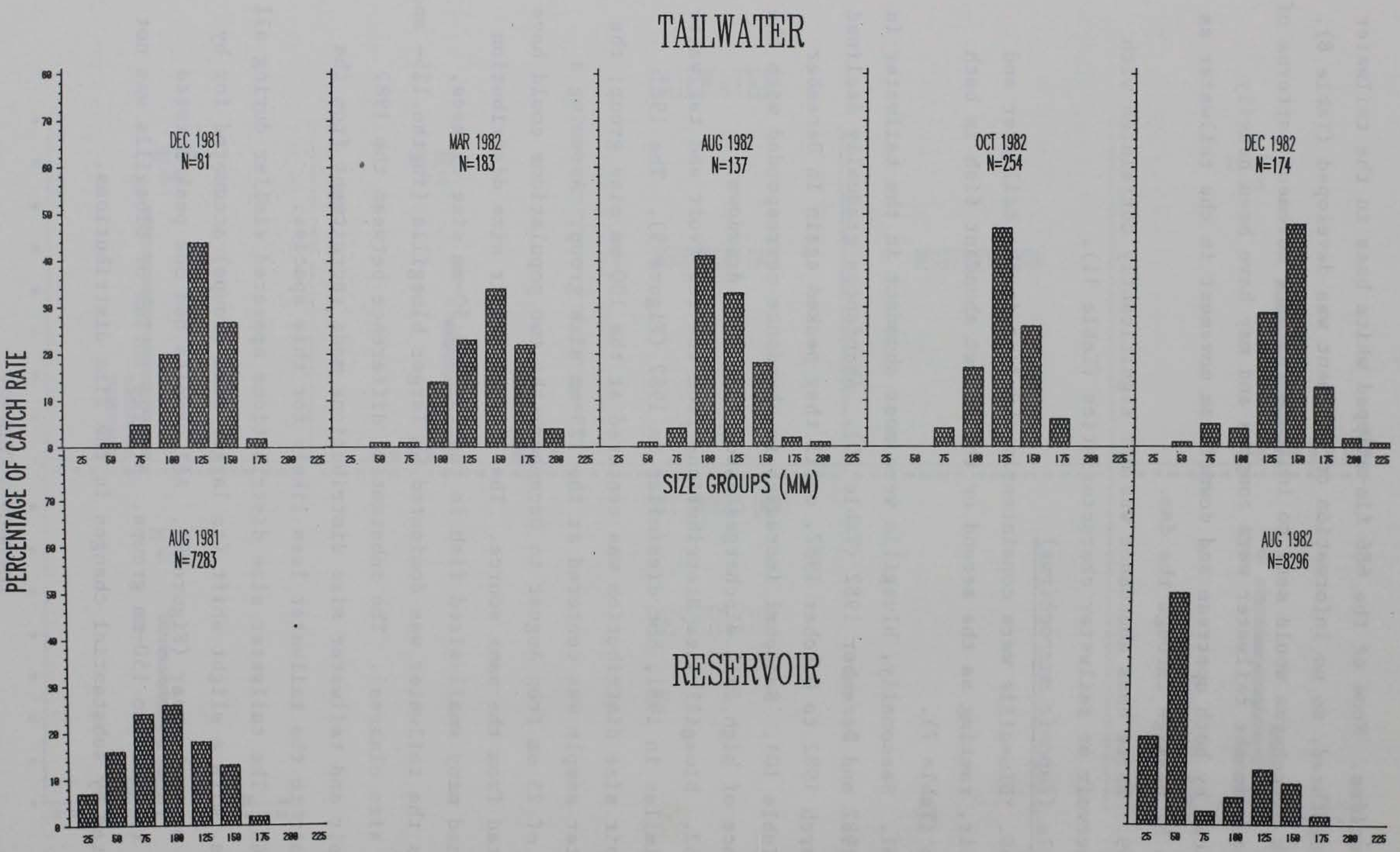

Figure 9. Size distributions of bluegills captured in Barren River Lake and tailwater

64. Fin-clipped bluegills showed very little movement in the tailwater. Only three of the 93 recaptured bluegill had moved (Tables 8 and 9).

65. Bluegill abundance was not significantly correlated with any of the tested reservoir or tailwater hydrologic variables (Table 11).

Longear sunfish (*Lepomis megalotis*)

66. Longear sunfish were abundant both in the tailwater and in the reservoir. Longear sunfish ranked as the fifth and third most abundant fish in the reservoir and the seventh and fifth most abundant fish in the tailwater in 1981 and 1982, respectively (Table 7).

67. Seasonal abundances of longear sunfish did not fluctuate substantially in the tailwater (Table 10). They were slightly more abundant in May 1982 than in other sampling months, and no seasonal abundance trends were evident.

68. Longear sunfish size distributions from the reservoir and tailwater were similar in 1981 and dissimilar in 1982 (Figure 10). In 1981, the reservoir and tailwater had one dominant size group, 100 mm. In 1982, the reservoir had two dominant size groups, 50 mm and 100 mm; the tailwater had only the larger size group.

69. Size distributions of longear sunfish in the tailwater did not change substantially over the duration of the study. Sudden shifts in size-class distribution that would have indicated the influx of newly recruited individuals were not observed.

70. Fin-clipped longear sunfish did not exhibit substantial movement in the tailwater (Tables 8 and 9). Only two of 70 recaptured fish had moved from the location in which they were originally marked.

71. Longear sunfish abundance was negatively correlated with the change in reservoir volume 30 days before each sample. Thus, large-volume discharges into the tailwater were associated with the greatest longear sunfish abundance (Table 12).

Spotted bass (*Micropterus punctulatus*)

72. Spotted bass were abundant in the reservoir during both years, but were among the ten most abundant tailwater species only in 1981 (Table 7).

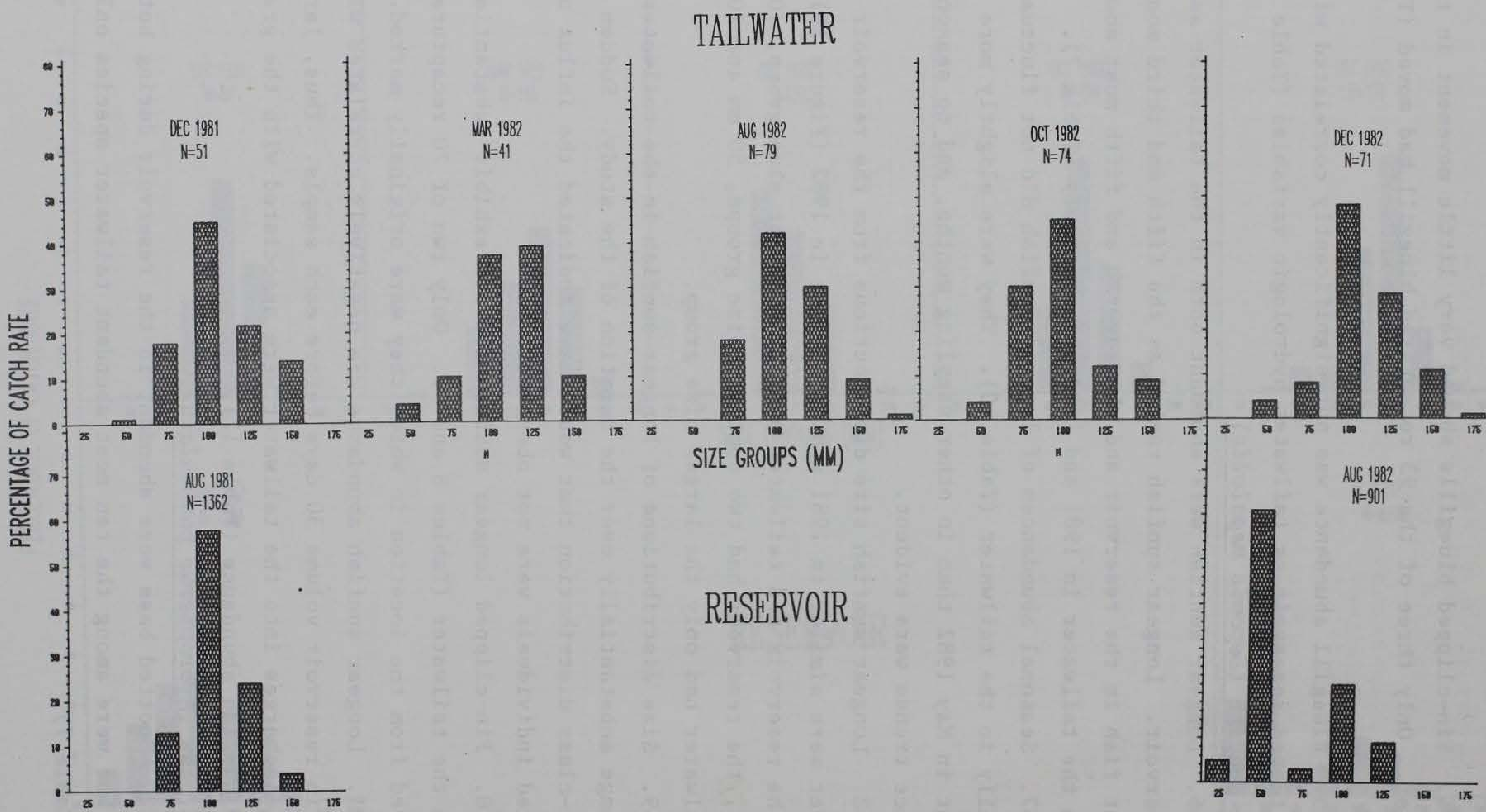

Figure 10. Size distributions of longear sunfish captured in Barren River Lake and tailwater

73. There was little seasonal change in spotted bass abundance in the tailwater (Table 10), and their abundance was not significantly correlated with any of the reservoir or tailwater variables (Table 11).

74. Size distribution data could not be prepared for spotted bass because too few specimens were captured in the tailwater.

75. Spotted bass exhibited no evidence of movement within the tailwater. All 12 recaptured specimens were taken at the same station at which they were marked (Table 10).

Largemouth bass (*Micropterus salmoides*)

76. Largemouth bass were abundant in the tailwater only in 1982 but were commonly collected in the reservoir during both years (Table 7).

77. Tailwater abundance of largemouth bass was similar for all samples (Table 10), and there were no significant correlations between abundance and hydrologic factors (Table 11). However, a number of largemouth bass collected in the tailwater exhibited abrasions and missing scales that may have occurred during passage through the reservoir outlet.

78. Too few specimens were captured to allow comparison of reservoir and tailwater size distributions or evaluate seasonal differences.

79. Recapture data did not indicate the movement of largemouth bass in the tailwater (Table 8). All recaptures were made at the station where the fish were fin-clipped.

White crappie (*Pomoxis annularis*)

80. White crappies were abundant in the tailwater both in 1981 and 1982, but were abundant in the reservoir only in 1981 (Table 7).

81. White crappies in the tailwater exhibited pronounced seasonal changes in abundance. White crappies were most abundant in December 1981 and March 1982, declined steadily through October 1982, and then increased again by December 1982 (Table 10). This species is normally most abundant in the tailwater during those time periods when conditions for movement from the reservoir into the tailwater are favorable.

Therefore, changes in the seasonal abundance patterns of white crappie strongly indicate recruitment from the reservoir in the winters of 1981 and 1982.

82. Size distributions of white crappie from the reservoir and tailwater were similar in both 1981 and 1982 (Figure 11). The 1981 reservoir size distribution had two peaks, one at 50 mm and another at 200 mm; the tailwater size distribution also had two peaks that were slightly larger, 100 mm and 225 mm. The larger size groups in the tailwater probably reflected fish growth from August to December. A similar situation may have occurred in 1982, when both reservoir and tailwater size distributions were bimodal with slightly larger-sized fish captured in the tailwater sample.

83. Pronounced seasonal changes in the size distribution of white crappie were observed in the tailwater. Tailwater size distributions were similar in December 1981 and March 1982 but had changed by August. August and October size distributions were similar (assuming 25-mm growth) but changed again in December 1982 (Figure 11). The large-size fish (greater than 225 mm) collected in December 1981 and March 1982 were poorly represented in the August and October samples. The larger fish may have moved downstream or may have been caught by fishermen since a substantial crappie fishery exists in the tailwater of Barren River Lake. In December 1982, the 225-mm size group reappeared in the tailwater and may have been recruited from the reservoir.

84. The tailwater fish movement portion of the study indicated that white crappies were seasonally mobile in the tailwater. Twenty-six of the 92 (28 percent) recaptured fish had moved (Tables 8 and 9). Most movement occurred during the late winter (between December 1981 and March 1982) in the downstream direction.

85. Tailwater abundance of white crappie was significantly related to hydrologic conditions in the reservoir and tailwater. The abundance of this species in the tailwater was negatively correlated with reservoir elevation, reservoir volume, and tailwater temperature (Table 11). Thus, low reservoir levels, small reservoir volumes, and

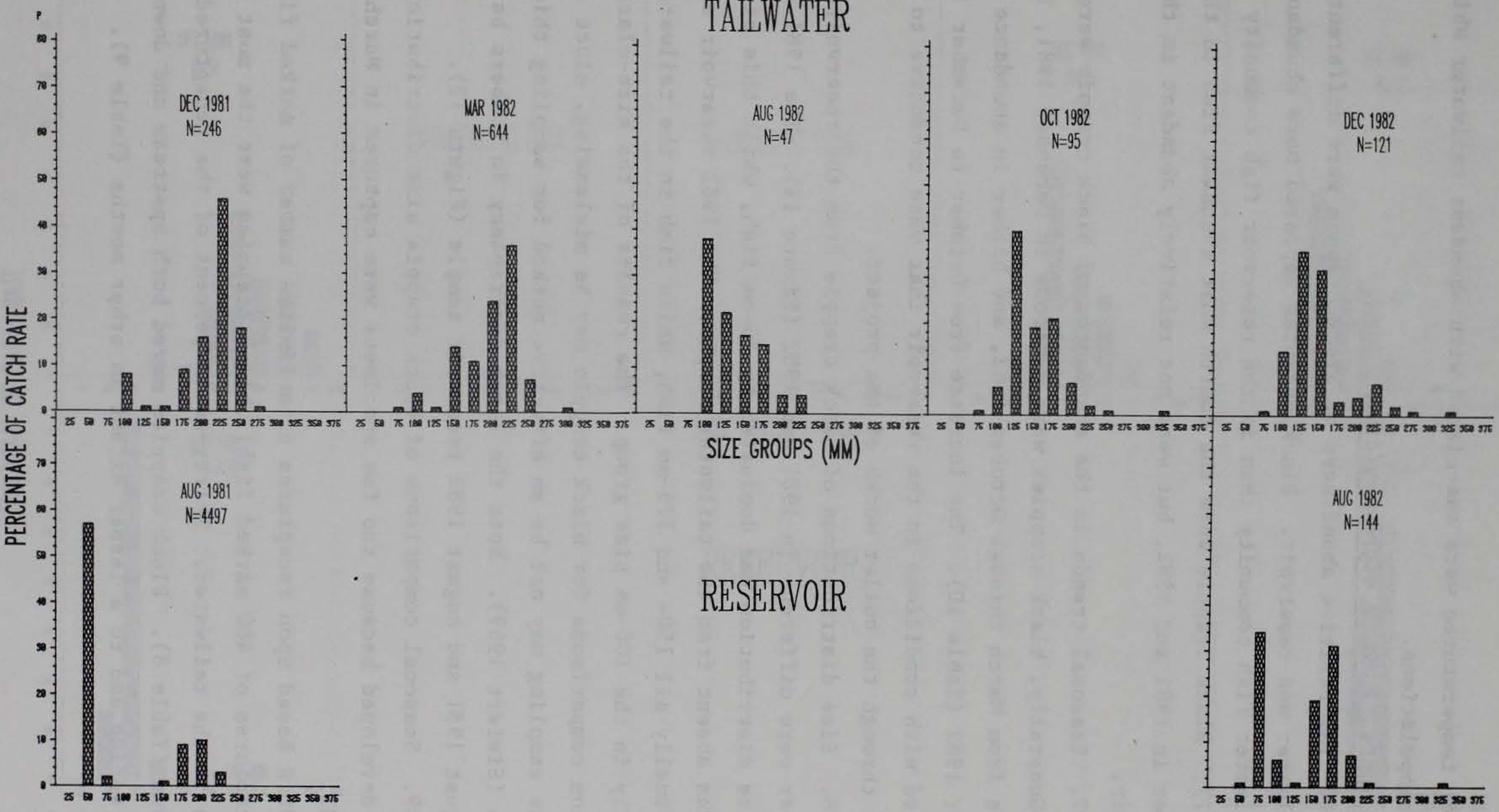

Figure 11. Size distributions of white crappies captured in Barren River Lake and tailwater

coldwater temperatures were associated with abundant tailwater white crappie populations.

Black crappie (*Pomoxis nigromaculatus*)

86. The relative abundances of black crappie were different in the tailwater and reservoir. Black crappies appeared more abundant in the tailwater fish community than in the reservoir fish community (Table 7). Black crappie were the fourth most abundant fish in the tailwater in 1981 and 1982, but were not relatively abundant in the reservoir.

87. Seasonal trends in the abundances of black crappie were evident. Generally, black crappies were numerous in December 1981, less numerous from March through October 1982, and higher in abundance by December 1982 (Table 10). The increase from October to December 1982 coincided with conditions in the reservoir that were conducive to fish passage through the outlet works of the project.

88. Size distributions of black crappie from the reservoir and tailwater were different in 1981 and 1982 (Figure 12). The 1981 reservoir size distribution was dominated by 75-mm fish, while this size class was absent from the tailwater sample. The 1982 reservoir sample was virtually all 150- and 175-mm fish, while fish in the tailwater were primarily in the 100-mm size group. The results of the size-class distribution comparisons for black crappie may be misleading, since cove rotenone sampling may not be an effective method for sampling this species (Siefert 1969). Note the large discrepancy in numbers between the August 1981 and August 1982 reservoir sample (Figure 12).

89. Seasonal comparisons of black crappie size distribution could not be developed because too few specimens were captured in March and May 1982.

90. Based upon recaptures of a limited number of marked fish (19 recaptures of 480 marked fish), black crappies were the most mobile species in the tailwater. Thirty-seven percent of the recaptured fish had moved (Table 8). Black crappies moved both upstream and downstream, in the spring and to a lesser extent in other months (Table 9).

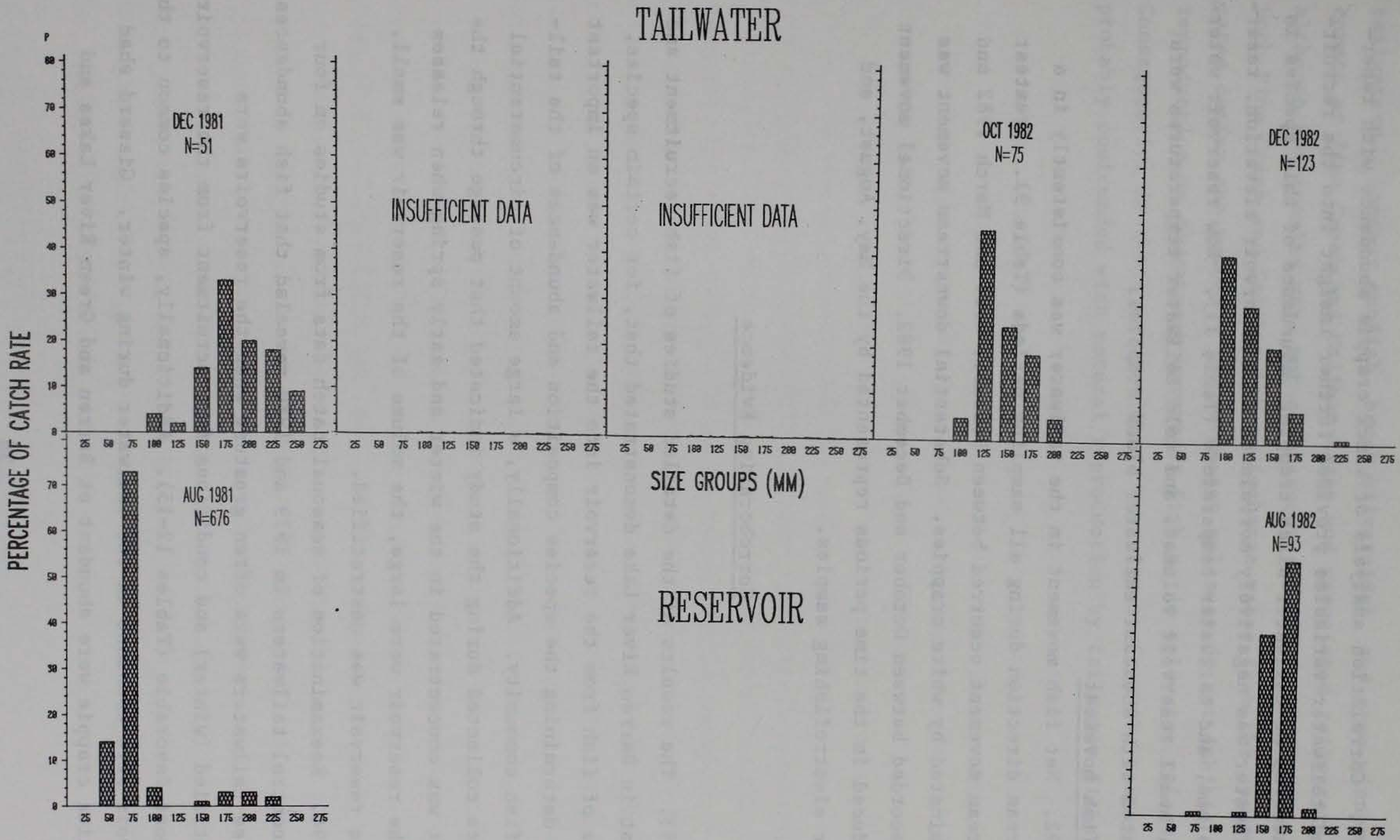

Figure 12. Size distributions of black crappies captured in Barren River Lake and tailwater

91. Correlation analysis of black crappie abundance with reservoir and tailwater variables provided further insight into the recruitment patterns of tailwater black crappie. Abundance of this species in the tailwater was negatively correlated with reservoir elevation, reservoir volume, and tailwater temperature (Table 11). Low reservoir water levels, small reservoir volumes, and cold tailwater temperatures were associated with abundant tailwater black crappies.

Total fish movement

92. Net fish movement in the tailwater was consistently in a downstream direction during all sampling periods (Table 9). Greatest downstream movement occurred between December 1981 and March 1982 and was dominated by white crappies. Substantial downstream movement was also recorded between October and December 1982. Directional movement was reduced in the time periods represented by the May, August, and October electrofishing samples.

Corroborating Evidence

93. The results of the detailed studies of fish recruitment and movement in Barren River Lake demonstrated that, for certain species, passage of fish from the reservoir into the tailwater was an important factor determining the species composition and abundances of the tailwater fish community. Additionally, a large amount of circumstantial evidence collected during the study indicated that passage through the project was concentrated in the winter and early spring when releases from the reservoir were large, the volume of the reservoir was small, and the reservoir was unstratified.

94. Reexamination of seasonal catch data from studies on four flood-control tailwaters in 1979 and 1980 revealed that fish abundances in these tailwaters were often greatest when the reservoirs were unstratified (winter) and conditions for recruitment from the reservoir were most favorable (Tables 12-15). Additionally, species common to the reservoir were abundant in the tailwater during winter. Gizzard shad and white crappie were abundant at Barren and Green River Lakes and

tailwaters. Longear sunfish, brook silversides, and some minnows were common at Pine Creek and Gillham Lakes and associated tailwaters, although the results were not as clearcut for the latter two reservoirs. Both Pine Creek and Gillham Lakes discharge water from the upper bypass gates during the summer. The warmwater releases do not inhibit natural reproduction by downstream warmwater fish as do coldwater releases. Consequently, in these two projects, recruitment from the reservoir is probably confounded with natural reproduction by tailwater fishes.

PART III: DISCUSSION

95. Based on the results of this study, the 11 most abundant tailwater species were grouped into three categories according to their most likely source of recruitment (Table 16). Two species, gizzard shad and white crappie, were almost certainly recruited from the reservoir. Circumstantial evidence indicated that white bass, bluegill, common carp, longear sunfish, and black crappie had a high probability of at least sporadic recruitment from the reservoir. Little or no evidence existed for recruitment of spotted sucker, channel catfish, spotted bass, or largemouth bass from the reservoir. The results of this study concurred with other studies that demonstrated the loss of fish from impoundments both over the spillway (Clark 1942, Louder 1958, and Elser 1960) and through the conduit (Parsons 1957 and Armbruster 1962).

96. Many of the species that appeared to have passed into the tailwater below Barren River Lake, particularly gizzard shad, white crappie, bluegill, and black crappie, feed on plankton in open-water areas or migrate to deeper water during the winter (Scott and Crossman 1973). These species were probably more susceptible to entrainment through the floodgates than species that remain in shallow water or near the littoral zone of the reservoir.

97. The large numbers of longear sunfish, common carp, and white bass present in the tailwater were probably not recruited entirely from the reservoir. Longear sunfish also probably reproduced in the tailwater since it is a common stream species in Kentucky (Clay 1975). Common carp and white bass, highly mobile species, probably migrated upstream into the tailwater. White bass, in particular, have been known to migrate into tailwaters during the spring spawning season (Eschmeyer and Manges 1945). However, the increased abundance of white bass in the tailwater between October and December 1982 could not be attributed to spawning migrations and occurred during a year when the species was relatively abundant in the reservoir.

98. Fish passage through the dam appeared to be highly seasonal, occurring primarily during the late fall, winter, and early spring.

Changes in reservoir conditions during these periods could increase the likelihood of fish passage into the tailwater. Conditions in the reservoir that fostered the passage of fish into the tailwater included:

a. Reservoir destratification. Fish were no longer kept from the vicinity of floodgates by poor water quality.

b. Increased releases. Large volumes of water were discharged from the dam during fall drawdown and spring floods, increasing the probability of entrainment.

c. Reduction in reservoir volume. Fish would be concentrated in the vicinity of the floodgates since the volume of the reservoir during winter is often only 25 percent of the summer volume.

99. The significant negative correlations of tailwater abundance of gizzard shad, white crappie, and black crappie with low reservoir elevation, low reservoir volume, and low water temperature further support the idea of winter recruitment. Additionally, Armbruster (1962), in a study below Berlin Dam on the Mahoning River, Ohio, found fish passage to be greatest between December and April.

100. Reevaluation of catch data below the four CE flood control dams also found seasonal increases in tailwater fish abundances that coincided with changes in reservoir conditions. In all cases, reservoir destratification and the onset of drawdown occurred prior to the influx of fish in the fall. Conversely, no increase in fall fish abundance was observed if the tailwater samples were collected before reservoir conditions changed.

101. The sport fishery in Barren River Lake appeared to be heavily influenced by fish migrating out of the reservoir. The most commonly caught species in the tailwater--white crappie, longear sunfish, bluegill, and white bass (unpublished creel survey)--all relied, to some extent, on the reservoir for recruitment.

102. Movement patterns of fish in the tailwater of Barren River Lake were different than those reported for an unregulated stream. Hall (1972) determined that most fish movement in an unregulated stream occurred in the spring; in contrast, movement in the tailwater occurred during the winter. Funk (1957) believed that movement of stream fish was caused by population pressure (high density). The major influx of

some species of fish from the reservoir resulted in high concentrations of fish in the tailwater. Competition may force the dense concentrations of fish to disperse and might ultimately result in their steady movement downstream.

103. Based on the results of this study, the following general statements can be made about the recruitment dynamics of tailwaters downstream from flood control (nonhydropower) projects. The most abundant fish in the tailwater are recruited from the reservoir. For a deep-release flood control project such as Barren River Lake, and the other flood control projects used in this study with a deep floodgate, recruitment occurs when conditions in the reservoir are favorable to fish passage through the dam. These conditions are generally present in the winter or late fall when the reservoir destratifies and fall drawdown occurs. Once these fish pass through the project, they tend to concentrate in the tailwater and slowly disperse downstream.

104. Hydropower storage reservoirs are also generally operated for flood control. The effects of flood control operation on the downstream fishery at these projects are currently unknown.

105. The results of this study indicate that the reservoir is an important source of recruitment for some sport and forage fish in the tailwater. Consequently, the quality of the tailwater fishery may be determined by conditions in the reservoir as much as by conditions in the tailwater. Thus, the reservoir and tailwater must be managed as an integrated unit. For example, attempts to enhance conditions for tailwater fish by increasing discharges from the reservoir may actually have the opposite effect if increased discharges result in a decline in the reservoir fishery and a subsequent reduction in recruitment to the tailwater.

106. Seasonality of fish abundances in the tailwaters of deep-release flood control projects is reversed from that observed in unregulated rivers. In unregulated rivers, fish abundance and recruitment is greatest in late spring and summer. However, in tailwaters downstream from flood control projects, the abundance of fish is lowest in the summer and fall probably because of altered water quality conditions, and

greatest during the late fall, winter, and early spring, probably because of recruitment from the reservoir. Studies designed to assess the tailwater fishery or the effects of flood control projects must include winter fish sampling to provide a balanced description of tailwater fish communities.

107. The tailwater fishery becomes very susceptible to relatively minor changes in the operation of reservoirs that stratify. For example, if fall drawdown occurs before destratification, potentially fewer fish will be passed into the tailwater. Conversely, if fall drawdown occurs after reservoir destratification, substantial numbers of reservoir fish may be passed into the tailwater.

108. The tailwater fishery may be severely impacted in projects that are retrofitted for hydropower generation, particularly if no change is made in flood control operation. Thus, fish that may ordinarily pass through the outlet works into the tailwater may instead pass through a turbine. Careful consideration should be given to the potential effects of hydropower retrofitting of flood control projects on the passage of reservoir fish into the tailwater to avoid or minimize turbine mortality.

PART IV: CONCLUSIONS

109. The major findings of this study are as follows:

a. The reservoir may be the source of recruitment for some of the fish in the tailwater of deep-release flood control projects.

b. The importance of recruitment from the reservoir to the abundance of tailwater fishes varies by species. Strong circumstantial evidence indicates that recruitment from the reservoir is substantial for some species (in this case, gizzard shad and white crappie).

c. The passage of some species of fish from the reservoir into the tailwater exhibits pronounced seasonality.

d. The seasonality of fish passage can be related to conditions in the reservoir relative to the behavior of certain common species of fish.

e. Substantial fish movement occurs for some species, generally in a downstream direction.

f. Similarities between the seasonal fish abundances at Barren River Lake and fish abundances at other tailwaters suggest that seasonal recruitment from the reservoir may be an important consideration for many tailwaters downstream from deep-release flood control projects.

g. Project operation may have substantial effects on the tailwater fishery by altering conditions that favor the movement of some species of reservoir fish into the tailwater.

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Table 1

Descriptions of the Flood Control Reservoirs Investigated

Reservoir, River, State, and Date of Closure	Project Purposes	Dam Construction and Release Type	Surface Area (ha) and Elevation (m above msl) at Summer Pool	Maximum Discharge Capacity m^3/sec	Elevation of Release Outlets m above msl	Minimum Established Discharge m^3/sec
Barren River Lake Barren River Kentucky March 1964	Flood control Recreation	Earth-fill multilevel outlet (two levels)	4,047/168.0	291.5 (floodgate) 14.2 (bypass)	146.0 162.0, 156.0	2.1
Green River Lake Green River Kentucky February 1969	Flood control Recreation	Earth-fill multilevel outlet (nine levels)	3,322/106.0	263.2 (floodgate) 14.4 (bypass)	185.0 203.0, 192.0	2.4
Pine Creek Lake Little River Oklahoma June 1969	Flood control Water Supply	Earth-fill, multilevel outlet (two levels)	2,025/135.3	226.4 (floodgate) 10.5 (bypass)	117.1 129.0, 123.8	1.8
Gillham Lake Cossatot River Arkansas May 1975	Flood control Water Supply	Earth-fill multilevel outlet (two levels)	555/153.1	84.9 (floodgate) 4.2 (bypass)	133.3 148.5, 144.0	0.8

Table 2

Description of Sampling Stations in the Tailwaters of Barren, Green, Pine Creek, and Gillham Lakes in 1979 and 1980 Studies

Tailwater	Distance Below Dam km	Average Width × Length m	Surface Area ha	Average Depth, Maximum Depth m	Substrate, % Composition		Station Description
Barren	2.4 in 1979	37 × 354	1.3	1.4 2.4	Silt/sand Gravel	30 70	1979-one large pool with a deep riffle located at the upstream end of the station (depth in the riffle was 0.7 m and pool depth was about 2 m); fallen logs, root balls, and undercut banks provided cover.
	1.6 in 1980	30 × 457	1.4	1.4 2.4	Silt/sand Gravel	30 70	1980-primarily a large pool with a gravel shoal (water <1.0 m deep) located in the center of the pool; 7% of the surface area had fallen trees, tree roots embedded in the bank, or undercut banks.
Green	1.5	30 × 457	1.4	0.6 1.8	Gravel Boulder	60 40	Approximately 40% of the station was shallow run (<0.5 m deep) with several riffles; few pools were present; cover was provided by large rocks and boulders.
Pine Creek	2.1	55 × 624	3.4	1.0 2.0	Silt Sand Gravel Cobble Boulder	11 40 17 22 10	Wide pool with a run at the upstream end and a riffle at the downstream end; extensive tree canopy covered both streambanks, and fallen trees provided cover.
Gillham	4.0	46 × 244	1.1	1.7 3.2	Silt Sand Gravel Cobble Boulder	19 39 23 9 10	Deep, wide pool with a run and gravel bar at the upstream end and a wide shallow run at the downstream end; tree canopy, boulders, and fallen trees provided cover.

Table 3

Sampling Schedule at Barren River Lake Tailwater,

December 1981 to December 1982

Sample Date	Fin Clips: Upstream Station	Fin Clips: Downstream Station	Cumulative Number Clipped (Available for Recapture)	Number Recaptured
Dec 81	Upper caudal	Lower caudal	4,192	--
Mar 82	Upper caudal	Lower caudal	9,181	93
May 82	No marks		9,181	70
Aug 82	Left pectoral	Left pelvic	10,983	77
Oct 82	Right pectoral	Right pelvic	13,087	91
Dec 82	No marks		13,087	179

Table 4

Water Temperature, Dissolved Oxygen, Iron, and Manganese Measurements, Stations 1 and 2 in the Barren River Lake Tailwater, 1980-1981

Year, Variable	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980									
Temperature, °C									
Station 1	12	16	21	20	20	19	15		
Station 2	13	19	22	27	24	24	11		
Dissolved oxygen, mg/ℓ									
Station 1		9.5	7.5		6.8		9.0		
Station 2		9.7	7.5		6.0		9.1		
Iron, mg/ℓ									
Station 1		0.3	0.1	0.2	0.6	0.2	0.4		
Station 2		0.6	0.0		0.7		0.1		
Manganese, mg/ℓ									
Station 1		0.1	0.4	0.4	0.4	0.9	1.6		
Station 2		0.1	0.0		0.2		0.1		
1981									
Temperature, °C*									
Station 1	14	16	16	24**		24**		16	6
Station 2	14	18	19	21		23		17	5
Dissolved oxygen, mg/ℓ									
Station 1	9.2	8.5	7.9	6.9		7.3		8.8	10.6
Station 2	10.4	8.7	7.4			6.1		7.4	10.2

* Water temperatures in January-February 1981 (not shown) were 4° and 4° C at Stations 1 and 2, respectively.

** High water temperatures were the result of releases from upper-level gate (162 m above mean sea level); water released from a lower gate would have maintained temperatures near 19° to 20° C.

Table 5

Reservoir and Tailwater Characteristics Correlated (Spearman's Rank Correlation) with Fish Catch Rate in Barren River Lake Tailwater

Reservoir or Tailwater Characteristics	Sampling Dates					
	Dec 81	Mar 82	May 82	Aug 82	Oct 82	Dec 82
Reservoir elevation (metres above msl)	159.5	164.7	167.3	167.5	168.9	161.9
Reservoir volume (acre-feet)	73,060	179,370	257,800	263,940	310,930	113,040
Change in reservoir volume for the previous 30 days (acre-feet)	-112,350	-4,800	+78,430	+4,130	-29,490	-103,290
Tailwater water temperature (°C)	7.5	11.0	13.5	19.5	19.0	10.0
Tailwater Secchi disk reading (cm)	60	30	70	26	118	52

Table 6

Schedule of Electrofishing Samples Taken at Four Flood-Control Reservoir Tailwaters in 1979 and 1980

Month of Sample	Reservoirs			
	Barren	Green	Pine Creek	Gillham
1979				
April			X	
May		X		
June	X	X	X	X
July				
August	X	X	X	
September				X
October	X	X		X
November			X	
1980				
February			X	X
April	X	X		
May	X			
June	X	X	X	X
July	X			X
August	X	X	X	
September	X		X	X
October	X	X		

Table 7

Rank Order (Relative Abundance) for the 10 Most Abundant Species in Barren River Lake and Tailwater in 1981 and 1982

Species	1981 Reservoir	1981 Tailwater	1982 Reservoir	1982 Tailwater
Gizzard shad	1	1	1	1
Rainbow trout	-	8	-	-
Common carp	-	5	-	6
Spotted sucker	-	-	9	9
Channel catfish	-	6	-	-
White bass	-	9	6	7
Bluegill	2	3	2	2
Longear sunfish	5	7	3	5
Spotted bass	7	10	7	-
Largemouth bass	4	-	8	8
White crappie	3	2	-	3
Black crappie	9	4	-	4
Madtom spp.	-	-	10	-
Green sunfish	-	-	5	10
Warmouth	6	-	-	-
Orange spotted sunfish	8	-	-	-
Logperch	10	-	4	-

Table 8

Number of Fish Marked and Recaptured, Direction of Movement, and Percentage of Recaptures That Moved* in Barren River Lake Tailwater, December 1981 to December 1982

Species	Number Marked	Number Recaptured	No Movement	Upstream Movement	Downstream Movement	Percent of Recaptures That Moved
Rainbow trout**	261	22	19	1	2	14
Common carp	1,204	88	79	4	5	10
Spotted sucker	205	23	16	--	7	30
Channel catfish	390	3	3	--	--	--
White bass	686	--	--	--	--	--
Bluegill	2,273	93	90	2	1	3
Longear sunfish	798	70	68	1	1	3
Spotted bass	. 173	12	12	--	--	0
Largemouth bass	202	46	46	--	--	0
White crappie	5,812	92	66	3	23	28

(Continued)

* For species with at least 10 recaptures.

** Rainbow trout were stocked in tailwater monthly and, therefore, did not recruit from reservoir.

Table 8 (Concluded)

Species	Number Marked	Number Recaptured	No Movement	Upstream Movement	Downstream Movement	Percent of Recaptures That Moved
Black crappie	480	19	12	5	2	37
Longnose gar	13	1	--	--	1	--
Northern hog sucker	16	1	1	--	--	--
River redhorse	21	4	4	--	--	--
Black redhorse	116	3	2	--	1	--
Golden redhorse	44	6	5	--	1	--
Flathead catfish	33	1	1	--	--	--
Rock bass	74	3	3	--	--	--
Green sunfish	182	13	13	--	--	0
Warmouth	67	6	6	--	--	--
Smallmouth bass	9	1	1	--	--	--
Dusky darter	4	1	1	--	--	--
Walleye	5	2	2	--	--	--
Freshwater drum	19	--	--	--	--	--
Total	13,087	510	450	16	44	

Table 9

Direction and Season of Movement for All Fish and for Some Selected Species as Indicated by Catch Rates (Fish/Electrofishing Hour) of Marked Fish That Moved in Barren River Lake Tailwater, December 1981 to December 1982

Direction of Movement	Month of Recapture				
	March	May	August	October	December
	All Fish Movement (Fish/Electrofishing Hour)				
Downstream	3.8	1.7	0.8	1.2	2.0
Upstream	0.1	1.5	0.2	0.3	0.5
Net movement (direction)	3.7 (DWN)	0.2 (DWN)	0.6 (DWN)	0.9 (DWN)	1.5 (DWN)
Downstream	Individual Species Movement				
Longnose gar	--	--	--	0.2	--
Rainbow trout	--	0.4	--	0.2	0.2
Common carp	--	--	0.2	--	0.5
Spotted sucker	--	--	0.2	0.6	0.5
Black redhorse	--	--	--	--	0.2
Golden redhorse	--	--	--	--	0.2
Bluegill	0.2	--	--	--	--
Longear sunfish	--	--	--	0.2	0
White crappie	3.4	0.9	0.4	--	0.4
Black crappie	0.2	0.4	--	--	--
Upstream					
Rainbow trout	--	--	0.1	--	--
Common carp	--	--	0.1	0.1	0.2
Bluegill	0.1	--	--	0.1	0.1
Longear sunfish	--	--	--	--	--
White crappie	--	0.9	--	--	--
Black crappie	--	0.6	--	0.1	0.2

Table 10

Catch Rates (Fish/Electrofishing Hour) and Numerical Catch (In Parentheses) For 11 Common Fish and Electrofishing Effect in the Barren River Lake Tailwater, December 1981 to December 1982

Species	Dec 81	Mar 82	May 82	Aug 82	Oct 82	Dec 82	Average (Total)
			Electrofishing Effort, hr				
	8.06	12.56	5.58	12.88	20.31	15.73	75.12
			Catch Rates				
Gizzard shad	5,250	2,925	2,900	1,462	90	4,480	2,581
Common carp	16 (126)	61 (765)	30 (167)	11 (147)	8 (166)	12 (185)	23 (1,556)
Spotted sucker	2 (15)	2 (27)	9 (50)	5 (61)	5 (102)	3 (51)	4 (306)
Channel catfish	15 (118)	10 (126)	4 (20)	4 (54)	4 (92)	1 (19)	6 (429)
White bass	5 (37)	41 (517)	2 (14)	9 (116)	1 (16)	7 (111)	11 (811)
Bluegill	39 (317)	63 (791)	54 (299)	41 (530)	31 (635)	75 (1,181)	50 (3,753)
Longear sunfish	13 (108)	18 (228)	24 (135)	17 (224)	12 (238)	13 (207)	16 (1,140)
Spotted bass	4 (31)	2 (27)	5 (27)	4 (48)	3 (67)	2 (28)	3 (228)
Largemouth bass	3 (27)	3 (40)	4 (21)	5 (65)	3 (70)	4 (70)	4 (293)

(Continued)

Table 10 (Concluded)

Species	Dec 81	Mar 82	May 82	Aug 82	Oct 82	Dec 82	Average (Total)
White crappie	384 (3,095)	177 (2,224)	81 (452)	22 (280)	11 (213)	35 (557)	118 (6,821)
Black crappie	22 (175)	8 (106)	16 (89)	2 (32)	8 (167)	27 (429)	14 (998)
Other fish*	18 (147)	12 (144)	25 (146)	21 (246)	18 (346)	11 (152)	18 (1,181)
Total (excluding shad)	521 (4,196)	397 (4,995)	254 (1,420)	141 (1,803)	104 (2,112)	190 (2,990)	267 17,516)

* Twenty-five species or hybrids, including longnose gar, rainbow trout, American eel, goldfish, spotfin shiner, silver shiner, golden shiner, northern hog sucker, black redhorse, river redhorse, golden redhorse, shorthead redhorse, yellow bullhead, flathead catfish, brook silverside, striped bass, white bass x striped bass hybrid, rock bass, green sunfish, warmouth, smallmouth bass, logperch, dusky darter, walleye, and freshwater drum.

Table 11

Spearman's Rank Correlation Coefficient for 11 Species Catch Rates (Fish/Electrofishing Hour) from Barren River Lake Tailwater and Five Reservoir and Tailwater Characteristics

	Correlation Coefficients (r)				
	Reservoir			Tailwater	
Species	Elevation m above msl	Volume acre-feet	Change in Volume 30 Days Before Sample	Water Temperature (°C)	Secchi Disk (cm)
Gizzard shad	-1.00*	-1.00*	-0.60	-0.94*	-0.20
Common carp	-0.54	-0.54	-0.20	-0.49	+0.20
Spotted sucker	-0.66	+0.66	-0.66	-0.66	-0.31
Channel catfish	-0.37	-0.37	+0.26	-0.37	-0.09
White bass	-0.31	-0.31	-0.09	-0.09	+0.69
Bluegill	-0.43	-0.43	-0.14	-0.31	+0.49
Longear sunfish	-0.07	-0.07	-0.73*	+0.10	+0.36
Spotted bass	+0.14	+0.14	-0.40	+0.23	-0.23
Largemouth bass	+0.13	+0.13	-0.41	+0.36	+0.50
White crappie	-0.83*	-0.83*	+0.26	-0.77*	+0.14
Black crappie	-0.76*	-0.76*	+0.59	-0.84*	-0.30
All fish (excluding shad)	-0.83*	-0.83*	-0.26	-0.77*	-0.14

* Significant correlation, $P < 0.05$.

Table 12

Catch Rates (Fish/Electrofishing Hours) for Selected Species and for All Fish in Barren River Lake Tailwater, 1979 and 1980

Species	1979			1980						
	Jun	Aug	Oct*	Apr	May	Jun	Jul	Aug	Sep	Oct*
Gizzard shad	6	7	9	215	95	145	84	31	20	201
Common carp	6	8	13	44	36	18	24	9	6	30
Brook silverside	0	0	0	17	7	7	0	4	0	54
White bass	0	0	0	17	5	0	0	0	0	24
Bluegill	7	7	9	11	24	17	10	12	10	35
White crappie	3	1	28	12	18	61	8	0	6	0
Black crappie	0	3	3	5	9	15	9	0	5	13
Total fish	50	62	109	340	235	255	146	65	68	316

* Reservoir unstratified in winter and early spring.

Table 13

Catch Rates (Fish/Electrofishing Hour) for Selected Species and for All Fish in Green River Lake Tailwater, 1979 and 1980

Species	1981 May	1981 Jun	1981 Aug	1981 Oct*	1982 Apr	1982 Jun	1982 Aug	1982 Oct
Gizzard shad	46	4	2	24	9	12	0	0
Common carp	4	2	9	4	9	18	7	0
White crappie	91	79	5	87	145	29	8	10
Total fish	199	155	78	179	278	127	108	100

* Reservoir unstratified in winter and early spring.

Table 14

Catch Rates (Fish/Electrofishing Hour) for Selected Species and for All Fish in Pine Creek Lake Tailwater, 1979 and 1980

Species	1981				1982			
	Apr	Jun	Aug	Nov*	Feb	Jun	Aug	Sep
Fathead minnow	5	0	0	11	0	0	0	0
Bluegill	19	44	38	49	44	37	40	42
Brook silverside	0	0	0	0	63	11	0	0
Longear sunfish	38	76	84	126	33	87	80	74
Total fish	113	231	231	241	199	243	205	190

* Reservoir unstratified in winter and early spring.

Table 15

Catch Rates (Fish/Electrofishing Hour) for Selected Species and for All Fish in Gillham Lake Tailwater, 1979 and 1980

Species	1979 Jun	1979 Sep	1979 Oct*	1980 Feb	1980 Jun	1980 Jul	1980 Sep
Black spotted topminnow	0	0	24	6	12	0	0
Bluegill	11	30	47	32	30	38	13
Steelcolor shiner	7	0	0	18	15	9	0
Longear sunfish	93	140	192	95	78	65	57
Total fish	171	358	410	258	324	188	177

* Reservoir unstratified in winter and early spring.

Table 16

Most Likely Source of Recruitment of 11 Fish Species Collected in Barren River Lake Tailwater in 1981 and 1982, As Determined by Abundance, Size, Distribution, and Movement Data

Recruitment Source and Species	Similar in Reservoir and Tailwater: Abundance	Similar in Reservoir and Tailwater: Size Distribution	Major Seasonal Change in Tailwater: Abundance	Major Seasonal Change in Tailwater: Size Distribution	Correlation Analysis	Downstream Movement
Reservoir						
Gizzard shad	X*	X*	X	X	X	N/A
White crappie	X**	X*	X	X	X	X
Reservoir (sporadic), upstream migration						
White bass	X†	X†	X	X		
Bluegill	X*	X**	X			
Common carp			X	X		
Longear sunfish		X†			X	
Black crappie			X		X	
Unknown (reservoir unlikely)						
Spotted sucker						X
Channel catfish						
Spotted bass						
Largemouth bass						

* Both 1981 and 1982.
** 1981 only.
† 1982 only.