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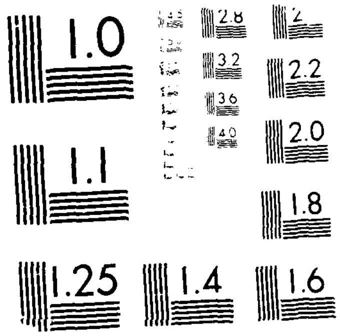

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US Army Corps of Engineers

AD-A190 601

TECHNICAL REPORT

EFFECTS OF SURFACE WATER WITHDRAWAL ON FISHES IN RIVERS OF NORTHEAST LOUISIANA

by

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Water demands for crop irrigation and commercial fish farming are increasing in northeast Louisiana. Withdrawal of surface water from the rivers is being considered as one alternative to alleviate the water shortage during the summer and fall months. Relationships between fish abundance and water volume were determined from data collected at 15 sites in northeast Louisiana and used to estimate changes in fish abundance resulting from various surface water withdrawal scenarios. For most scenarios, water demands exceeded the water supply for 1 or more months resulting in a 100-percent loss of fishes due to dewatering effects, migration from the area, and a severe reduction in habitat quality. Approximately 70 percent of the fishes lost were minnows/darters and juvenile shad, followed by juvenile sunfishes (20 percent) and harvestable sport and commercial fishes (10 percent).

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In addition to water volume, the influence of other physical and chemical variables on fish abundance was evaluated using stepwise multiple regression. Variability in fish abundance was best explained by water volume, dissolved oxygen, and conductivity (R^2 = 0.77). Other variables (pH, water depth, percent cover, temperature, turbidity, water velocity, and discharge) had no significant influence on increasing the predictive capability of the regression equation. Although changes in dissolved oxygen and conductivity may accompany decreases in water volume, the ability to make these predictions as part of an impact assessment was beyond the scope of this study. However, these variables should be considered as potential limiting habitat factors in rivers of northeast Louisiana during the summer and early fall months and can provide a basis of monitoring habitat quality under actual surface water withdrawal conditions.

An index of biotic integrity (IBI) was used to compare the quality of the existing fish community structure between study sites. The IBI can be incorporated in a management plan to identify both pristine and degraded habitat conditions, but is not intended as a predictive technique to estimate changes in fish abundance for future conditions. The IBI integrates attributes of species richness and composition, trophic composition, and fish abundance to rate the fish community structure as excellent, fair, or poor. In northeast Louisiana, poor habitat conditions are usually associated with high numbers of juvenile shad, while excellent habitat is dominated by minnows, shiners, and darters. Bayou Bartholomew was the only major river in the study area that consistently exhibited high species richness, trophic composition representative of undisturbed habitat, and a relatively high number of total fishes compared with other rivers in northeast Louisiana. High quality fish habitats that do exist in other rivers, such as gravel substrate, continuous flowing water, and high amounts of instream cover, are intermittent and uncommon and are usually associated with small tributaries or are below water-control structures. Bayou Bartholomew is one of the few remaining water bodies in northeast Louisiana that is considered an ecologically significant stream because of its high diversity of stream-dwelling fish species.

PREFACE

This study provides an inventory of the existing fish community structure and evaluates the effects of surface water withdrawal on fishes in northeast Louisiana as part of a water supply study on the Boeuf River, Tensas River, and Bayou Bartholomew basins being conducted by the US Army Engineer District, Vicksburg (VXD). Funding for this project was provided by VXD; partial funding for the development of the Index of Biotic Integrity was provided by the Environmental Impact Research Program (Work Unit 32390). This report was prepared by Mr. K. Jack Killgore, Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), and Dr. Neil H. Douglas, Northeast Louisiana University, Monroe, La. Assistance in the field was provided by Mr. Kenneth Conley, Mr. Frank Ferguson, and Ms. Teressa Naimo, Aquatic Habitat Group (AHG), WES, and Mr. Jan Hoover, University of Oklahoma. Technical Monitor from VXD was Mr. Marvin Cannon. Technical reviews of the report were provided by Dr. Barry S. Payne, Dr. Andrew C. Miller, Mr. Johnny Franklin, AHG, and Dr. John M. Nestler, Water Quality Modeling Group, WES, and Dr. James A. Gore, University of Tulsa. The report was edited by Ms. Lee T. Byrne of the WES Information Products Division, Information Technology Laboratory.

This study was conducted under the general supervision of Mr. Richard Coleman and Mr. Edwin A. Theriot, Acting Chiefs, AHG; Dr. Conrad J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL, WES.

Commander and Director of WES was COL Dwayne G. Lee, CE. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

LIST OF FIGURES

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENTS

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acre-feet	1,233.489	cubic metres
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
gallons	3.785412	cubic decimetres
square feet	0.09290304	square metres

PART 1: INTRODUCTION

Background and Purpose

1. Surface water demands are rapidly increasing in northeast Louisiana for irrigation and commercial fish farming and, to a lesser extent, for industrial and municipal purposes (Henning 1985). Because a diverse fish community inhabits the numerous streams, bayous, and rivers in northeast Louisiana (Douglas 1974), an increase in surface water demand will result in competition for available water supplies between human consumption and aquatic habitat. Water is required for crop irrigation and commercial fish farming throughout the summer and early fall months (Henning 1985) when stream levels are low. Therefore, reduction in water levels from surface water withdrawal may affect the spatial requirements of fishes for foraging, spawning, and predator avoidance (Fraser 1972, Petts 1984), leading to a decrease in their condition and abundance.

2. The purpose of this study was to determine the effects of surface water withdrawal on fishes in northeast Louisiana during the summer and early fall months, as part of a water supply study of the Boeuf River, Tensas River, and Bayou Bartholomew basins. The objectives of this report were to evaluate changes in fish abundance resulting from various future water demand scenarios developed by Henning (1985), determine important physical and chemical variables that may limit fish abundance, and document the fish community structure that currently exists in the study area.

Description of Study Area

3. This study focused only on relatively small rivers in northeast Louisiana that were bordered by irrigated, agricultural land. These included the Boeuf River, Tensas River, Bayou Macon, Big Creek, and Bayou Bartholomew. These rivers have undergone extensive water resource development in the form of channelization, single-purpose dams, and various types of weirs, dikes, jettys, and outlet structures. Rivers in the study area are usually nonflowing during the summer and early fall as the result of low water or

backwater effects from dams, diversions, logjams, and larger rivers (Black and Ouachita Rivers). However, measurable discharge does occur immediately below some larger dams (e.g., Gumby Dam on the Tensas River) and other outlet structures. The substrate is composed of clay and sand. An exception is the Bayou Bartholomew, where gravel riffles still exist and flowing water occurs year-round. Trees commonly fall into the rivers and provide the only substantial instream cover available to the fishes.

4. Although removal of water from rivers should have no substantial effect on water levels in the immediate vicinity of the pumps because of inflow from upstream or downstream sources, the numerous low-water dams, logjams, and diversions that occur throughout the study area prevent a free-flowing exchange of water from the headwaters to the mouth during the summer and fall. For example, rock dams are commonly placed below a water intake to form a pool and ensure an adequate water supply during low-water periods. Consequently, surface water withdrawal should result in a decrease in water volume near the vicinity of the intake structure. The dams and diversions also make it difficult to establish a reliable stage-discharge relationship for gaging stations in the study area in order to apply hydraulic models for predicting changes in discharge over time.* Although stage height fluctuates throughout the summer and fall, it generally results from backwater effects after rainfall and continuous surface water withdrawal for irrigation.* This is particularly pronounced in the upper reaches of the Boeuf River, which becomes virtually dewatered as a result of surface water withdrawal.

Approach and Assumptions

5. A threefold approach was used in this study and incorporated both abiotic and biotic variables to predict impacts of surface water withdrawal on fishes, identify potential limiting factors on fish abundance, and classify streams according to the quality of the fish community structure. First, impacts of future water demands on fish abundance were determined according to a relationship between water volume and number of fish. Second, the

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* Personal communication, July 1987, Robert Walsworth, US Geological Service, Ruston, La., and Tommy Reynolds, US Army Engineer District, Vicksburg, Vicksburg Miss.

importance of other physical and water quality variables on fish abundance was evaluated using multiple regression techniques. Third, species and trophic compositions of the fish community structure were compared between rivers in the study area to identify ecologically significant river reaches.

Relationship between
water volume and fish abundance

6. The lack of reliable stage-discharge relationships at the various gaging stations, the influence of the numerous dams, diversions, and water intakes on the flow regime, and the size of the study area (approximately 700 river miles) prevented the utilization of established water quality and hydraulic models in the impact assessment process. Consequently, the mean number of fish per unit volume of water was calculated based upon field data collected throughout the study area and multiplied by future changes in water volume according to Henning's (1985) water demand report. It was assumed that the magnitude of declines in fish abundance from future surface water withdrawal could be estimated from an existing mean number of fishes per unit volume of water. Validation of this assumption could be made by monitoring fish populations under actual withdrawal conditions. In addition, it was assumed that water removed from specific river reaches would not be replaced from other instream sources because of the influence of dams, diversions, and other structures and that long-term reductions in water levels would occur. Short-term fluctuations in water levels might only displace fishes, followed by recovery of stream volume and habitat quality. Conversely, long-term declines in water levels over several months could decrease fish abundance due to an overall reduction of usable stream habitat. Since water demands for irrigation and commercial fish farming occur from May through October (Henning 1985), long-term reductions in water levels will likely occur if surface water is used.

7. The primary objective of this study was to estimate changes in fish abundance resulting from Henning's (1985) future water demand predictions. However, Henning's report was not written for use in biological impact analysis, and the application of his results to this study presented several major problems. First, Henning determined changes in water volume demands without consideration to other habitat variables such as water quality. Second, Henning determined total water demands without indicating the amount required from surface water. Walter (1982) provides the only data (for 1980) on water

usage that distinguishes surface from ground-water withdrawal (Table 1). It was assumed that the rate of future ground-water withdrawal would equal that of 1980. Only ground water was used in Tensas and Madison Parishes according to Walter (1982); therefore, it was assumed that there would be no surface water demands for these two parishes. For parishes requiring some surface water in 1980, it was assumed that all increased demands in the future would be met solely by increased use of surface water. Thus, the percent surface water used in each parish according to Walter's (1982) estimates was multiplied by total water demands determined by Henning (1985) to obtain future demands of surface water only. Third, Henning did not indicate the source of water (river, lake, or pond) but simply expressed demands by parish. As a worst-case scenario, it was assumed that all surface water demands would be met by the five rivers in the study area. Although there are numerous oxbow lakes along the Mississippi and other rivers in this area, their inclusion in this analysis was beyond the scope of the study.

Multivariate habitat analysis

8. The distribution and abundance of fishes are influenced by a variety of habitat factors other than just water volume (Whiteside and McNatt 1972; Platts 1979; Fausch, Karr, and Yant 1984; Miranda, Shelton, and Bryce 1984; Schlosser 1985). The multivariate approach to impact analysis on fish populations has become an established technique to determine fish abundance due to changes in physical, chemical, and biotic variables. For example, using multiple regression, Binns and Eiserman (1979) developed a habitat quality index (HQI) that related standing crop of coldwater fishes to nine habitat attributes. Oswood and Barber (1982) used a similar approach for salmonids. Several multivariate habitat models for warmwater streams have also been developed to predict fish standing crop (Paragamian 1981, Layher and Maughan 1985), although some are subjective and not well verified (McClendon and Rabeni 1987). Other habitat assessment methods that use indices to describe the quality of the environment to fishes include the Instream Flow Incremental Methodology (IFIM) (Bovee 1982) and the Habitat Evaluation Procedures (HEP) (US Fish and Wildlife Service (USFWS) 1980). These and other habitat-based models are still evolving in an attempt to develop an acceptable fishery habitat classification system for resource planning and management (Platts 1980).

9. A multivariate analysis was employed in this study to identify selected physical and water quality variables that may limit fish abundance. The results were not used to predict changes in fish abundance according to Henning's (1985) water demands, because, as previously mentioned, variables other than water volume were not provided for future conditions and the ability to predict changes in other habitat variables resulting from surface water withdrawal was beyond the scope of this study.

Species and trophic
compositions of fishes

10. The final approach used in this study was to describe and compare the integrity of the fish community structure in northeast Louisiana using the index of biotic integrity (IBI) proposed by Karr (1981). This index evaluates an aquatic resource based on the attributes (species composition, trophic composition, and health and abundance of fish) of the indigenous fish community (Leonard and Orth 1986). The fish community can be classified as excellent, fair, or poor according to the final IBI score. This index can ultimately be used to identify ecologically significant areas in northeast Louisiana that are sensitive to water resource development and to monitor changes in the quality of the fish community structure.

PART II: FIELD METHODS

11. Relationships between fish abundance (number of fishes) and physiochemical variables were examined at 15 different river locations in the study area during low-water periods in September and October (Figure 1). Numerous studies have shown that fish assemblages can be quite different due to the quality of fish habitat (Hynes 1970; Krumholz 1980; Ross, Matthews, and Echelle 1985); therefore, sites were selected to account for variability in channel shape and dimensions, amounts of instream cover, water velocity, and substrate type (gravel or clay). Each individual site, however, was relatively uniform in habitat features. The length of the sites ranged from 33 to 380 ft* in order to assess the relationship between water volume and fish abundance. However, the mean ($\pm$SD) length of all sites was 148 $\pm$92.

12. Each site was isolated with upstream and downstream blocknets (0.5-mm mesh). Three consecutive passes of equal effort were made through the site using a boat-mounted electroshocker (output was 350 to 400 v at 4 to 7 amp). All fishes collected were identified to species and measured (standard length). The number of fishes per unit volume of water was determined using the Zippin Depletion Method (Zippin 1958), and the standard error of these estimates was determined as described by Platts, Megahan, and Minshall (1983). Based upon frequency of occurrence (individuals per class divided by total individuals), fishes were separated into the following groups: harvestable sport and commercial species, juvenile sport and commercial species, minnows, darters, madtoms, and rough fishes. Fishes of harvestable size were identified using length criteria furnished by the US Army Engineer District, Vicksburg (VXD).

13. After fishes were collected, depth, velocity, cover (presence or absence), and water quality were measured at 2- to 5-ft intervals across a transect and used to describe the morphology, water volume, and average water quality conditions for the study site (Table 2). Because each individual site was relatively uniform with respect to channel shape and location of instream cover, a single transect was considered adequate to represent the habitat variability within the site. Water depth was measured to the nearest 0.1 ft

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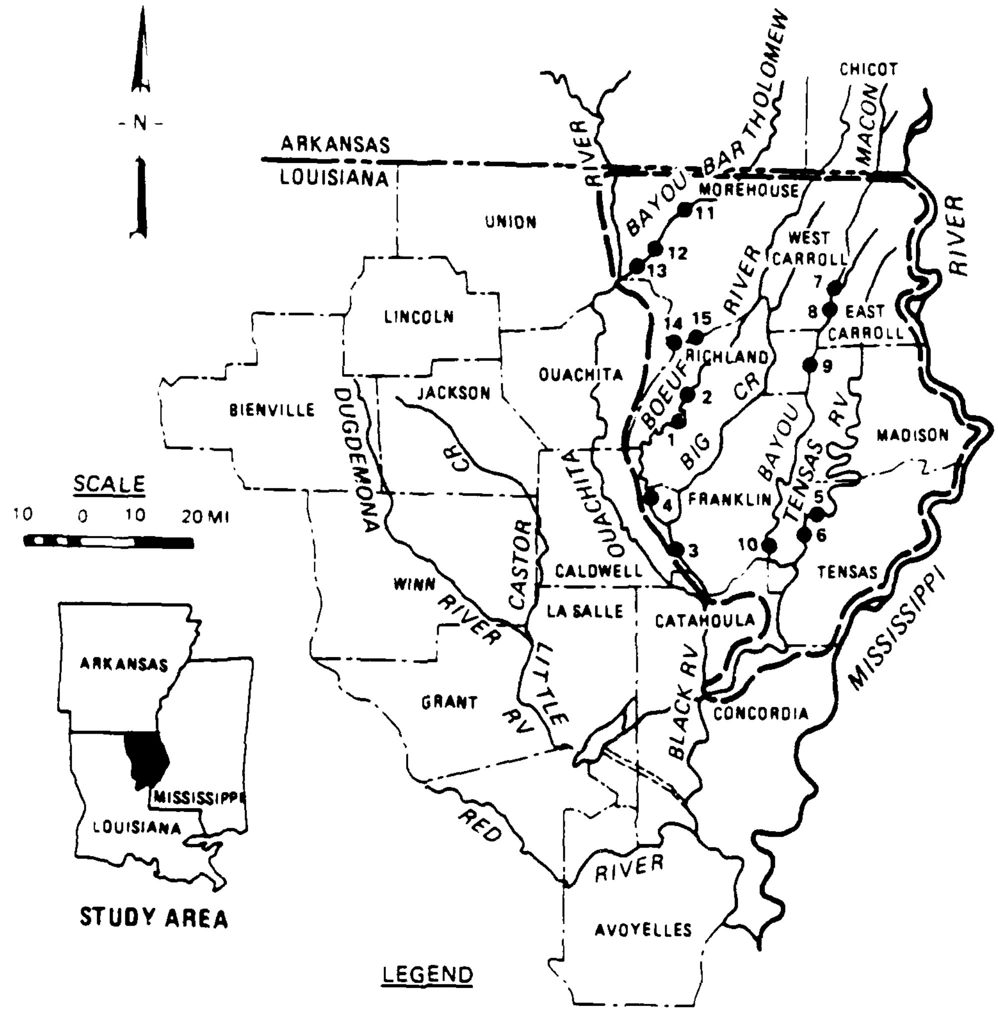
* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.



LEGEND

1 BOEUF RIVER 1 MILE ABOVE HWY 15 NEAR ALTO
2 BOEUF RIVER 5 MILES ABOVE HWY 15 NEAR ALTO
3 JOE'S BAYOU ON THE BOEUF RIVER NEAR FT. NECESSITY
4 BOEUF RIVER 3 MILES BELOW GUMBY DAM NEAR HEBERT
5 BIG ROARING BAYOU ON THE TENSAS RIVER NEAR NEWLIGHT
6 COVE ON THE TENSAS RIVER BELOW HWY 4 NEAR NEWLIGHT
7 BAYOU MACON 3.5 MILES ABOVE HWY 2 NEAR OAK GROVE (ABOVE RIFFLE)
8 BAYOU MACON 3.5 MILES ABOVE HWY 2 NEAR OAK GROVE (RIFFLE)
9 BAYOU MACON 5 MILES ABOVE HWY 80 NEAR DELHI
10 BAYOU MACON 1 MILE ABOVE HWY 562 NEAR WISNER
11 BAYOU BARTHOLOMEW 1 MILE BELOW HWY 139 NEAR BASTROP
12 BAYOU BARTHOLOMEW 7 MILES ABOVE CONFLUENCE WITH OUACHITA RIVER
13 BAYOU BARTHOLOMEW 2 MILES ABOVE CONFLUENCE WITH OUACHITA RIVER
14 BAYOU LAFOURCHE IMMEDIATELY ABOVE LAFOURCHE DAM NEAR CREW LAKE
15 BAYOU LAFOURCHE 1 MILE ABOVE LAFOURCHE DAM NEAR CREW LAKE

Figure 1. Location of study area and field collection sites

using a metered rod. Water velocity was measured to the nearest 0.1 ft/sec using a Marsh-McBirney Model 201 current meter. If total depth (TD) was less than or equal to 3.0 ft, velocity was measured at 0.6 TD. If TD exceeded 3.0 ft, velocity was measured at both 0.2 and 0.8 TD. Percent cover was determined by dividing the intervals with cover by the total number of intervals across the transect. Water quality parameters were measured with a Martek (Mark XV) water quality analyzer and included temperature, dissolved oxygen, pH, conductivity, and turbidity.

PART III: IMPACT ASSESSMENT OF SURFACE WATER WITHDRAWAL

Data Analysis

14. Based on the fish population and water volume measurements collected at the study sites (Table 2), the mean number of fish (±95-percent confidence interval) per 1-million gal of water was 1,064 ± 291. One site was deleted (Bayou Macon 3.5 miles above Hwy 2 near Oak Grove at riffle RM 132) because the fish abundance value (19,489 fish/1-million gal) was disproportionately high and not considered representative of the study area. Based upon 20 years of fish collecting in the study area, riffle habitat in Bayou Macon is rare and is usually created from silt deposition or logjams. Therefore, use of this value would artificially increase the variability of the mean estimate and would not accurately depict fish-volume relationships for a basin-wide study. However, this site shows the importance of riffle-type habitat on fish abundance and should be considered in a site-specific assessment.

15. The mean estimate was held constant and multiplied by water volumes currently existing in each river under wet to drought conditions and as a result of future water demands. Water volumes were determined from historic stage height data collected at 13 gaging stations (Figure 2) spread throughout northeast Louisiana. Each gaging station represented hydrological conditions at a specific reach of river in the study area. The procedure used to calculate water volumes that exist for wet to drought conditions and associated number of fishes is outlined in Appendix A.

16. Future water demands were developed for all parishes in Louisiana by Henning (1985). However, only the parishes where the five rivers occurred were considered in this study and included Catahoula, East Carroll, Franklin, Madison, Morehouse, Richland, Tensas, and West Carroll. Henning predicted the amount of water required for crop irrigation and aquaculture from May to October over a 40-year period (1990 to 2030) according to four scenarios: 50-percent chance of water need without conservation measures, 50-percent chance of water need with conservation measures, 90-percent chance of water need without conservation measures, and 90-percent chance of water need with conservation measures. For each scenario, a mean water demand was calculated by month from the values of the 5 target years (1990, 2000, 2010, 2020, 2030)

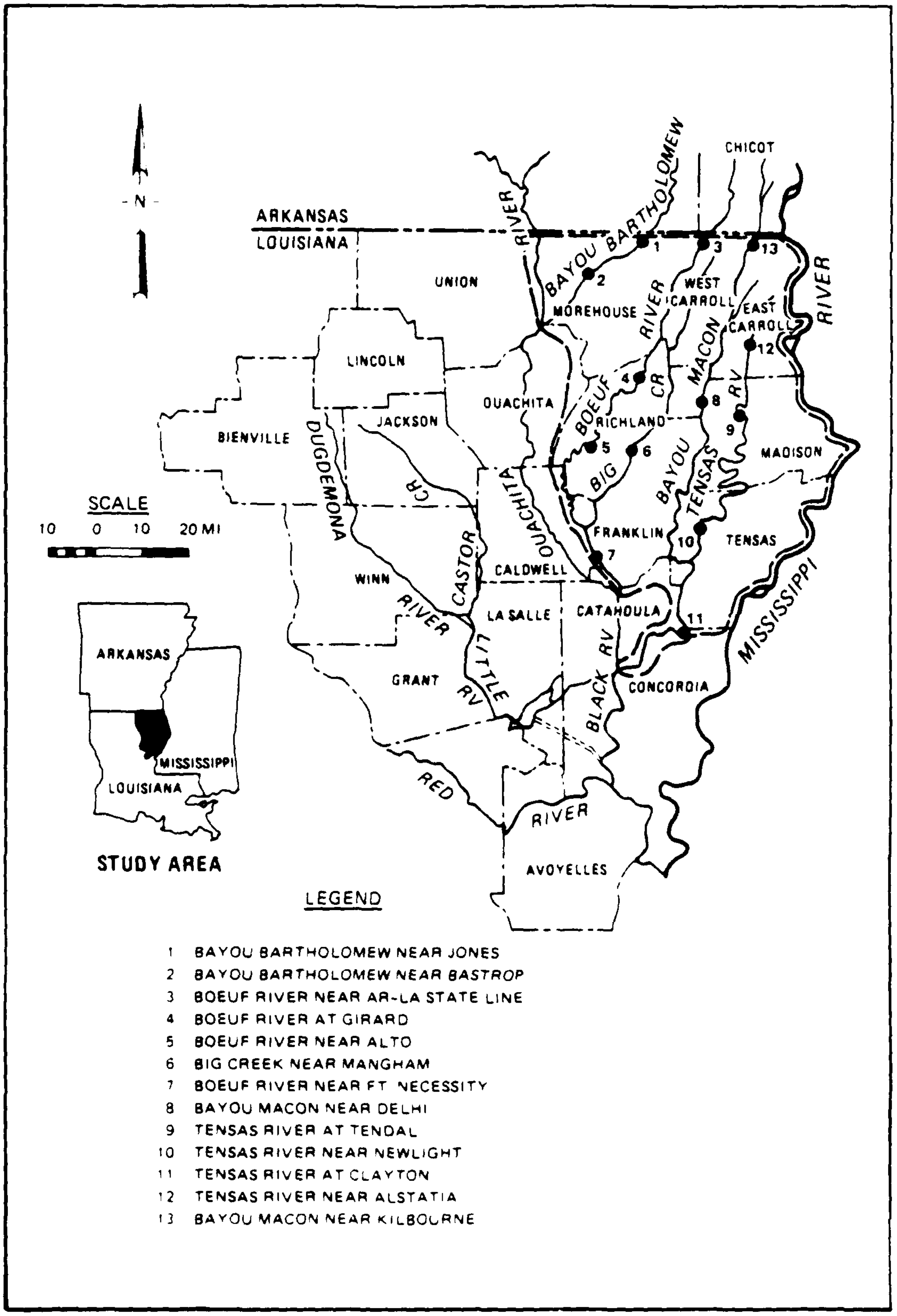


Figure 2. Location of stream gaging stations used to determine historic water levels in the Boeuf River, Tensas River, Bayou Macon, Bayou Bartholomew, and Big Creek

to simplify data presentation. Water demand was expressed as million gallons of water per day (MGD) and was calculated by dividing the number of days in each month into the total monthly water volume. Therefore, this value indicates the amount of water available for withdrawal on a daily basis using constant pumping rates and does not refer to a stream discharge rate.

Description of Future Water Demand Scenarios

17. The four water demand scenarios are described below according to Henning (1985). Scenario 1 (50-percent chance of water need without conservation measures) projected supplemental irrigation water requirements for rice, soybeans, cotton, wheat, corn, grain sorghum, and the necessary amount of water to maintain catfish ponds under conditions of average (50-percent chance of water need) rainfall in northeast Louisiana. Scenario 2 (50-percent chance of water need with conservation measures) estimated water use for average rainfall conditions with conservation employed to irrigation and aquaculture practices. On-farm conservation measures included land leveling, flow measurement devices, recycling of water, and matching irrigation systems to soil and crop conditions. Off-farm conservation measures, although not normally practiced, included lining conveyance canals and laterals, weed control along conveyance channels, and improved scheduling allocation. Scenario 3 (90-percent chance of water need without conservation measures) estimated water use when rainfall was below normal. Below normal rainfall conditions were considered to be a drought situation where historic average rainfall was expected to exceed estimated rainfall 9 years in 10. Scenario 4 (90-percent chance of water need with conservation measures) estimated water use for drought conditions with conservation measures previously described.

Determination of Minimum Water Volume

18. A threshold value (the minimum volume necessary to maintain a viable fishery) was determined for the rivers in each parish using a modification of the Tennant Method (Tennant 1976) and referred to as "minimum volume" (MV). The Tennant Method uses a predetermined percentage of the historic average water discharge (volume in this study) to indicate the quality of fish habitat that ranges from "flushing or maximum" to "severe

degradation." This method was chosen because it is relatively unbiased in that it does not incorporate subjective reasoning into the recommended water volume and it can be developed quickly and inexpensively (Annear and Conder 1984); however, it does not incorporate habitat preferences of fishes or seasonal variability in water levels in the decision-making process.

19. In this study, 40 percent (defined as "good" by Tennant) of the median monthly water volume (50-percent exceedance value) was used to determine the MV. The median monthly water volume was determined by parish according to the procedure in Appendix A. If two or more rivers existed in one parish, their median water volumes were summed, and the MV was calculated from this value. However, the MV can be determined for each individual river in a parish using the data provided in Table 4. Although other studies commonly used 30 percent of the mean annual water volume (Annear and Conder 1984), this value was considered too low, since in most cases it would result in water levels typical of severe drought situations. Tennant (1976) concluded that 30 percent of the mean annual water volume would provide adequate water levels to cover most substrates, provide some instream cover for fishes, allow most side channels to carry some water, and provide adequate water temperatures that would not become limiting to the fishes. Therefore, 40 percent of the median water volume by month is considered a conservative value and incorporates monthly variability in water levels.

20. No single technique is available to objectively define a minimum water volume necessary to maintain a viable fishery in rivers where flow occurs intermittently because of dams and other water restrictions. The Tennant Method was originally applied to salmonid riverine habitat and was based on percentages of mean annual discharge. The use of the median water volume, rather than the mean annual value, provided a reasonable minimum volume based upon local hydrological conditions, but should be used with caution because of its lack of empirical verification. Other "minimum flow" techniques previously used in impact analysis include the wetted perimeter method, the habitat retention method, use of physical habitat simulation models, and subjectively identified inflection points on hydrographs of habitat-discharge relationships (Annear and Conder 1984). However, these methods have been designed for flowing water conditions and are not considered appropriate for rivers in northeast Louisiana.

Fish Abundance and Water Volume Without Water Demands

21. Based upon a review of historic fish collections at the Museum of Zoology at Northeast Louisiana University, a total of 116 species have been identified in the study area (excluding Ouachita and Black Rivers), with 51 common and 65 uncommon species (Appendix B). Bayou Bartholomew has the highest number of species (97), followed by Boeuf River (69), Big Creek (50), Bayou Macon (43), and Tensas River (38) (see Appendix B). In this study, 59 species were collected by electroshocking. Juvenile shad (36.6 percent) was the most abundant species (Table 3), particularly in rivers other than Bayou Bartholomew. Shad have broad niche requirements and are often abundant in sluggish rivers, impoundments, and areas where habitats have been disturbed by water resource development (Carlander 1969, Pflieger 1975, Becker 1983). Minnows, darters, and madtoms were the second most abundant group of fishes (34.6 percent) throughout the study area and were usually the dominant group of fish at Bayou Bartholomew. These species usually have narrow niche requirements, are sensitive to environmental degradation, and dominate the fish assemblage in warmwater rivers that sustain flows year-round (Pflieger 1975, Pennington et al. 1981, Becker 1983, Page 1983). Juvenile sunfishes were the only other group of fishes common in all rivers. Harvestable sport and commercial fishes made up less than 10 percent of the total number of fishes collected.

22. The available water volume (MGD) that currently exists in the study area and associated numbers of fish are shown in Table 4 by river and parish. The water volume is provided for a range of high-water (river stage is exceeded 30 percent of the time) to extreme low-water (river stage is exceeded 90 percent of the time) conditions. In addition, the stage height that corresponds to the volume of water is given for a representative gaging station (Figure 2). Rivers occasionally formed partial boundaries between parishes and were assigned to the parish where the highest number of river miles occurred.

23. The water volume was highest in May at all parishes and steadily decreased throughout the summer months because of lower amounts of rainfall. West Carroll and East Carroll Parishes had the least amount of surface water, whereas Tensas and Franklin Parishes had the highest amount of surface water. Monthly fish abundance values ranged from 6,000,000 (199,700 fish/MGD) in the

lower reaches of Bayou Bartholomew in Morehouse Parish during high-water periods to less than 5,000 (100 fish/MGD)in the headwaters of the Boeuf River in West Carroll Parish during drought conditions. The abundance of harvestable sport and commercial fishes can be determined for a given river reach by multiplying the percentage of a particular group shown in Table 3 by the fish abundance value.

Fish Abundance and Water Volume With Water Demands

24. The effects of surface water withdrawal on fish abundance are presented by parish in Figures 3 through 10 for each of the four scenarios previously described. Each figure indicates water volume (MGD) and associated number of fish with and without demands. In addition, the MV for normal and drought conditions is provided to indicate the amount of water available to partially meet the demands and still provide adequate habitat to maintain the existing fish community structure. If two or more rivers occurred in one parish, their water volume and fish abundance values were summed by month for the "without demand" variable (see Table 4). The "without demand" variable for Scenario 1 (50-percent chance of water need without conservation measures) and Scenario 2 (50-percent chance of water need with conservation measures) reflect the 50-percent exceedance values (median water volume) shown in Table 4, while Scenario 3 (90-percent chance of water need without conservation measures) and Scenario 4 (90-percent chance of water need with conservation measures) reflect the 90-percent exceedance values (drought conditions). A "loss" of fishes referred to in subsequent paragraphs can be caused by fishes leaving the area for an extended period of time, high mortality rates for those fishes stranded because of extremely low-water conditions, or a reduction in recruitment of future year classes because of degraded habitat conditions.

25. Water demands exceeded total water supply for most parishes. Except for Richland, Tensas, and Madison Parishes, a 100-percent loss of fishes would occur in 1 or more months as the result of complete dewatering of the river (Table 5). Fish losses were similar with and without conservation measures. In Richland Parish, where water demands were relatively low, Scenarios 1 and 2 resulted in only a slight decrease in water volume with a maximum fish loss of 2 percent (Figure 3). During drought conditions

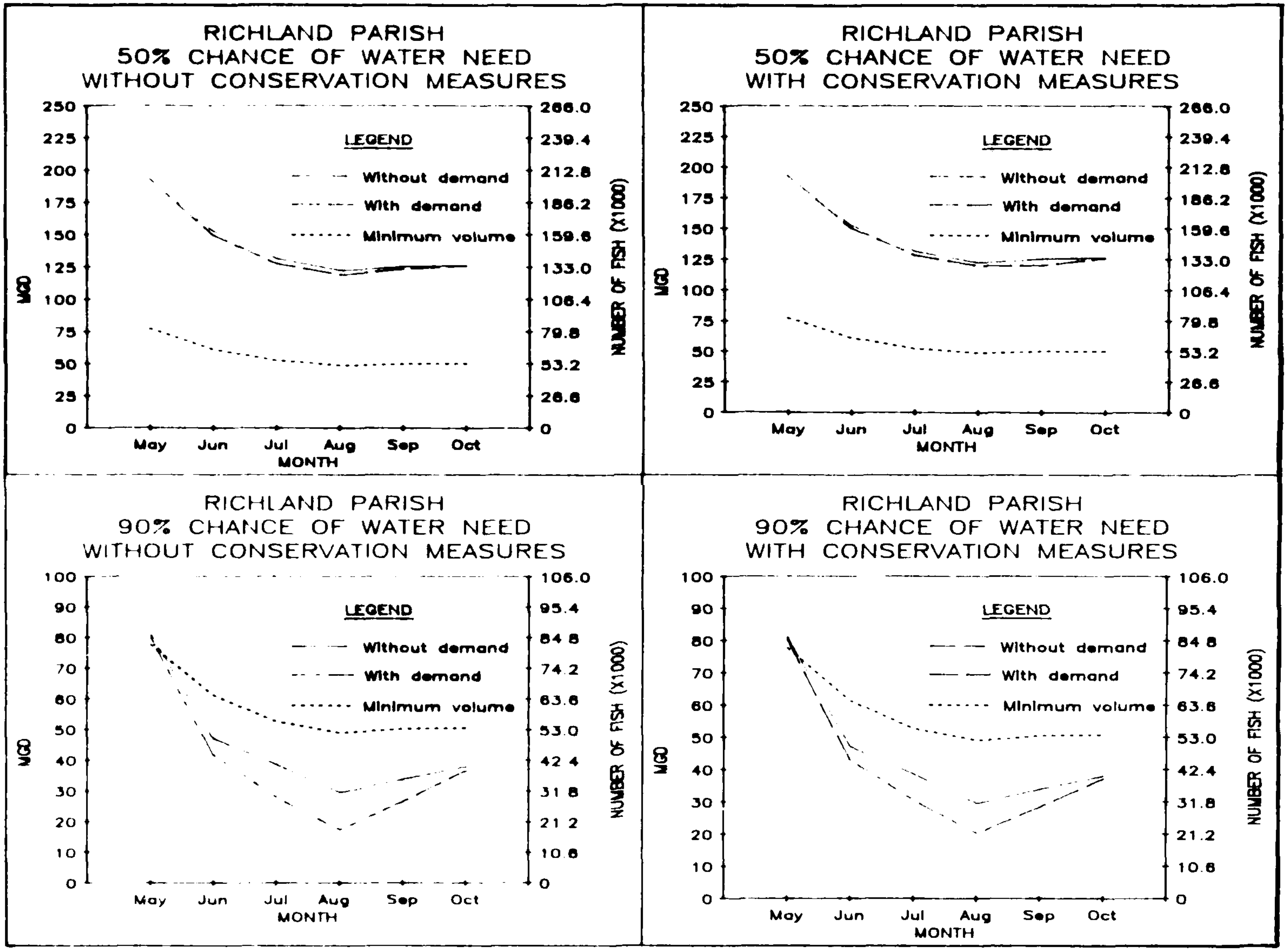


Figure 3. Number of fishes with and without water demands (MGD) and the MV for rivers in Richland Parish

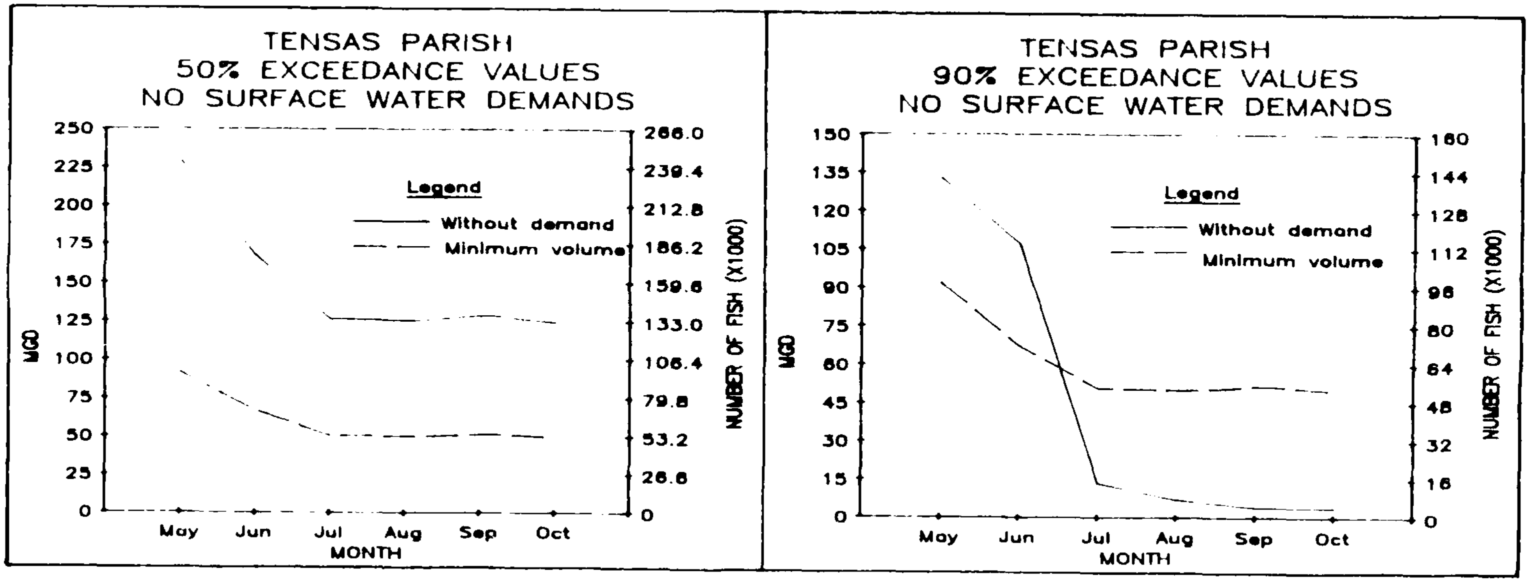


Figure 4. Number of fishes with and without water demands (MGD) and the MV for rivers in Tensas Parish

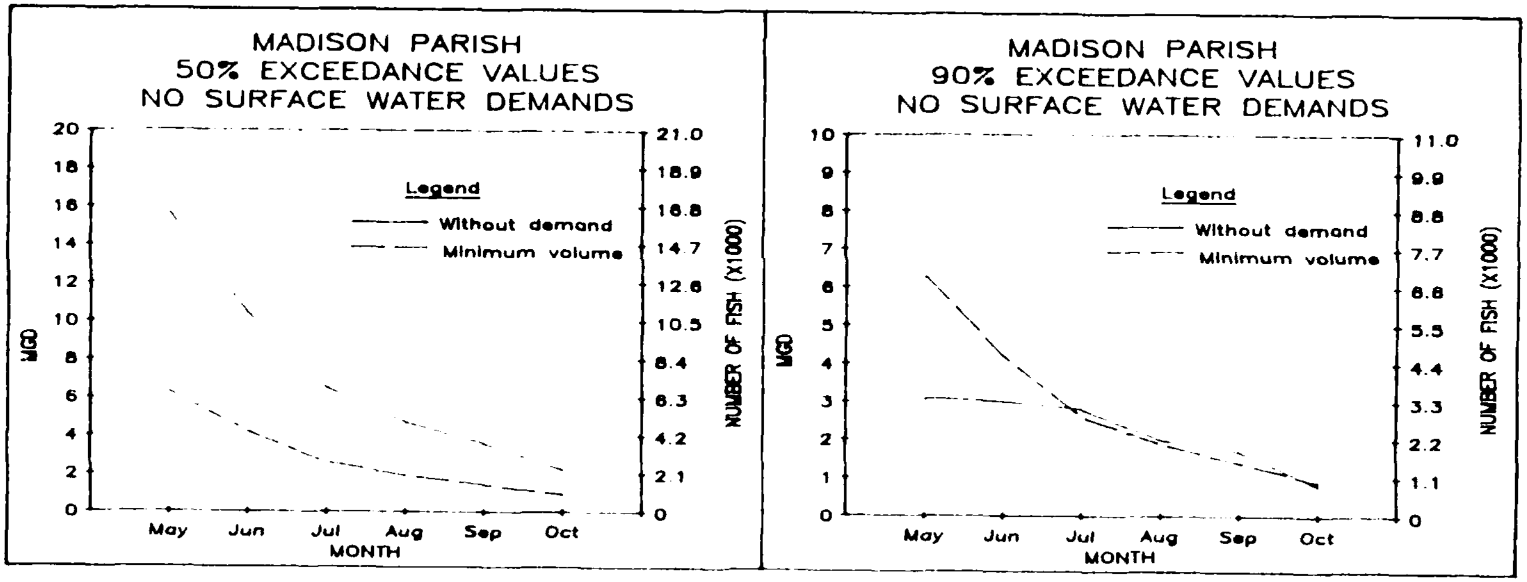


Figure 5. Number of fishes with and without water demands (MGD) and the MV for rivers in Madison Parish

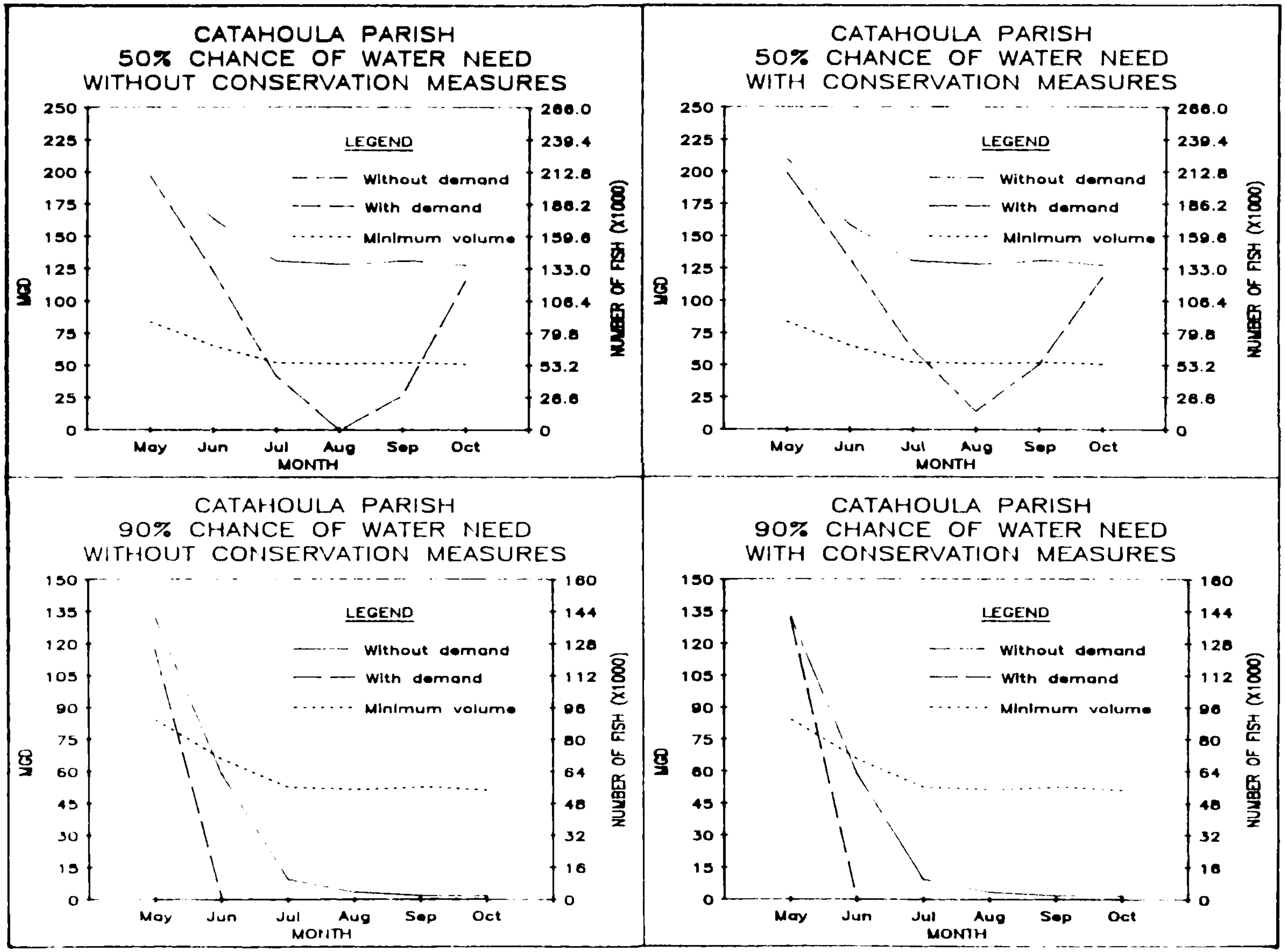


Figure 6. Number of fishes with and without water demands (MGD) and the MV for rivers in Catahoula Parish

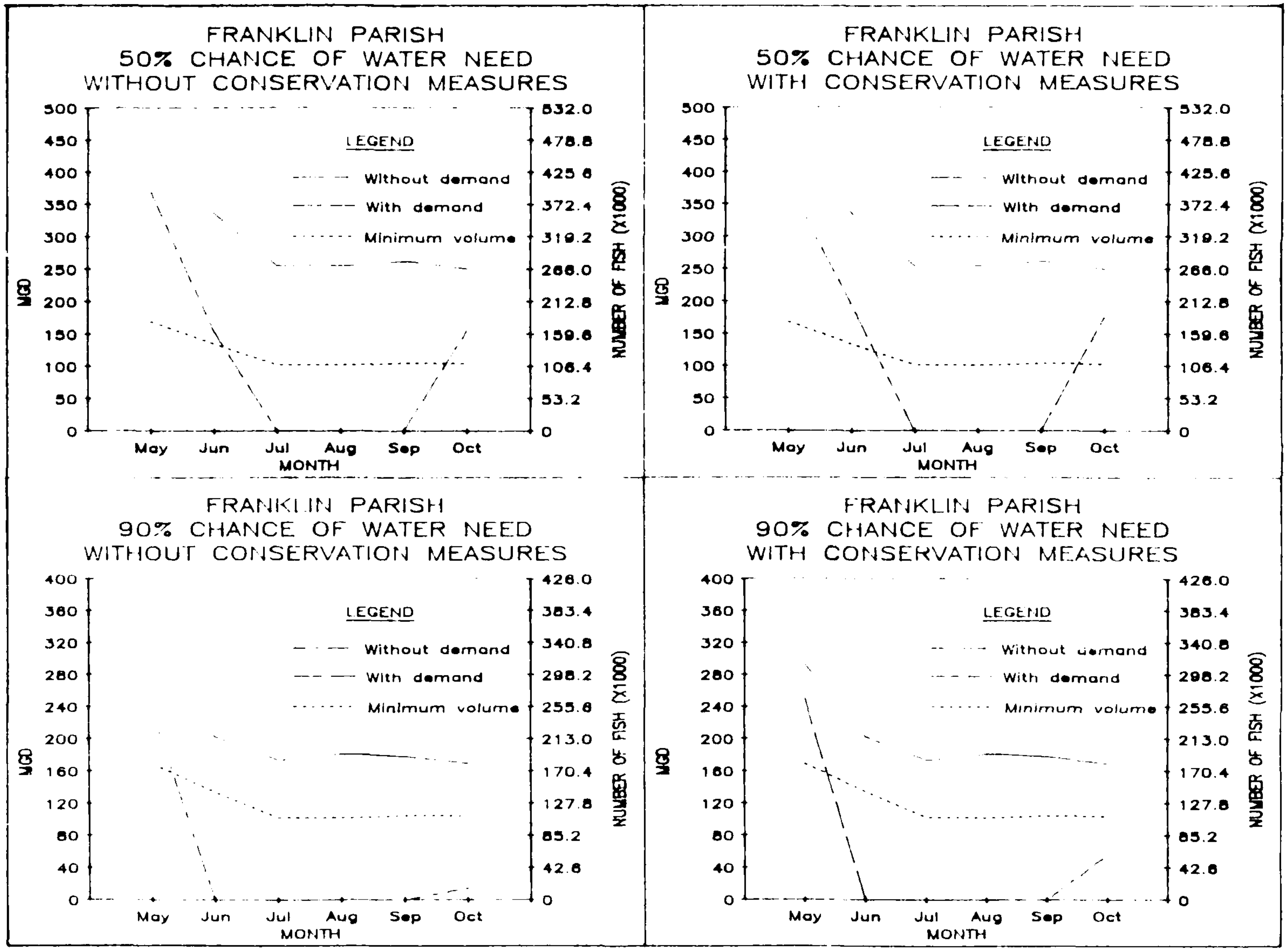


Figure 7. Number of fishes with and without water demands (MGD) and the MV for rivers in Franklin Parish

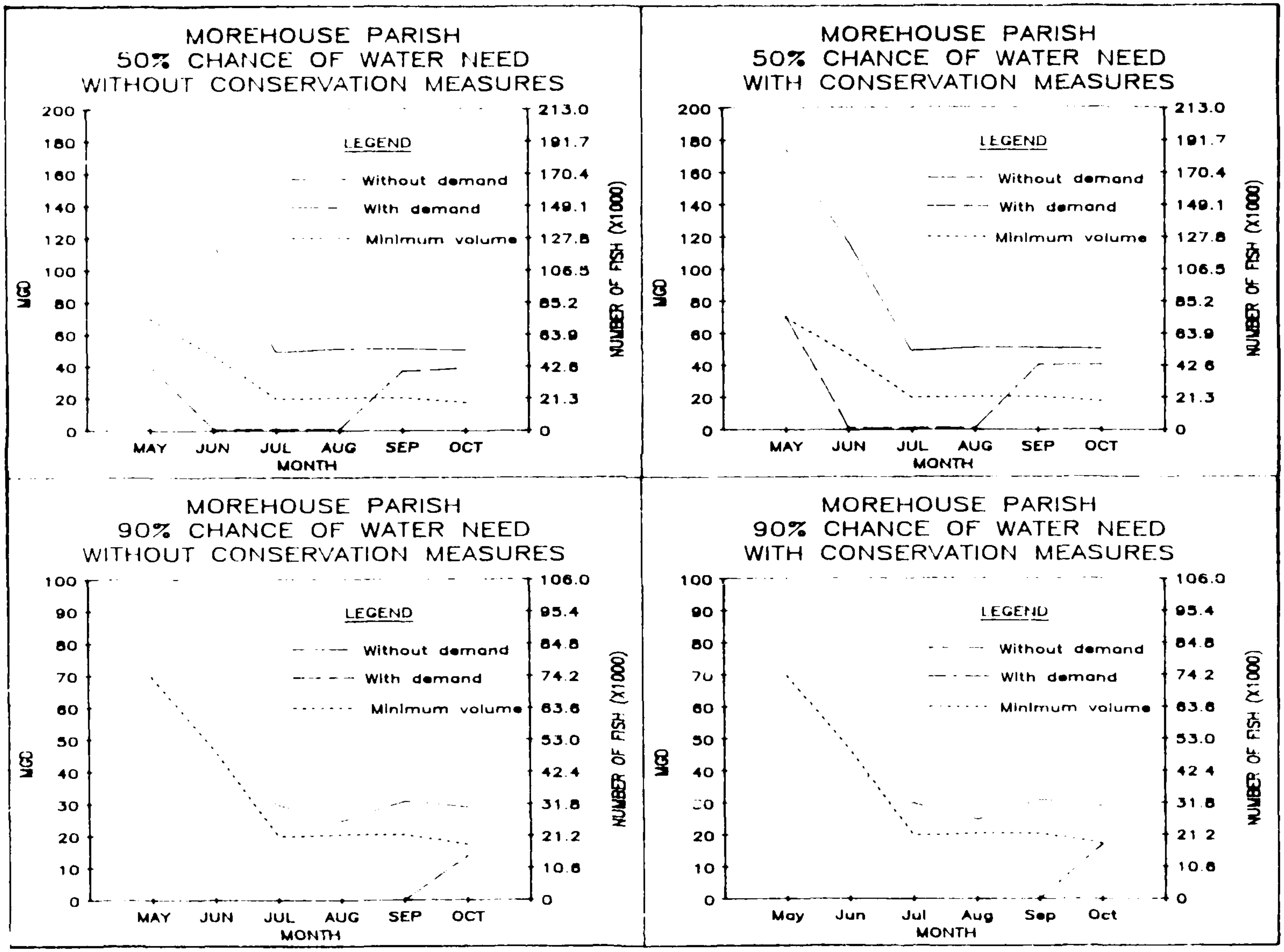


Figure 8. Number of fishes with and without water demands (MGD) and the MV for rivers in Morehouse Parish

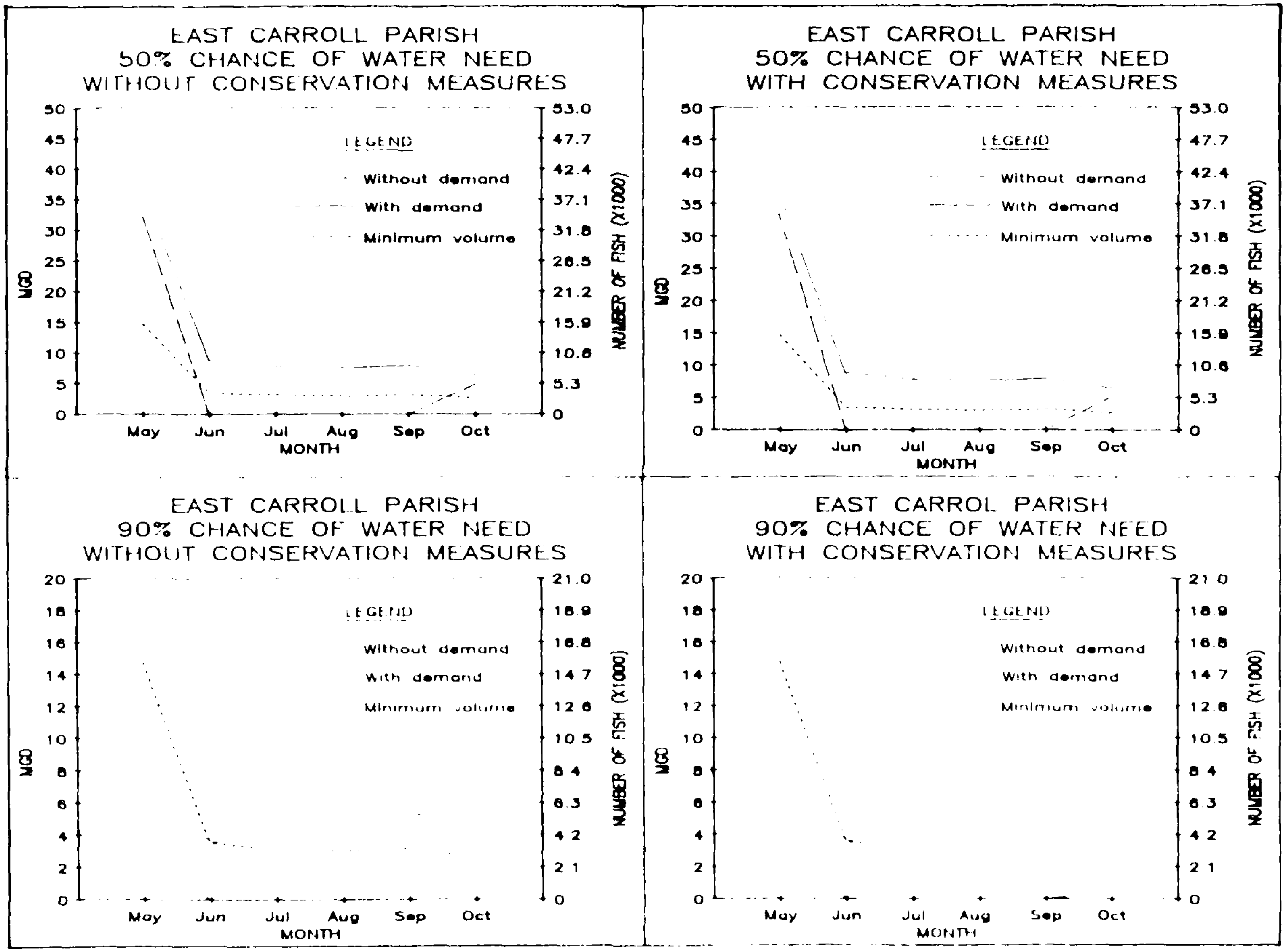


Figure 9. Number of fishes with and without water demands (MGD) and the MV for rivers in East Carroll Parish

has the highest water supply, followed by Tensas, Catahoula, Richland, Morehouse, East Carroll, Madison, and West Carroll Parishes.

30. Juvenile shad would be the primary fish lost because of surface water withdrawal. This species is an important forage fish for sport and predator fishes (Becker 1983) and can form a major part of the diet for at least 17 sport fishes (Miller 1960). Therefore, the cumulative effects of losing high numbers of shad may have significant effects on sport fish production. In addition to a loss of forage fishes, a relatively high number of harvestable sport and commercial fishes will be lost as the result of surface water withdrawal. For example, out of a total of 1-million fishes lost in typical river reaches, 2,000 would be harvestable bass, 3,000 would be harvestable sunfishes, 4,000 would be harvestable crappie, 5,000 would be harvestable catfish, and 17,000 would be harvestable buffalo. Recruitment would also be affected, especially for sunfishes, since 18 percent of the fishes collected were juvenile sunfishes. A high number of minnows, darters, and madtoms (34 percent) would also be lost because of dewatering effects, particularly in Bayou Bartholomew. Although these fishes do not directly contribute to the sport and commercial fishery, they are important forage fishes and ecologically significant. They also indicate a high diversity fish community, and studies have suggested that these types of aquatic systems are more affected by perturbations than those of low diversity (Petts 1984).

31. This study shows that the water demands predicted by Henning (1985) will create major impacts to the fish community structure in northeast Louisiana under the assumptions previously stated. Alternative water supplies will have to be identified in order to meet future water demands, or many of the rivers will be dewatered as a result of surface water withdrawal. The assumptions made in this analysis should be critically reviewed if new data become available. For example, assuming that future ground-water withdrawal will remain at the 1980 rate may be erroneous, but no new information is available to modify these predictions. If new water demand data do become available, the fish abundance estimates can be used to modify the impacts of surface water withdrawal to the fish community. The validity of the fish abundance-water volume relationship can also be tested in any long-term monitoring efforts that may occur in the future under actual water withdrawal conditions.

PART IV: MULTIVARIATE RELATIONSHIPS BETWEEN HABITAT AND FISH ABUNDANCE

32. Fish abundance can be influenced by a variety of habitat variables other than water volume. The interaction of both physical and chemical properties of the aquatic environment can regulate the size and distribution of fish populations. This section provides an analysis of the physical habitat and water quality variables measured in association with fish population estimates to determine which and how many variables are most important in predicting fish abundance; this section also identifies potential limiting factors on fish abundance in the rivers of northeast Louisiana.

Data Analysis

33. The 10 physical and water quality variables measured in the field (Table 2) were separately correlated to the fish population estimates. Variables with correlation coefficients near or greater than 0.30 were entered into a stepwise multiple regression using the maximum R^2 improvement technique (SAS Institute Inc. 1985). A predictive equation was developed to explain the majority of variations in fish abundance according to these physical and water quality variables. The precision of the equation was examined by regressing predicted fish abundance values against actual fish abundance values measured in the field and the examining correlation coefficients (McClendon and Rabeni 1987).

Results and Discussion

34. Of the 10 habitat variables measured in the field, only 5 had correlation coefficients (R) near or greater than 0.30 (Table 7). These included water volume (0.75), conductivity (-0.46), pH (0.46), water depth (0.32), and dissolved oxygen (0.29). However, water volume was the only variable significantly ($P < 0.05$) correlated to fish abundance. Because of the narrow range of pH values (7.0 to 7.8) throughout the study area, this variable was eliminated. Therefore, only water volume, conductivity (Cond), water depth, and dissolved oxygen (DO) were subjected to stepwise multiple regression.

35. Fish abundance was best determined from water volume, conductivity, and dissolved oxygen. The predictive equation is expressed as follows:

$$\text{Number of fish} = 9.946 + 570.461\,(\text{Vol}) + 58.505\,(\text{DO}) - 0.837\,(\text{Cond}) \quad (1)$$

This equation explained 77 percent of the variation in fish abundance ($R^2 = 0.77$) and was significant at $P < 0.01$. Water depth increased the R^2 to only 0.78 and was therefore not used in the predictive equation. Correlation of the predicted and observed fish abundance values shows a relatively high level of precision ($R^2 = 0.88$) and was significant $P < 0.01$). However, the accuracy of the equation can be determined only from an independent data set collected in future years.

36. As water volume decreases, the amount of usable fish habitat is reduced, and inter- and intraspecific competition for food, predator avoidance, and suitable spawning areas becomes more likely. Therefore, water volume should be highly correlated to fish abundance, unless other habitat variables become limiting. The results of this analysis has identified dissolved oxygen and conductivity as two potential limiting factors on fish abundance. Dissolved oxygen is important to the physiological, biochemical, and behavioral processes in fishes (Davis 1975). Low dissolved oxygen usually results in low species richness and abundance of fishes. For example, fish abundance and species richness were relatively low at the Boeuf River 1 mile above Hwy 15 near Alto, where the lowest dissolved oxygen value (4.7 mg/ℓ) was measured during the study (Table 2). Conductivity was important to fish abundance due to the influence of Bayou Bartholomew. The water in Bayou Bartholomew has a lower conductivity than the other four rivers sampled as well as a higher number of fish per unit volume (see Table 2). Therefore, a negative correlation existed between conductivity and fish abundance (Table 7). The degree of land utilization practices and nutrient loading can be indicated by conductivity. Most rivers in agricultural environments, such as northeast Louisiana, are subjected to high rates of sedimentation, usually composed of fine clay materials high in colloidal material or organic matter (Schmidt 1972), causing the water to be highly conductive. Thus, an increase in conductivity may coincide with degrading habitat conditions.

37. The predictive equation presented previously can be used in determining changes in the number of fish resulting from decreasing water volumes

with associated changes in dissolved oxygen and conductivity. However, the difficulty of predicting water quality changes resulting from altered hydrology of the rivers in northeast Louisiana may limit the usefulness of the equation. Furthermore, the predictive equation does not necessarily imply a cause and effect relationship, since fish populations can be regulated by other unmeasured variables such as competition, predation, and extreme climatic conditions.

PART V: INTEGRITY OF THE FISH COMMUNITY STRUCTURE

38. Another approach to impact analysis of water resource projects is to determine changes in the biotic component of aquatic environment. The IBI proposed by Karr (1981) provides a means of evaluating the status of the fish community structure according to biotic variables that can be measured in the field. The IBI can assess the biological integrity of the stream resource and, along with information on physical and chemical conditions, should provide a sound basis for management decisions (Angermeier and Karr 1986). An IBI was developed for rivers in northeast Louisiana to compare the quality of the fish community structure between study sites. In addition, the IBI can be used to monitor impacts of surface water withdrawal, as well as other water resource projects in northeast Louisiana, to the fish community structure if fish population data are collected under future impact conditions.

Description and Development of the IBI

39. The IBI consists of three biotic categories, each composed of different attributes (metrics). The categories include species richness and composition, trophic composition, and health and abundance of fish (Table 8). The value of each metric within the three categories reflects a level of stream degradation. The basic premise is that low habitat quality is associated with relatively low species richness, fewer numbers of total fishes, and a high number of omnivores. Further explanation of each metric is explained in Karr (1981); Fausch, Karr, and Yant (1984); Angermeier and Karr (1986); and Leonard and Orth (1986).

40. The observed value of each metric was determined from the fish population estimates taken at each study site (see Table 3). Several study sites were deleted from this analysis (both sites at Bayou Macon near Oak Grove and both sites on Lake LaFourche) because they were considered too small to accurately represent the fish community structure. Prior to calculating the IBI score, all species were placed into the trophic categories of omnivores, insectivorous cyprinids, and top carnivores according to literature based information (Table 9). The observed metric values were then assigned a score from 1 (worst) to 5 (best) based on their relationship to pristine or relatively undisturbed habitat conditions. After all metric criteria were

set, the individual metric scores were added to obtain a total IBI score that was used to classify the fish community as excellent, fair, or poor (Angermeier and Karr 1986). Input from biologists familiar with the study area is necessary to develop a defensible IBI. Furthermore, an IBI may be specific to a drainage basin because metric values will vary with stream size and zoogeographic region (Karr 1981; Fausch, Karr, and Yant 1984).

41. Modifications of IBI metrics proposed by other researchers were necessary to account for different fish assemblages and habitat conditions that exist in northeast Louisiana. In the category of species richness and composition, high proportions of green sunfish (Karr 1981) or creek chubs (Leonard and Orth 1986) usually indicate degraded habitat conditions. However, in rivers of northeast Louisiana, high numbers of shad are more appropriate indicators of degraded habitat conditions. The presence of intolerant species (Karr 1981) was deleted from this category because their selection was considered a subjective process (Leonard and Orth 1986). Two additional metrics were deleted from the category of fish abundance and health proportion of individuals as hybrids, and proportion of fish with disease or anomalies. Identification of hybrids is difficult, even for an experienced ichthyologist, and fishes with disease or anomalies were not observed during field collections. However, the existence of hybrids and fish with disease or anomalies over 1 percent indicates highly degraded habitat conditions (Karr 1981; Fausch, Karr, and Yant 1984; Leonard and Orth 1986). It should be noted that hybrids in the genus *Lepomis* and *Notropis* have been collected in all rivers in northeast Louisiana over the past 20 years.

Application of the IBI on Rivers in Northeast Louisiana

42. The values of the fish community metrics at Bayou Bartholomew were equal to or higher than the metrics measured at other rivers in northeast Louisiana (Table 10). Species richness, as well as fish abundance, was generally higher at Bayou Bartholomew because of relatively high numbers of minnows, shiners, and darters. Shad were relatively lower in number (less than 36 percent of the total number of fishes) at Bayou Bartholomew than at other rivers and were usually confined to the lower reaches of Bayou Bartholomew near its confluence with the Ouachita River. Conversely, shad were distributed throughout all reaches of the other four rivers, except for

the extreme headwaters. The proportion of individuals as insectivorous cyprinids was highest (indicating high quality habitat) at Bayou Bartholomew, except for Bayou Macon near Delhi, where a high number of insectivorous red shiners were collected. The proportion of individuals as omnivores was higher in rivers of northeast Louisiana, including Bayou Bartholomew, than in rivers where IBI metrics have been developed (Fausch, Karr, and Yant 1984; Angermeier and Karr 1986), primarily because of the high numbers of omnivorous shad collected at each study site. However, this is to be expected because of regional variability in fish assemblages and habitat quality. With few exceptions, the number of sunfish species, the number of sucker species (buffalo were the only suckers collected during this study), and the proportion of individuals as top carnivores were consistent across study sites.

43. Based upon the values of each individual metric across study sites, 20 years of collecting fish in the study area, and considering Bayou Bartholomew as an indicator of relatively pristine habitat conditions, scoring criteria were developed for each metric (Table 8). Total IBI scores ranged from a high of 35 at Bayou Bartholomew near Bastrop to a low of 15 at the Boeuf River 1 mile above Alto (Table 10). The IBI scores for the three sites at Bayou Bartholomew were equal to or greater than the scores determined for the other rivers, indicating the ecological importance of Bayou Bartholomew in northeast Louisiana. In conclusion, river reaches with IBI scores greater than 29 should be considered excellent habitat, whereas IBI scores between 20 and 29 represent fair habitat and scores below 20 represent poor habitat. Excellent fish habitat do occur in isolated areas in northeast Louisiana other than Bayou Bartholomew (e.g., Big Roaring Bayou on the Tensas River, see Table 2), but are usually confined to small tributaries that have not been subjected to severe bank erosion and that have high amounts of instream cover (greater than 30 percent), and to short reaches below water control structures with measurable discharge during the summer and fall months.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

44. The existing water volume and associated number of fishes, as well as the maximum amount of water that can be withdrawn on a monthly basis for each parish while still maintaining a viable fishery, are provided over a range of wet to dry conditions for each river and parish. These data can be used to estimate the effects of any water withdrawal scenario on the fish community structure.

45. Future water demands determined by Henning (1985) will result in the rivers being dewatered for 1 or more months with fish losses ranging from 5,000 to 4,000,000 for the following parishes: Catahoula, East Carroll, Franklin, Morehouse, and West Carroll. Relatively low water demands occur in Richland Parish and have little effect on fish abundance. No surface water demands occur for Tensas and Madison Parishes according to published water usage reports. The assumptions made in this analysis should be critically reviewed if new water demand data become available. However, given the current data base, alternative water supplies should be considered, or substantial effects will occur to the fish community structure as the result of dewatering from surface water withdrawal.

46. Water volume, dissolved oxygen, and conductivity were identified as three important habitat variables that can potentially limit fish abundance in rivers of northeast Louisiana, and when incorporated into a multiple regression equation, provide a relatively high predictive capability to estimate number of fishes. Other physical and chemical habitat variables (water depth, water velocity, discharge, percent cover, water temperature, pH, and turbidity) had no significant influence on fish abundance.

47. A diverse fish community exists in northeast Louisiana with over 100 species of fishes residing in the numerous rivers, streams, and bayous. Bayou Bartholomew has the most diverse and abundant fish community because it has flowing water year-round with scattered amounts of gravel substrate. The dominant group of fishes collected at Bayou Bartholomew consisted of minnows, shiners, darters, and madtoms. In contrast, other major rivers in northeast Louisiana have clay or sand substrate and are usually nonflowing during the summer and early fall because of various types of water restrictions. In addition, the fish assemblage is composed primarily of juvenile shad. An IBI identified Bayou Bartholomew as an ecologically significant area in northeast

Louisiana with excellent habitat conditions, whereas other major rivers in the study area were classified as fair to poor habitat.

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Table 1

Percent Ground Water and Surface Water Used in 1980 To Meet Total Agriculture and Aquaculture Water Use Demands*

Parish	Percent Ground Water	Percent Surface Water
Catahoula	25.1	74.9
East Carroll	92.2	7.9
Franklin	14.1	85.9
Madison	100.0	0.0
Morehouse	41.4	58.9
Richland	98.6	1.4
Tensas	100.0	0.0
West Carroll	72.6	27.4

* Based on Walter (1982).

Table 2

Description of Fish Abundance, Morphometry, and Water Quality for Each Study Site in Northeast Louisiana

Site	Number of Fish ± SE	Number of Fish Species	Million Gallons	Number of Fish per 1 million gallons	Surface Area ft^2	Mean Depth ft	Mean Velocity ft/sec	Discharge cfs	Percent Cover	Temperature °C	Dissolved Oxygen mg/l	pH	Conductivity µmhos/cm	Turbidity NTU
Boeuf River 1 mile above Hwy 15 near Alto (RM 101)	205 ± 8	12	0.6029	340.0	17,050	4.? ± 2.3	0	[illegible]	20	26.?	[illegible]	7.0	248	20
Boeuf River 5 miles above Hwy 15 near Alto (RM 106)	861 ± 38	21	1.2482	689.8	29,250	5.? ± 2.2	0	0	12	21.?	5.0	7.5	185	21
Joe's Bayou on the Boeuf River near Fort Necessity (RM 37)	201 ± 29	15	0.4302	467.2	17,990	3.2 ± 1.5	0	[illegible]	9	[illegible]	8.4	7.3	590	26
Boeuf River 3 miles below Gumby Dam near Hebert (RM 48)	542 ± 81	19	0.6453	839.9	19,620	4.4 ± 1.6	0.51 ± 0.25†	244	[illegible]	[illegible]	8.0	7.4	188	2?
Big Roaring Bayou on the Tensas River 1 mile above Hwy 4 near Newlight (RM 62)	573 ± 35	22	0.4726	1,212.4	18,000	3.6 ± 1.9	0	0	[illegible]	[illegible]	8.?	7.5	365	32
Cove on the Tensas River 4 miles below Hwy 4 near Newlight (RM 57)	579 ± 164	13	0.3487	1,660.4	16,270	2.8 ± 1.6	0	0	[illegible]	28.?	[illegible]	7.8	420	5?
Bayou Macon 3.5 miles above Hwy 2 near Oak Grove above riffle (RM 132)	94 ± 4	7	0.0424	2,217.0	2,604	2.1 ± 0.6	0.4? ± 0.28	41	0	1?.	8.?	-	450	3?
Bayou Macon 3.5 miles above Hwy 2 near Oak Grove at riffle (RM 132)	191 ± 3	4	0.0098	19,489.8*	1,050	1.28 ± 0.7	1.35 ± 0.3?	41	0	19.?	8.0		450	30
Bayou Macon 6 miles above Hwy 80 near Delhi (RM 69)	332 ± 26	13	0.6583	504.3	21,000	4.2 ± 0.9	0.18 ± 0.1?	93	11	28.8	[illegible]	7.3	39?	[illegible]
Bayou Macon 1 mile above Hwy 562 near Wisner (RM 11)	286 ± 15	19	0.6551	416.5	13,650	6.4 ± 1.8	0.14 ± 0.08	96	[illegible]	25.?	[illegible]	?.2	488	[illegible]
Bayou Bartholomew 1 mile below Hwy 139 near Bastrop (RM 38)	481 ± 61	27	0.2249	2,138.?	14,950	2.0 ± 0.6	0.?8 ± 0.?5	63	[illegible]	[illegible]	8.?	?.0	1?0	[illegible]
Bayou Bartholomew 7 miles above confluence with Ouachita River (RM ?)	879 ± 98	22	0.5834	1,?06.?	28,1??	4.8 ± 2.4	0.10 ± 0.10	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
Bayou Bartholomew 2 miles above confluence with Ouachita River (RM ?)	1,0?? ± ?1	[illegible]	[illegible]	[illegible]	182,?00	?.8 ± 1.1	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1?0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
				[illegible]**										

* [illegible] used in calculating mean number of fish per million gallons of water. See text for discussion.

** Mean ± [illegible] percent confidence interval.

† Mean ± standard deviation.

Table 3

Percent Occurrence of Harvestable Fishes for Rivers in Northeast Louisiana

Group	Percent Occurrence	Length Criteria
Harvestable sunfishes	0.3	>127
Harvestable crappie	0.4	>191
Harvestable black bass	0.2	>241
Harvestable bullheads	0.1	>203
Harvestable shad	0.3	>279
Harvestable catfish	0.5	>305
Harvestable gar	0.9	>406
Harvestable buffalo	1.7	>305
Harvestable carp	1.1	>356
Juvenile sunfishes	18.4	≤127
Juvenile shad	36.6	≤279
Juvenile crappie, bass, bullheads, catfish, gar, buffalo, and carp	4.3	-
Minnows, darters, and madtoms	34.6	all sizes
Drum, bowfin, and herrings	0.6	all sizes

Table 4

Summary of Stage Height, MGD, and Number of Fish for Each River and Parish in the Study Area

Parish	River	Representative Gaging Station	Location of River Segment Represented	Month	30 Stage ft	30 MGD	30 No. Fish (×1000)	50 Stage ft	50 MGD	50 No. Fish (×1000)	70 Stage ft	70 MGD	70 No. Fish (×1000)	90 Stage ft	90 MGD	90 No. Fish (×1000)
Morehouse	Bartholomew	Hwy 83 near Jones	21 miles from Ark. La. state line to Hwy 139 near Bastrop	May	16.22	36.5	38.8	12.45	28.5	30.3	7.69	[illegible]	19	[illegible]	10	[illegible]
				Jun	12.81	30.2	32.1	7.74	19.0	[illegible]	3.87	[illegible]	[illegible]	2.15	6.6	[illegible]
				Jul	4.28	11.0	11.7	2.88	8.0	8.5	2.11	[illegible]	6.8	[illegible]	4.8	[illegible]
				Aug	4.48	11.4	12.1	3.06	8.4	8.9	1.58	[illegible]	5.5	1.02	4.0	4.3
				Sep	4.64	12.2	13.0	2.88	8.3	8.8	2.08	[illegible]	6.9	1.42	[illegible]	[illegible]
				Oct	3.51	9.4	10.0	2.41	7.0	[illegible]	1.45	[illegible]	[illegible]	1.34	[illegible]	[illegible]
Morehouse	Bartholomew	Hwy 139 near Bastrop	49 miles from Hwy 139 near Bastrop to the mouth of Bayou Bartholomew	May	-	187.7	199.7	-	146.3	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
				Jun	-	150.3	160.0	-	97.7	[illegible]		[illegible]	[illegible]		34.2	[illegible]
				Jul	-	58.4	62.0	-	41.1	[illegible]		[illegible]	34.8		24.8	26.4
				Aug		58.7	62.4	-	41.1	45.8	-	26.8	[illegible]		20.7	22.0
				Sep	--	62.5	66.5	-	[illegible]	45.2		[illegible]	[illegible]	-	[illegible]	[illegible]
				Oct	--	48.1	51.2	-	36.0	[illegible]		[illegible]	[illegible]	-	24.2	[illegible]
West Carroll	Boeuf	Near Ark. La. state line	61 miles from the Ark. La. state line to the Richland West Carroll Parish line	May	2.70	19.9	21.2	1.80	7.9	[illegible]	1.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jun	1.81	8.3	8.8	1.50	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.2
				Jul	1.63	5.6	5.9	1.43	[illegible]	[illegible]	1.28	[illegible]	[illegible]	[illegible]	0.1	0.1
				Aug	1.58	5.0	5.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	1.56	4.9	5.2	1.41	2.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	1.42	2.8	3.0	1.36	2.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Richland	Boeuf	Hwy 80 at Girard	27 miles from the West Carroll Richland Parish line to Hwy 15 near Alto	May	6.10	8.6	9.1	[illegible]	[illegible]	5.6	[illegible]	[illegible]	[illegible]	3.85	[illegible]	1.6
				Jun	5.13	5.7	6.1	[illegible]	[illegible]	3.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jul	4.68	4.1	4.4	[illegible]	2.9	[illegible]	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Aug	4.51	3.6	3.8	4.22	[illegible]	2.9	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	4.38	3.3	3.5	4.16	2.6	[illegible]	3.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	4.34	3.1	3.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Richland	Boeuf	Hwy 15 near Alto	30 miles from Hwy 15 near Alto to the Richland Franklin Parish line	May	18.3	101.5	108.0	[illegible]	89.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jun	16.8	86.5	92.0	[illegible]	82.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jul	[illegible]	82.5	87.8	[illegible]	82.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Aug	[illegible]	82.5	87.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	16.8	86.5	[illegible]	[illegible]	[illegible]	[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	[illegible]	[illegible]	85.3	16.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Big Creek	Hwy 15 near Mangham	47 miles from the West Carroll Richland Parish line to the mouth of Big Creek	May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.6	[illegible]	[illegible]
				Jun	[illegible]	[illegible]	[illegible]	[illegible]	66	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jul	[illegible]	[illegible]	[illegible]	[illegible]	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Aug	[illegible]	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	[illegible]	[illegible]	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Boeuf	Hwy [illegible] near Fort Necessity	32 miles from the Richland Franklin Parish line to the mouth of Boeuf River	May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jun	[illegible]	[illegible]	188	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jul	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Aug	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	[illegible]	[illegible]	[illegible]	[illegible]

(Continued)

Table 4 (Concluded)

Parish	River	Representative Gaging Station	Location of River Segment Represented	Month	30 Stage ft	30 MGD	30 No. Fish (×1000)	50 Stage ft	50 MGD	50 No. Fish (×1000)	70 Stage ft	70 MGD	70 No. Fish (×1000)	90 Stage ft	90 MGD	90 No. Fish (×1000)
					Percent Time a Given Value Is Equalled or Exceeded											
Franklin	Macon	Hwy 80 near Delhi	88 miles from the East Carroll-Franklin Parish line to the mouth of Bayou Macon	May	9.65	140.9	149.9	8.81	128.9	137.1	8.14	119.3	126.9	7.41	108.9	115.9
				Jun	8.63	130.5	138.8	8.06	122.1	129.9	7.60	115.3	122.7	7.16	108.8	115.8
				Jul	8.16	119.6	127.2	7.68	112.7	119.9	7.39	108.6	115.5	7.03	101.4	110.0
				Aug	7.89	115.7	123.1	7.54	110.7	117.8	7.33	107.7	114.6	7.07	104.0	110.[illegible]
				Sep	8.05	121.9	129.7	7.61	115.4	122.8	7.42	112.6	119.8	7.17	108.9	115.9
				Oct	7.69	112.9	120.1	7.49	110.0	117.0	7.33	107.[illegible]	114.6	7.15	105.[illegible]	119.[illegible]
Madison	Tensas	Hwy 80 at Tendal	71 miles from the East Carroll-Madison Parish line to the Madison-Tensas Parish line	May	10.14	28.4	30.2	7.83	15.7	16.7	6.29	7.2	7.7	5.53	3.1	3.3
				Jun	8.22	18.5	19.7	6.80	10.4	11.1	6.05	6.1	6.5	5.51	3.0	3.2
				Jul	6.89	10.5	11.2	6.16	6.5	6.9	5.81	4.6	4.9	5.49	2.8	3.0
				Aug	6.18	6.6	7.0	5.82	4.7	5.0	5.62	3.6	3.8	5.35	2.1	2.2
				Sep	5.75	4.4	4.7	5.60	3.6	3.8	5.45	2.7	2.9	5.27	1.6	1.[illegible]
				Oct	5.56	3.2	3.4	5.37	2.2	2.3	5.34	1.5	1.6	5.12	0.8	0.8
Tensas	Tensas	Hwy 4 near Newlight	47 miles from the Madison-Tensas Parish line to the Tensas-Catahoula Parish line	May	46.8	263.4	280.1	43.7	229.7	244.4	38.[illegible]	171.2	184.3	34.8	133.0	141.[illegible]
				Jun	44.8	249.7	265.7	37.5	167.7	178.4	35.3	143.0	152.1	32.1	107.0	113.8
				Jul	35.1	136.2	144.9	34.2	126.4	134.5	29.8	78.6	83.6	23.8	13.4	14.[illegible]
				Aug	34.3	127.5	135.7	34.1	125.3	133.3	25.3	29.7	31.6	23.2	6.8	7.[illegible]
				Sep	34.2	130.6	139.0	34.1	129.5	137.8	23.6	22.6	[illegible]	22.9	3.7	3.9
				Oct	34.3	127.5	135.7	34.0	124.2	132.1	25.1	27.5	29.3	22.9	3.6	3.8
Catahoula	Tensas	Hwy 15 at Clayton	29 miles from the Tensas-Catahoula Parish line to the mouth of the Tensas River	May	46.6	238.8	254.1	43.3	210.7	224.2	37.4	160.5	170.8	34.1	132.4	140.[illegible]
				Jun	44.7	230.0	244.7	37.2	164.1	174.6	34.4	139.5	148.4	25.2	58.6	62.3
				Jul	34.7	137.5	146.3	33.9	130.7	139.1	33.6	128.2	136.4	19.6	9.1	9.[illegible]
				Aug	33.7	129.0	137.3	33.6	128.2	136.4	23.8	44.8	47.7	18.9	1.1	[illegible]
				Sep	33.6	132.4	140.9	33.5	131.6	140.0	20.4	16.4	17.4	18.[illegible]	1.5	[illegible]
				Oct	33.2	129.0	137.2	33.5	127.3	135.4	21.6	26.1	27.8	18.[illegible]	1.4	[illegible]
East Carroll	Tensas	Parish Road near Alsatia	19 miles from Hwy 155 near Transylvania to the East Carroll-Madison Parish line	May	67.1	3.9	4.1	64.9	2.3	2.4	63.[illegible]	1.3	[illegible]	62.[illegible]	0.8	[illegible]
				Jun	65.3	2.2	2.9	63.9	1.7	1.8	63.[illegible]	1.1	[illegible]	62.[illegible]	0.8	0.8
				Jul	64.0	1.7	1.8	63.3	1.2	1.3	63.[illegible]	1.0	1.1	62.[illegible]	[illegible]	[illegible]
				Aug	65.0	2.4	2.5	63.0	1.0	1.1	62.8	0.8	[illegible]	[illegible]	0.6	[illegible]
				Sep	62.9	0.9	1.0	62.8	0.9	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	62.7	0.7	0.7	62.6	0.7	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
East Carroll	Macon	Hwy 585 near Kilbourne	57 miles from Ark.-La. state line to East Carroll-Franklin Parish line	May	8.00	41.2	46.0	6.50	34.7	36.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jun	2.50	12.5	13.3	1.58	7.1	7.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Jul	1.91	8.7	9.2	1.52	6.5	6.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Aug	1.78	8.0	8.5	1.53	6.6	7.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Sep	[illegible]	9.2	9.8	1.59	7.1	7.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				Oct	1.54	6.6	7.0	1.18	[illegible]	6.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5

Percent Loss of Fishes Resulting from Surface Water Withdrawal According to Scenarios 1-4

Parish	May				June				July				August				September				October			
	Scenario				Scenario				Scenario				Scenario				Scenario				Scenario			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Catahoula	6	1	11	5	22	16	100	100	68	52	100	100	100	99	100	100	80	61	100	100	9	7	100	100
Franklin	13	10	19	14	54	41	100	100	100	100	100	100	100	100	100	100	100	100	100	100	38	30	91	67
Morehouse	[illegible]	[illegible]	100	100	99	99	100	100	99	99	100	100	99	99	100	100	27	20	100	100	21	19	52	41
East Carroll	12	9	61	49	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	23	18	100	88
West Carroll	85	66	91	93	100	100	87	85	100	100	67	62	100	100	67	62	100	100	87	81	100	100	93	91
Richland	1	<1	1	1	2	2	11	9	3	2	27	21	3	2	41	31	1	<1	21	16	<1	<1	3	2

Table 6

Comparison Between Water Demands for Normal* and Dry ** Conditions With (C) and Without (NC) Conservation and the

Maximum Available Water Supply That Can Be Withdrawn and Still Maintain a Viable Fishery

Parish	May Demand MGD C	May Demand MGD NC	May Maximum Availability MGD	June Demand MGD C	June Demand MGD NC	June Maximum Availability MGD	July Demand MGD C	July Demand MGD NC	July Maximum Availability MGD	August Demand MGD C	August Demand MGD NC	August Maximum Availability MGD	September Demand MGD C	September Demand MGD NC	September Maximum Availability MGD	October Demand MGD C	October Demand MGD NC	October Maximum Availability MGD
50% chance of water need																		
Catahoula	10	13	126	31	40	93	68	89	78	114	148	77	81	105	79	9	12	76
Franklin	41	53	254	139	181	202	301	390	153	339	441	153	269	350	158	74	95	146
Morehouse	104	135	105	270	351	70	271	352	29	152	157	31	10	13	30	2	3	26
East Carroll	3	5	22	9	12	5	11	14	5	12	15	5	8	9	5	1	1	4
West Carroll	5	7	5	19	24	2	45	58	2	66	85	2	46	59	2	6	8	12
Richland	1	1	117	2	3	92	3	4	79	3	3	73	1	1	76	<1	<1	76
Madison	0	0	9	0	0	6	0	0	4	0	0	3	0	0	2	0	0	1
Tensas	0	0	137	0	0	101	0	0	76	0	0	75	0	0	78	0	0	4
90% chance of water need																		
Catahoula	12	15	48	89	116	0	216	280	0	458	595	0	358	465	0	16	21	0
Franklin	43	55	124	234	30	68	525	682	71	698	942	80	606	787	[illegible]	113	154	[illegible]
Morehouse	104	135	0	283	367	0	311	404	16.5	191	248	[illegible]	61	78	11	12	15	[illegible]
East Carroll	3	5	0	16	21	<1	33	43	<1	52	[illegible]	2	45	59	[illegible]	5	6	[illegible]
West Carroll	5	7	0	35	46	0	88	115	0	127	165	0	[illegible]	116	0	[illegible]	[illegible]	[illegible]
Richland	1	1	1	4	5	0	8	11	0	9	12	0	6		0	[illegible]	[illegible]	
Madison	0	0	0	0	0	0	0	0	<1	0	0	1	0	0	<1	0	0	
Tensas	0	0	41	0	0	40	0	0	0	0	0	0	0	0	0	0	0	

* Normal = 50-percent chance of water need.
** Dry = 90 percent chance of water need.

Table 7

Correlations Between Numbers of Fish and Habitat Variables for Rivers in Northeast Louisiana

Habitat Variables	Symbol	R	R^2	F	P
Volume of Water, ft^3	X_1	0.75	0.56	14.29	0.003
Conductivity, μmhos/cm	X_2	-0.46	0.21	3.01	0.11
pH	X_3	0.46	0.22	3.04	0.11
Depth, ft	X_4	0.32	0.10	1.29	0.28
Dissolved oxygen, mg/ℓ	X_5	0.29	0.08	1.01	0.34
Percent cover	X_6	0.18	0.03	0.35	0.56
Turbidity, NTU	X_7	-0.12	0.01	0.16	0.70
Velocity, ft/sec	X_8	0.06	<0.01	0.04	0.84
Temperature, °C	X_9	0.02	<0.01	0.01	0.93
Discharge, ft^3/sec	X_{10}	0.02	<0.01	<0.01	0.96

Table 8

Scoring Criteria for Metrics Used in the Index of Biotic Integrity for Rivers in Northeast Louisiana*

Category	Metric	Scoring Criteria 5 (Best)	3 (Fair)	1 (Worst)
Species richness and composition	Total number of fish species	>20	15-20	<15
	Number of darter species	>3	1-3	0
	Number of sunfish species	>7	5-7	<5
	Number of sucker species	>2	1-2	0
	Proportion of individuals as shad	<10%	10-50%	>50%
Trophic composition	Proportion of individuals as omnivores	<50%	50-80%	>80%
	Proportion of individuals as insectivorous cyprinids	<20%	5-20%	<5%
	Proportion of individuals as top carnivores	>6%	3-6%	<3%
Fish abundance	Number of individuals/0.5 acre	>600	300-600	<300

* Modified from Fausch, Karr, and Yant (1984) and Leonard and Orth (1986).

Table 9

Trophic Classification of Fishes Collected in Rivers of Northeast Louisiana from August-October 1986

Species	Omnivores	Insectivorous Cyprinids	Piscivores	Unknown/Other
Chestnut lamprey			X	
Spotted gar			X	
Longnose gar			X	
Shortnose gar			X	
Bowfin			X	
Skipjack herring			X	
Threadfin shad	X			
Gizzard shad	X			
Common carp	X			
Silver chub		X		
Emerald shiner		X		
Bullhead minnow		X		
Redfin shiner		X		
Spotfin shiner		X		
Blacktail shiner	X			
Weed shiner	X			
Bluntnose minnow		X		
Silvery minnow	X			
Ribbon shiner				X
Red shiner	X			
Smallmouth buffalo	X			
Bigmouth buffalo	X			
Black buffalo	X			
Channel catfish	X			
Blue catfish	X			
Flathead catfish			X	
Yellow bullhead	X			
Freckled madtom				X
Freshwater eel			X	
Blackspotted topminnow	X			
Mosquito fish	X			
Brook silverside				X
Spotted bass			X	
Largemouth bass			X	
Green sunfish			X	
Warmouth			X	
Orangespotted sunfish	X			
Bluegill	X			
Dollar sunfish	X			
Longear sunfish	X			
Redear				X
Spotted sunfish	X			

(Continued)

Table 9 (Concluded)

Species	Omnivores	Insectivorous Cyprinids	Piscivores	Unknown/Other
Black crappie			X	
White crappie			X	
River darter				X
Dusky darter				X
Speckled darter				X
Logperch				X
Bluntnose darter				X
Cypress darter				X
Freshwater drum	X			

Table 10

Summary of Species Richness and Composition, Trophic Composition, Fish Abundance, and IBI Scores for Study Sites in Northeast Louisiana

Site	Species Richness and Composition: Total Number of Fish Species	Number of Darter Species	Number of Sunfish Species	Number of Sucker Species	Proportion of Individuals as Shad, %	Trophic Composition: Proportion of Individuals as Omnivores, %	Proportion of Individuals as Insectivorous Cyprinids, %	Proportion of Individuals as Top Carnivores, %	Volume of Site ft^3	IBI Score*
Bayou Bartholomew 1 mile below Hwy 139 near Bastrop (RM-38)	22	5	6	1	1	78	9	5	29,900	35
Bayou Bartholomew 3 miles above confluence with Quachita River (RM 3)	[illegible]	[illegible]	[illegible]	1	[illegible]	59	2?	3?	78,14?	35
Bayou Bartholomew 3 miles above confluence with Quachita River (RM 2)	[illegible]	[illegible]	[illegible]	1	15	22	9	3?	182,400	29
Boeuf River 2 miles above Hwy 15 near Alto (RM 106)	21	0	8	1	31	96	0	1?	166,725	29
Boeuf River 1 mile above Hwy 15 near Alto (RM-101)	1?	0	5	1	83	9?	0	1?	80,476	15
Boeuf River 3 miles below Gumby Dam near Hebert (RM-48)	19	0	6	2	19	67	0	[illegible]	86,328	23
...'s Bayou on the Boeuf River near Fort Necessity (RM-3?)	15	0	[illegible]	1	41	76	0	9	57,568	[illegible]
Big Roaring Bayou on the Tensas River 1 mile above Hwy 4 near Newlight (RM 12)	[illegible]	1	6	2	6?	89	[illegible]	[illegible]	64,800	[illegible]
Tensas River five 4 miles below Hwy 4 near Newlight (RM-57)	1?	1	4	1	49	8?	[illegible]	1?	46,81?	[illegible]
Bayou Macon 6 miles above Hwy 80 near Delhi (RM 69)	13	0	4	0	29	46	35	5	88,20?	23?
Bayou Macon 1 mile above Hwy 56 near Wisner (RM 1)	19	0	5	1	33	55?	9	2	87,36?	2?

* See Table 8 for scores of individual metrics.

APPENDIX A: PROCEDURE TO ESTIMATE HISTORIC WATER LEVELS IN THE STUDY AREA

The purpose of this appendix is to describe the procedure used to determine the volume of surface water (million gallons) in five rivers over a range of high-water to drought conditions by parish.

Step 1. Obtain stage height readings of historic water levels conditions for each river. Stage duration tables were obtained for 13 stream gaging locations in northeast Louisiana (see Figure 2 in main text). Stage duration tables are cumulative frequency distributions of daily or monthly river stage heights measured over a 10- to 20-year period of record by the US Army Engineer District (VXD), Vicksburg, or the US Geological Survey (USGS) and are expressed as percent exceedance values. The 90-percent exceedance value indicates extreme dry conditions when stream levels are lowest, whereas the 10-percent exceedance value coincides with relatively high-water levels, usually resulting from an above normal amount of rainfall. Gage locations were chosen to represent morphological and hydrological conditions of specific reaches of the Boeuf River, Tensas River, Bayou Macon, Big Creek, and Bayou Bartholomew. Table 4 (see main text) shows the stage duration values for each river reach in the study area.

Step 2. Develop correlations between river stage and water volume for each gaging station and summarize existing water volume by parish. Each gage location represented a defined reach of a particular river. However, Henning (1985)* presented future water demand scenarios by parish and did not indicate the source of the water. Therefore, to relate existing water volume to future demands, the monthly volume of water that occurred at each representative gage location during wet to dry water conditions (30- to 90-percent exceedance values) was extrapolated to the entire length of one or more rivers lying in each parish and was expressed as million gallons of water per day (MGD). This was accomplished by first obtaining stream width and depth measurements collected at various stage heights by USGS and VXD survey crews and converting them into regression equations to predict stream width and average depth at stage heights representing the 30- to 90-percent exceedance values. The number

* See References at the end of main text.

of river miles in each parish was then determined from USGS 1:24,000 topographic maps using a cartometer. For each stage height, water volume (million gallons) was calculated by multiplying surface area (stream width × stream length) by the appropriate water depth and dividing by 1 million. This value was then divided by the number of days that occurred in each month to obtain MGD. If more than one river existed in a parish, the sum of their water volumes were taken to represent total water volume by parish. The mean fish abundance value (number of fishes per 1-million gal of water) determined from the field-measured population estimates was multiplied by the volume of water for wet to dry water conditions (see Table 4). As discussed in the main text, this procedure assumed that water removed from a specific reach of the river will not be replaced from other upstream or downstream sources because of the numerous dams and other water restrictions that exist throughout the study area and that changes in fish abundance can be explained from an existing relationship between numbers of fish and water volume. Although there will certainly be exceptions, it was concluded that these assumptions will hold true for the majority of river reaches in northeast Louisiana.

Step 3. Synthesize stage heights for ungaged stream reaches. The lower reach of Bayou Bartholomew did not have an established gaging station, and the water levels were substantially different from those of upstream locations where gaging stations were located. Therefore, historic water levels had to be synthesized using field-measured discharges at the lower reaches of Bayou Bartholomew and correlated to the upstream gaging location at Jones. A transect was established across several downstream locations (Hwy 139 and near the mouth), and discharge was measured. The stage-discharge readings measured by VXD were obtained for the gage near Jones on the same day the discharge was measured at the downstream locations. The percent change in discharge was determined between the downstream segments and the gage at Jones. It was assumed that discharge was steady from the gage at Jones to the lower reaches of Bayou Bartholomew. The water volume (MGD) that occurred at Jones over the range of historic stage heights was increased by this percentage to represent the water volume at downstream reaches of Bayou Bartholomew.

APPENDIX B: LISTS OF FISH SPECIES THAT OCCUR IN FIVE RIVERS IN NORTHEAST LOUISIANA

Table B1

Distributional Status of Fish Species Throughout the Study Area

Common Species	Uncommon Species	
Spotted gar	Southern brook lamprey	Goldstripe darter
Longnose gar	Chestnut lamprey	Speckled darter
Shortnose gar	Shovelnose sturgeon	Redfin darter
Bowfin	Paddlefish	Logperch
Gizzard shad	Alligator gar	Channel darter
Threadfin shad	Skipjack herring	Blackside darter
Grass pickerel	Goldeye	Saddleback darter
Chain pickerel	Mooneye	Dusky darter
Carp	Stoneroller	River darter
Silvery minnow	Goldfish	Stargazing darter
Golden shiner	Grass carp	Sauger
Emerald shiner	Cypress minnow	Walleye
Ghost shiner	Speckled chub	Striped mullet
Pugnose minnow	Silver chub	Inland silverside
Weed shiner	Silver carp	
Redfin shiner	Pallid shiner	
Blacktail shiner	Bigeye shiner	
Mimic shiner	Ironcolor shiner	
Bullhead minnow	Southern striped shiner	
Lake chubsucker	Ribbon shiner	
Smallmouth buffalo	Bluehead shiner	
Bigmouth buffalo	Longnose shiner	
Spotted sucker	Red shiner	
Black bullhead	Taillight shiner	
Yellow bullhead	Sabine shiner	
Channel catfish	Silverband shiner	
Flathead catfish	Steelcolor shiner	
Tadpole madtom	Bluntnose shiner	
Golden topminnow	Creek chub	
Blackstripe topminnow	River carpsucker	
Mosquito fish	Quillback	
Pirate perch	Blue sucker	
White bass	Highfin carpsucker	
Flier	Creek chubsucker	
Green sunfish	Golden redhorse	
Warmouth	Blacktail redhorse	
Orangespotted sunfish	Blue catfish	
Bluegill	Brown bullhead	
Dollar sunfish	Brindled madtom	
Longear sunfish	Freckled madtom	
Redear	Brown madtom	

(Continued)

Table B1 (Concluded)

Common Species	Uncommon Species
Spotted sunfish	American eel
Bantam sunfish	Yellow bass
Spotted bass	Crystal darter
Largemouth bass	Western sand darter
White crappie	Scaly sand darter
Black crappie	Mud darter
Bluntnose darter	Creole darter
Cypress darter	Swamp darter
Drum	Slough darter
Brook silverside	Harlequin darter

Table B2

List of Fishes of Bayou Bartholomew Drainage*

Name	Scientific Name	Occurrence
Spotted gar	*Lepisosteus oculatus*	common
Longnose gar	*Lepisosteus osseus*	common
Shortnose gar	*Lepisosteus platostomus*	common
Bowfin	*Amia calva*	common
Gizzard shad	*Dorosoma cepedianum*	abundant
Threadfin shad	*Dorosoma petenense*	uncommon
Mooneye	*Hiodon tergisus*	uncommon
Grass pickerel	*Esox americanus vermiculatus*	common
Chain pickerel	*Esox niger*	common
Carp	*Cyprinus carpio*	uncommon
Cypress minnow	*Hybognathus hayi*	common
Silvery minnow	*Hybognathus nuchalis*	common
Speckled chub	*Hybopsis aestivalis*	abundant
Silver chub	*Hybopsis storeriana*	uncommon
Golden shiner	*Notemigonus crysoleucas*	abundant
Pallid shiner	*Notropis amnis*	common
Emerald shiner	*Notropis atherinoides*	abundant
Bigeye shiner	*Notropis boops*	rare
Ghost shiner	*Notropis buchanani*	common
Ironcolored shiner	*Notropis chalybaeus*	common
Southern striped shiner	*Notropis chrysocephalus isolepis*	rare
Pugnose minnow	*Notropis emiliae*	abundant
Ribbon shiner	*Notropis fumeus*	abundant
Bluehead shiner	*Notropis hubbsi*	uncommon
Red shiner	*Notropis lutrensis*	common
Taillight shiner	*Notropis maculatus*	abundant
Weed shiner	*Notropis texanus*	abundant
Redfin shiner	*Notropis umbratilis*	abundant
Blacktail shiner	*Notropis venustus*	abundant
Mimic shiner	*Notropis volucellus*	abundant
Steelcolor shiner	*Notropis whipplei*	rare
Bullhead minnow	*Pimephales vigilax*	abundant
River carpsucker	*Carpiodes carpio*	common
Quillback	*Carpiodes cyprinus*	rare
Highfin carpsucker	*Carpiodes velifer*	rare
Blue sucker	*Cycleptus elongatus*	rare
Creek chubsucker	*Erimyzon oblongus*	abundant
Lake chubsucker	*Erimyzon sucetta*	rare
Smallmouth buffalo	*Ictiobus bubalus*	common
Bigmouth buffalo	*Ictiobus cyprinellus*	common
Black buffalo	*Ictiobus niger*	uncommon

(Continued)

* Species list compiled from an examination of 61,055 specimens taken from 189 collections at 41 locations.

(Sheet 1 of [illegible])

Table B2 (Continued)

Name	Scientific Name	Occurrence
Spotted sucker	*Minytrema melanops*	abundant
Golden redhorse	*Moxostoma erythrurum*	rare
Blacktail redhorse	*Moxostoma poecilurum*	rare
Blue catfish	*Ictalurus furcatus*	common
Black bullhead	*Ictalurus melas*	uncommon
Yellow bullhead	*Ictalurus natalis*	common
Channel catfish	*Ictalurus punctatus*	abundant
Tadpole madtom	*Noturus gyrinus*	common
Freckled madtom	*Noturus nocturnus*	abundant
Flathead catfish	*Pylodictis olivaris*	uncommon
American eel	*Anguilla rostrata*	rare
Golden topminnow	*Fundulus chrysotus*	common
Blackstripe topminnow	*Fundulus notatus*	uncommon
Starhead topminnow	*Fundulus notti*	uncommon
Blackspotted topminnow	*Fundulus olivaceus*	abundant
Mosquito fish	*Gambusia affinis*	abundant
Pirate perch	*Aphredoderus sayanus*	abundant
White bass	*Morone chrysops*	uncommon
Yellow bass	*Morone mississippiensis*	uncommon
Flier	*Centrarchus macropterus*	uncommon
Green sunfish	*Lepomis cyanellus*	common
Warmouth	*Lepomis gulosus*	common
Orangespotted sunfish	*Lepomis humilis*	abundant
Bluegill	*Lepomis macrochirus*	abundant
Dollar sunfish	*Lepomis marginatus*	common
Longear sunfish	*Lepomis megalotis*	common
Redear sunfish	*Lepomis microlophus*	uncommon
Spotted sunfish	*Lepomis punctatus*	common
Bantam sunfish	*Lepomis symmetricus*	common
Spotted bass	*Micropterus punctulatus*	uncommon
Largemouth bass	*Micropterus salmoides*	common
White crappie	*Pomoxis annularis*	uncommon
Black crappie	*Pomoxis nigromaculatus*	common
Banded pigmy sunfish	*Elassoma zonatum*	abundant
Crystal darter	*Ammocrypta asprella*	rare
Western sand darter	*Ammocrypta clara*	rare
Scaly sand darter	*Ammocrypta vivax*	uncommon
Mud darter	*Etheostoma asprigene*	common
Bluntnose darter	*Etheostoma chlorosomum*	abundant
Swamp darter	*Etheostoma fusiforme*	uncommon
Slough darter	*Etheostoma gracile*	common
Harlequin darter	*Etheostoma histrio*	abundant
Goldstripe darter	*Etheostoma parvipinne*	rare
Cypress darter	*Etheostoma proeliare*	common
Speckled darter	*Etheostoma stigmaeum*	uncommon

(Continued)

Sheet [illegible]

Table B2 (Concluded)

Name	Scientific Name	Occurrence
Redfin darter	*Etheostoma whipplei*	common
Logperch	*Percina caprodes*	uncommon
Blackside darter	*Percina maculata*	uncommon
Saddleback darter	*Percina ouachitae*	uncommon
Dusky darter	*Percina sciera*	common
River darter	*Percina shumardi*	common
Stargazing darter	*Percina uranidea*	rare
Freshwater drum	*Aplodinotus grunniens*	common
Brook silverside	*Labidesthes sicculus*	abundant

(Sheet 3 of 3)

Table B3

List of Fishes of the Bayou Macon Drainage*

Name	Scientific Name	Occurrence
Spotted gar	*Lepisosteus oculatus*	uncommon
Shortnose gar	*Lepisosteus platostomus*	common
Gizzard shad	*Dorosoma cepedianum*	abundant
Grass pickerel	*Esox americanus vermiculatus*	common
Carp	*Cyprinus carpio*	common
Silvery minnow	*Hybognathus nuchalis*	uncommon
Speckled chub	*Hybopsis aestivalis*	uncommon
Golden shiner	*Notemigonus crysoleucas*	common
Emerald shiner	*Notropis atherinoides*	uncommon
Ghost shiner	*Notropis buchanani*	common
Red shiner	*Notropis lutrensis*	common
Redfin shiner	*Notropis umbratilis*	common
Blacktail shiner	*Notropis venustus*	common
Mimic shiner	*Notropis volucellus*	uncommon
Bullhead minnow	*Pimephales vigilax*	abundant
Lake chubsucker	*Erimyzon sucetta*	uncommon
Smallmouth buffalo	*Ictiobus bubalus*	common
Bigmouth buffalo	*Ictiobus cyprinellus*	common
Black buffalo	*Ictiobus niger*	uncommon
Yellow bullhead	*Ictalurus natalis*	common
Channel catfish	*Ictalurus punctatus*	common
Tadpole madtom	*Noturus gyrinus*	common
Freckled madtom	*Noturus nocturnus*	rare
American eel	*Anguilla rostrata*	uncommon
Golden topminnow	*Fundulus chrysotus*	uncommon
Starhead topminnow	*Fundulus notti*	uncommon
Blackspotted topminnow	*Fundulus olivaceus*	abundant
Mosquito fish	*Gambusia affinis*	abundant
Pirate perch	*Aphredoderus sayanus*	uncommon
Green sunfish	*Lepomis cyanellus*	common
Warmouth	*Lepomis gulosus*	common
Orangespotted sunfish	*Lepomis humilis*	common
Bluegill	*Lepomis macrochirus*	abundant
Dollar sunfish	*Lepomis marginatus*	abundant
Longear sunfish	*Lepomis megalotis*	abundant
Spotted sunfish	*Lepomis punctatus*	uncommon
Bantam sunfish	*Lepomis symmetricus*	uncommon
Largemouth bass	*Micropterus salmoides*	common
White crappie	*Pomoxis annularis*	common
Black crappie	*Pomoxis nigromaculatus*	common
Banded pigmy sunfish	*Elassoma zonatum*	common
Freshwater drum	*Aplodinotus grunniens*	common
Brook silverside	*Labidesthes sicculus*	common

* Species list compiled from an examination of 2,140 specimens taken from 14 collections at 11 locations.

Table B4

List of Fishes of the Big Creek Drainage*

Name	Scientific Name	Occurrence
Spotted gar	*Lepisosteus oculatus*	common
Longnose gar	*Lepisosteus osseus*	uncommon
Bowfin	*Amia calva*	uncommon
Gizzard shad	*Dorosoma cepedianum*	abundant
Threadfin shad	*Dorosoma petenense*	common
Grass pickerel	*Esox americanus vermiculatus*	common
Chain pickerel	*Esox niger*	uncommon
Carp	*Cyprinus carpio*	common
Silvery minnow	*Hybognathus nuchalis*	common
Speckled chub	*Hybopsis aestivalis*	common
Golden shiner	*Notemigonus crysoleucas*	common
Emerald shiner	*Notropis atherinoides*	common
Ghost shiner	*Notropis buchanani*	common
Pugnose minnow	*Notropis emiliae*	common
Red shiner	*Notropis lutrensis*	abundant
Weed shiner	*Notropis texanus*	uncommon
Redfin shiner	*Notropis umbratilis*	common
Blacktail shiner	*Notropis venustus*	common
Mimic shiner	*Notropis volucellus*	common
Bullhead minnow	*Pimephales vigilax*	common
Lake chubsucker	*Erimyzon sucetta*	uncommon
Smallmouth buffalo	*Ictiobus bubalus*	common
Bigmouth buffalo	*Ictiobus cyprinellus*	common
Yellow bullhead	*Ictalurus natalis*	uncommon
Channel catfish	*Ictalurus punctatus*	common
Tadpole madtom	*Noturus gyrinus*	uncommon
Brown madtom	*Noturus phaeus*	rare
Golden topminnow	*Fundulus chrysotus*	uncommon
Blackspotted topminnow	*Fundulus olivaceus*	common
Mosquito fish	*Gambusia affinis*	abundant
Pirate perch	*Aphredoderus sayanus*	common
Flier	*Centrarchus macropterus*	uncommon
Green sunfish	*Lepomis cyanellus*	common
Warmouth	*Lepomis gulosus*	common
Orangespotted sunfish	*Lepomis humilis*	common
Bluegill	*Lepomis macrochirus*	abundant
Dollar sunfish	*Lepomis marginatus*	common
Longear sunfish	*Lepomis megalotis*	abundant
Redear sunfish	*Lepomis microlophus*	uncommon
Spotted sunfish	*Lepomis punctatus*	uncommon
Bantam sunfish	*Lepomis symmetricus*	uncommon
Largemouth bass	*Micropterus salmoides*	common

(Continued)

* Species list compiled from an examination of 3,069 specimens taken from 29 collections at 18 locations.

Table B4 (Concluded)

Name	Scientific Name	Occurrence
White crappie	*Pomoxis annularis*	common
Black crappie	*Pomoxis nigromaculatus*	uncommon
Banded pigmy sunfish	*Elassoma zonatum*	uncommon
Scaly sand darter	*Ammocrypta vivax*	uncommon
Bluntnose darter	*Etheostoma chlorosomum*	abundant
Cypress darter	*Etheostoma proeliare*	common
Freshwater drum	*Aplodinotus grunniens*	common
Brook silverside	*Labidesthes sicculus*	common

Table B5

List of Fishes of Tensas River Drainage*

Name	Scientific Name	Occurrence
Spotted gar	*Lepisosteus oculatus*	abundant
Shortnose gar	*Lepisosteus platostomus*	common
Gizzard shad	*Dorosoma cepedianum*	abundant
Grass pickerel	*Esox americanus vermiculatus*	common
Chain pickerel	*Esox niger*	common
Carp	*Cyprinus carpio*	common
Silvery minnow	*Hybognathus nuchalis*	common
Golden shiner	*Notemigonus crysoleucas*	common
Emerald shiner	*Notropis atherinoides*	common
Ghost shiner	*Notropis buchanani*	common
Weed shiner	*Notropis texanus*	common
Redfin shiner	*Notropis umbratilis*	common
Blacktail shiner	*Notropis venustus*	abundant
Mimic shiner	*Notropis volucellus*	uncommon
Bullhead minnow	*Pimephales vigilax*	abundant
Lake chubsucker	*Erimyzon sucetta*	common
Smallmouth buffalo	*Ictiobus bubalus*	common
Bigmouth buffalo	*Ictiobus cyprinellus*	common
Yellow bullhead	*Ictalurus natalis*	common
Channel catfish	*Ictalurus punctatus*	common
Tadpole madtom	*Noturus gyrinus*	uncommon
Golden topminnow	*Fundulus chrysotus*	common
Blackstripe topminnow	*Fundulus notatus*	uncommon
Starhead topminnow	*Fundulus notti*	uncommon
Blackspotted topminnow	*Fundulus olivaceus*	common
Mosquito fish	*Gambusia affinis*	abundant
Pirate perch	*Aphredoderus sayanus*	uncommon
Green sunfish	*Lepomis cyanellus*	common
Warmouth	*Lepomis gulosus*	common
Orangespotted sunfish	*Lepomis humilis*	common
Bluegill	*Lepomis macrochirus*	abundant
Spotted sunfish	*Lepomis punctatus*	uncommon
Bantam sunfish	*Lepomis symmetricus*	uncommon
Black crappie	*Pomoxis nigromaculatus*	common
Banded pigmy sunfish	*Elassoma zonatum*	common
Bluntnose darter	*Etheostoma chlorosomum*	common
Cypress darter	*Etheostoma proeliare*	common
Brook silverside	*Labidesthes sicculus*	abundant

* Species list compiled from an examination of 2,179 specimens taken from 23 collections at 16 locations.

Table B6

List of Fishes of the Boeuf River Drainage*

Name	Scientific Name	Occurrence
Spotted gar	*Lepisosteus oculatus*	common
Shortnose gar	*Lepisosteus platostomus*	common
Bowfin	*Amia calva*	common
Gizzard shad	*Dorosoma cepedianum*	uncommon
Threadfin shad	*Dorosoma petenense*	uncommon
Goldeye	*Hiodon alosoides*	uncommon
Grass pickerel	*Esox americanus vermiculatus*	common
Chain pickerel	*Esox niger*	common
Carp	*Cyprinus carpio*	common
Cypress minnow	*Hybognathus hayi*	uncommon
Silvery minnow	*Hybognathus nuchalis*	abundant
Speckled chub	*Hybopsis aestivalis*	uncommon
Golden shiner	*Notemigonus crysoleucas*	abundant
Pallid shiner	*Notropis amnis*	rare
Emerald shiner	*Notropis atherinoides*	abundant
Ghost shiner	*Notropis buchanani*	common
Pugnose minnow	*Notropis emiliae*	common
Ribbon shiner	*Notropis fumeus*	uncommon
Red shiner	*Notropis lutrensis*	abundant
Taillight shiner	*Notropis maculatus*	uncommon
Weed shiner	*Notropis texanus*	common
Redfin shiner	*Notropis umbratilis*	common
Blacktail shiner	*Notropis venustus*	abundant
Mimic shiner	*Notropis volucellus*	common
Bullhead minnow	*Pimephales vigilax*	abundant
Creek chubsucker	*Erimyzon oblongus*	uncommon
Lake chubsucker	*Erimyzon sucetta*	uncommon
Smallmouth buffalo	*Ictiobus bubalus*	common
Bigmouth buffalo	*Ictiobus cyprinellus*	common
Black buffalo	*Ictiobus niger*	uncommon
Blue catfish	*Ictalurus furcatus*	rare
Black bullhead	*Ictalurus melas*	uncommon
Yellow bullhead	*Ictalurus natalis*	common
Brown bullhead	*Ictalurus nebulosus*	rare
Channel catfish	*Ictalurus punctatus*	abundant
Tadpole madtom	*Noturus gyrinus*	uncommon
Freckled madtom	*Noturus nocturnus*	rare
Flathead catfish	*Pylodictis olivaris*	rare
Golden topminnow	*Fundulus chrysotus*	common
Blackstripe topminnow	*Fundulus notatus*	common
Starhead topminnow	*Fundulus notti*	uncommon
Blackspotted topminnow	*Fundulus olivaceus*	common
Mosquito fish	*Gambusia affinis*	abundant

(Continued)

* Species list compiled from an examination of 15,844 specimens taken from 97 collections at 27 locations.

Table B6 (Concluded)

Name	Scientific Name	Occurrence
Pirate perch	*Aphredoderus sayanus*	uncommon
White bass	*Morone chrysops*	uncommon
Yellow bass	*Morone mississippiensis*	uncommon
Flier	*Centrarchus macropterus*	rare
Green sunfish	*Lepomis cyanellus*	common
Warmouth	*Lepomis gulosus*	common
Orangespotted sunfish	*Lepomis humilis*	common
Bluegill	*Lepomis macrochirus*	abundant
Longear sunfish	*Lepomis megalotis*	abundant
Redear sunfish	*Lepomis microlophus*	common
Spotted sunfish	*Lepomis punctatus*	common
Bantam sunfish	*Lepomis symmetricus*	rare
Spotted bass	*Micropterus punctulatus*	common
Largemouth bass	*Micropterus salmoides*	common
White crappie	*Pomoxis annularis*	uncommon
Black crappie	*Pomoxis nigromaculatus*	common
Banded pigmy sunfish	*Elassoma zonatum*	common
Scaly sand darter	*Ammocrypta vivax*	uncommon
Mud darter	*Etheostoma asprigene*	rare
Bluntnose darter	*Etheostoma chlorosomum*	common
Swamp darter	*Etheostoma fusiforme*	uncommon
Slough darter	*Etheostoma gracile*	uncommon
Cypress darter	*Etheostoma proeliare*	uncommon
River darter	*Percina shumardi*	rare
Freshwater drum	*Aplodinotus grunniens*	abundant
Brook silverside	*Labidesthes sicculus*	abundant

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