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Larval Fish Dynamics in a Riverine Wetland of the Lower Mississippi Basin

by Jan Jeffrey Hoover, K. Jack Killgore, Mark A. Konikoff

October 1995 – Final Report

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Final report

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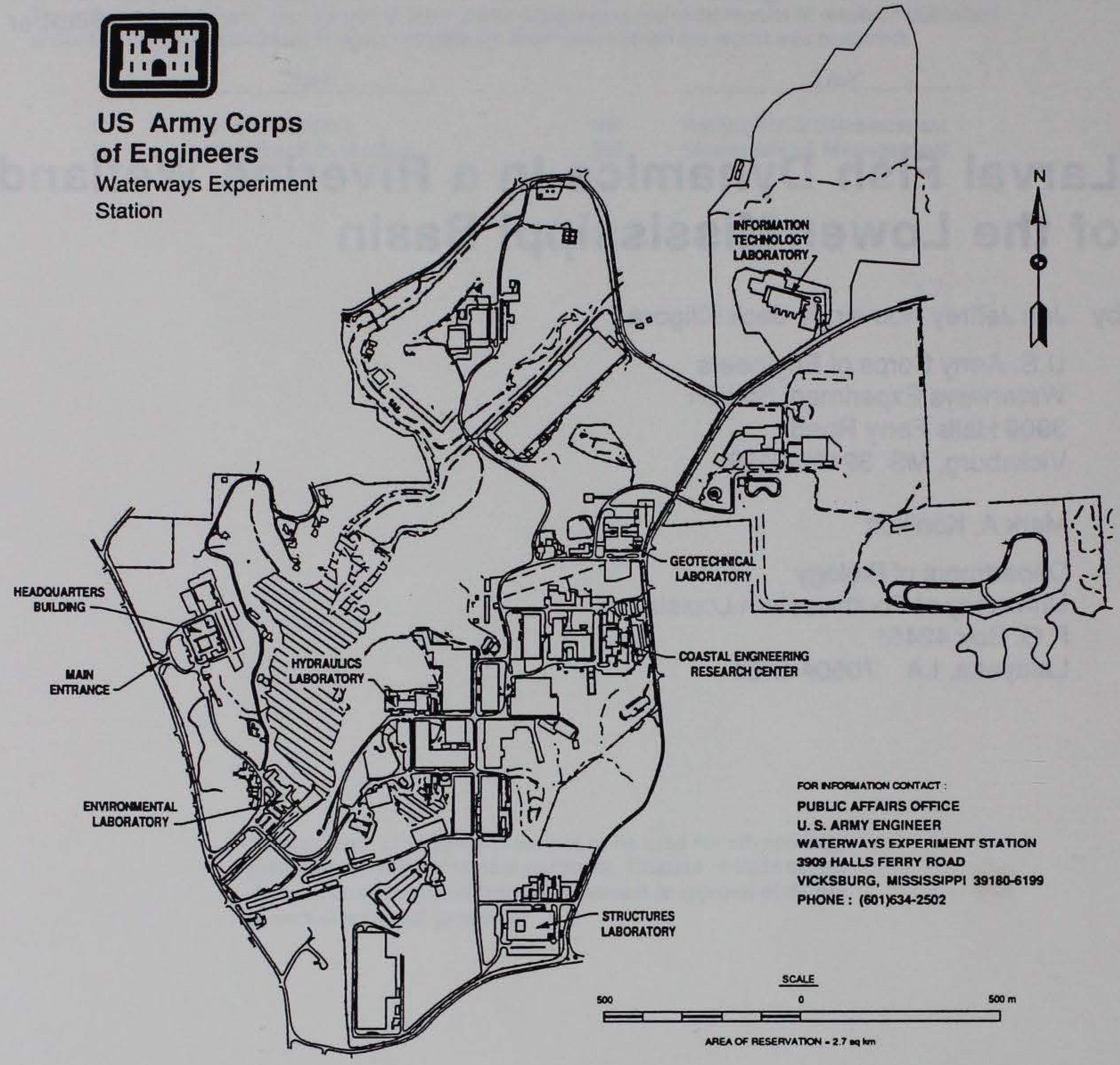

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Wetland Functions

Larval Fish Dynamics in a Riverine Wetland of the Lower Mississippi Basin (TR WRP-SM-10)

ISSUE:

Backwater wetlands are presumed to be important spawning and nursery grounds for riverine fishes, but use by individual taxa and importance of different habitats are rarely quantified in field studies. To effectively enhance wetland fish assemblages, it is neccesary to determine timing of reproduction and the physical parameters correlated with larval fish abundance.

RESEARCH:

Abundance and composition of larval and juvenile fishes were documented for a backwater-stream system in which connections can be regulated by a water control structure. Four locations were sampled semi-monthly, March-July 1992. Fish-habitat relationships were described quantitatively for nine taxa: gizzard shad, threadfin shad, buffalo, minnows, mosquitofish, crappie, sunfishes, black bass, and darters.

SUMMARY:

Collections of larval fishes indicated higher fish biodiversity than previously documented from surveys of juveniles and adults. At least one third of the taxa known spawn in the backwater. Eight fish taxa exhibited pronounced segregation in timing of reproduction, spatial distribution of larvae, and physical characteristics correlated with larval fish abundance. Wetland-riverine connections prior to 1 May and after 1 July will enhance commercial (buffalo) and recreational (black bass) fisheries and assemblage biodiversity (nearctic minnows). Mid-season isolation will prevent influx of undesirable forage (gizzard shad), exotic species (Asian carps), and fishes already abundant in the wetland (bluegill).

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Authors:

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Stewardship and Management Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32766, "Fisheries Management," for which Dr. K. Jack Killgore was Principal Investigator. Mr. Chester Martin was the Task Area Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work.

Mr. Dave Mathis (CERD-C) was the WRP coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitor's Representative. Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the WRP Program Manager.

This report was prepared by Drs. Jan Jeffrey Hoover and K. Jack Killgore, Environmental Laboratory (EL), WES, and Dr. Mark A. Konikoff, University of Southwestern Louisiana, under the general supervision of Dr. Al Cofrancesco, Chief, Aquatic Ecology Branch; Dr. Conrad J. Kirby, Chief, Environmental Resources Division; Dr. Edwin A. Theriot, Assistant Director; and Dr. John W. Keeley, Director, EL.

The study area was suggested by Ms. Maryetta Smith, and hydraulic data were provided by Messrs. C. Fred Pinkard and Frankie Griggs, U.S. Army Engineer District, Vicksburg. Larval fish collections and sample processing were conducted by Messrs. T. B. Shields and R. DuBois, with identification by Mr. R. Wallus. Specimens were deposited in the Museum of Zoology, Northeast Louisiana University, by Dr. Neil H. Douglas, curator.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

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

Multiply	By	To Obtain
feet	0.3048	meters

1 Introduction

Riverine backwaters of the lower Mississippi Basin are physically distinct habitats from river channels (Baker, Killgore, and Kasul 1991). Backwaters are usually nonflowing. Depths are shallower than in channels, which, combined with limited water movement, allow water to warm earlier in the year and attain higher temperatures. Turbidity is low. Total dissolved solids (TDS) and potential productivity are comparatively high. Dissolved oxygen (DO) is more variable than in the channel, but high concentrations may occur at the surface, hypoxia in the hypolimnion. Woody cover (brush, trees) and aquatic plants are more common than in the channel. Consequently, backwaters provide velocity refugia and thermal cues for spawning adults, submersed substrates for egg attachment, and clear water for fishes that feed visually.

These wetlands, invaded by stream fishes during floods, become important spawning grounds and nurseries which influence population and community structure of fishes (Starrett 1951, Johnson 1963, Ross and Baker 1983, Kwak 1988). Approximately 90 percent of fish species in the lower Mississippi Basin exploit backwaters (sloughs, oxbows), and characteristic fish assemblages are observed (Baker, Killgore, and Kasul 1991; Baker and Killgore 1994; Turner et al. 1994). Migrations and spawning behavior of buffalo on overflowed land are conspicuous (Breder and Rosen 1966, Burr and Heidinger 1983, Robison and Buchanan 1988). Shad, mosquitofish, black (largemouth) bass, and (white) crappie are abundant; shiners and darters are variable in abundance depending upon species (Baker, Killgore, and Kasul 1991).

Spawning periods of these fishes are well established (Carlander 1969, Carlander 1977, Robison and Buchanan 1988), but environmental factors influencing reproductive success are not. Annual change in photoperiod is accepted as the primary factor regulating the reproductive season (Hontela and Stacey 1990). Several variables, however, influence the survival of young fishes. Temperature, which regulates metabolism and developmental rates, and wetland morphology, which determines extent of littoral and pelagic habitat, are both correlated with larval fish abundance (Floyd, Hoyt, and Timbrook 1984, Dewey and Jennings 1992, Brown and Coon 1994). Availability of submersed structures is associated with occurrence of larval fishes (Van den Avyle and Petering 1988), dissolved oxygen and turbidity with physiology and survival (Davis 1975, Wilber 1983).

In southern latitudes, spawning of stream fishes is associated with spring rains (Hontela and Stacey 1990), but spawning seasons are protracted (e.g., Floyd, Hoyt, and Timbrook 1984; Turner et al. 1994) with some species exhibiting temporally pulsed reproduction and multiple clutches (e.g., Heins and Dorsett 1986). Consequently, identification of habitat variables important to individual taxa is possible. To do this, the number of young observed in the field is related to concurrent environmental conditions. During the 1992 spawning season, larval fish assemblages were monitored in Grassy Lake, Louisiana, a riverine backwater wetland. Variables correlated with spawning were identified by observing changes in relative abundance of larvae coincident with temporal changes in physical parameters. Spawning chronologies (time and temperature), spatial pattern (distance from shore), and habitat utilization (depth and water quality) were evaluated for eight taxa.

2 Description of Study Site

Grassy Lake (S 7 and 18, T 6 N, R 7 E; Catahoula Parish, LA) is part of a system of oxbows, sloughs, and bayous connected to the Black River (Figure 1). Grassy Lake is shallow (<5 m), elongate (100 by 4,800 m), and seasonally connected to a secondary backwater, Old River Slough. Water exchange, however, is restricted by a narrow berm (44.0 ft[1] as referenced to the National Geodetic Vertical Datum (NGVD)) that bisects the wetland, and by a levee (64.2 ft NGVD) that separates Grassy Lake from the Black River. In 1990, a water control structure was installed at the mouth of Grassy Lake (U.S. Army Corps of Engineers (USACE) 1991). This structure permits interchange of water between Grassy Lake and the Black River, and allows Grassy Lake to function as a riverine backwater. The inlet of the structure consists of a stoplog weir 5.5 m wide capable of raising water elevation from 34.0 ft NGVD to 41.0 ft NGVD. The outlet of the structure is a 1.5-m-wide gated concrete pipe at 32.0 ft NGVD. The structure is operated by Tensas Basin Levee District. Operation is intended to allow interchange of waters between Grassy Lake and Black River "beneficial to the fisheries and water quality of Grassy Lake" (USACE 1991).

Four distinct regions are evident at Grassy Lake: river channel, outlet channel, inlet channel, and remote backwater (Figure 2). At 35 ft NGVD, the channel of the Black River is 300 m wide, with cover consisting of timber and inundated terrestrial vegetation, and substrates of silt, mud, and clay. Water velocities are unknown, but velocities and discharge downstream (Jonesville, LA) on four dates (17 April, 22 May, 15 June, 17 July 92) were 13 to 110 cm/s and 170 to 1,316 m^3/s, respectively (Corps of Engineers, unpublished data). Pool elevation is controlled by Jonesville Lock and Dam and maintained at 34.0 ft NGVD. At the water's surface, the river embayment that serves as the outlet of the control structure is 9 m wide, 45 m long, and 2 m deep. The bottom width of the channel is 3 m, the length is 44 m, and the side slopes are 1 on 3. The submerged cover is sparse, and the bottom consists of sand, mud, and gravel riprap. At 41 ft NGVD, the inlet at south Grassy Lake is 15 m wide and 1 to 3 m deep. The bottom width is 3 m, the length is 27 m, and the slopes are 1 on 3. Cover includes cypress trees,

1 A table of factors for converting non-SI units of measurement to SI units is presented on page vii.

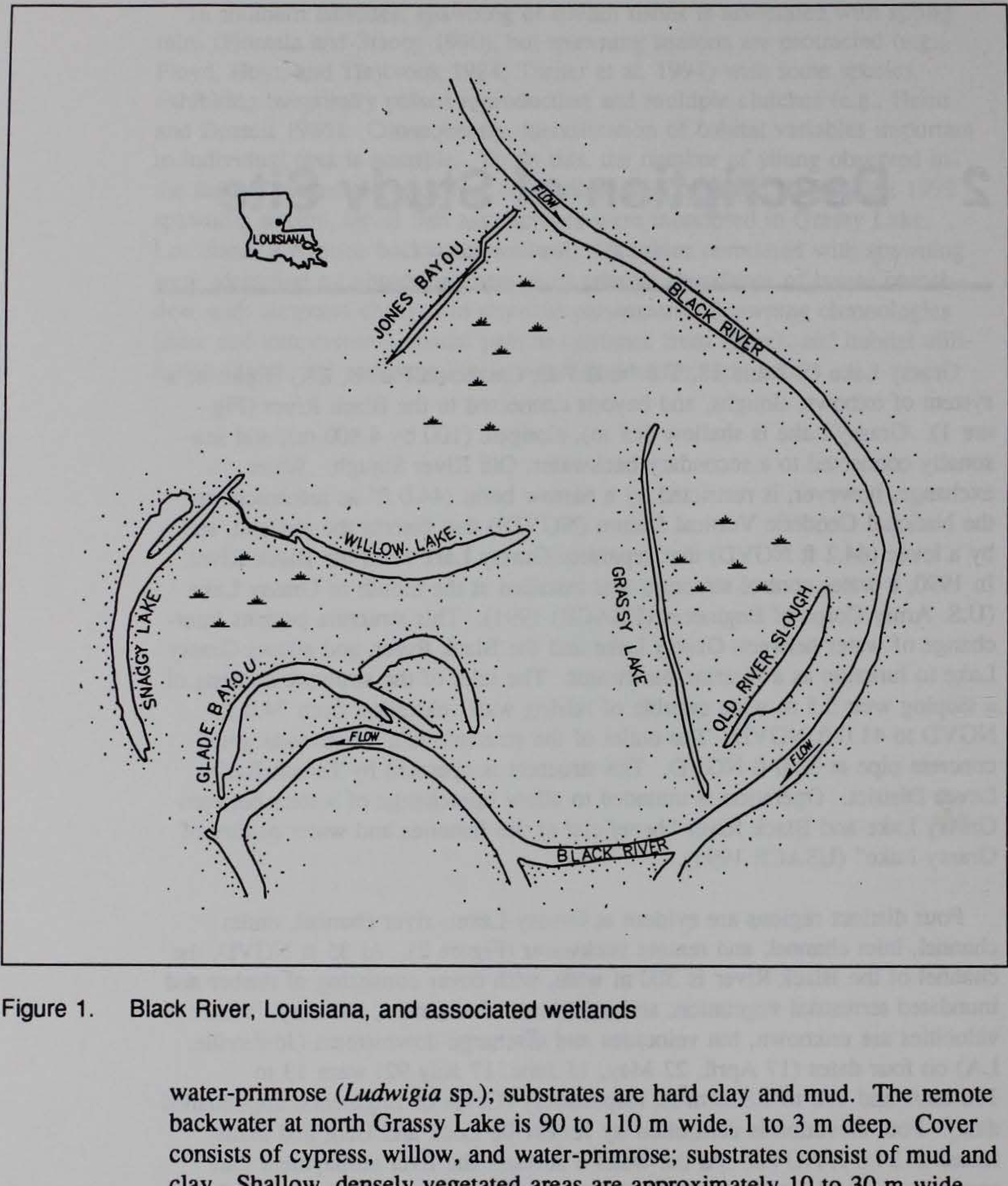

Figure 1. Black River, Louisiana, and associated wetlands

water-primrose (*Ludwigia* sp.); substrates are hard clay and mud. The remote backwater at north Grassy Lake is 90 to 110 m wide, 1 to 3 m deep. Cover consists of cypress, willow, and water-primrose; substrates consist of mud and clay. Shallow, densely vegetated areas are approximately 10 to 30 m wide. From spring through summer 1992, all stoplogs remained in place, and water levels were low (<40 ft NGVD), so Grassy Lake was physically isolated from the Black River.

Thirty-nine species of fish are known as juveniles and adults from the study area (Hoover, Konikoff, and Killgore 1993). These include minnows and sunfishes (12 species each), gars (3 species), silversides, shad, buffalo (2 species each), pickerel, topminnows, mosquitofish, darter, and drum (1 species each). Numerically dominant minnows are bluntnose minnow (*Pimephales*

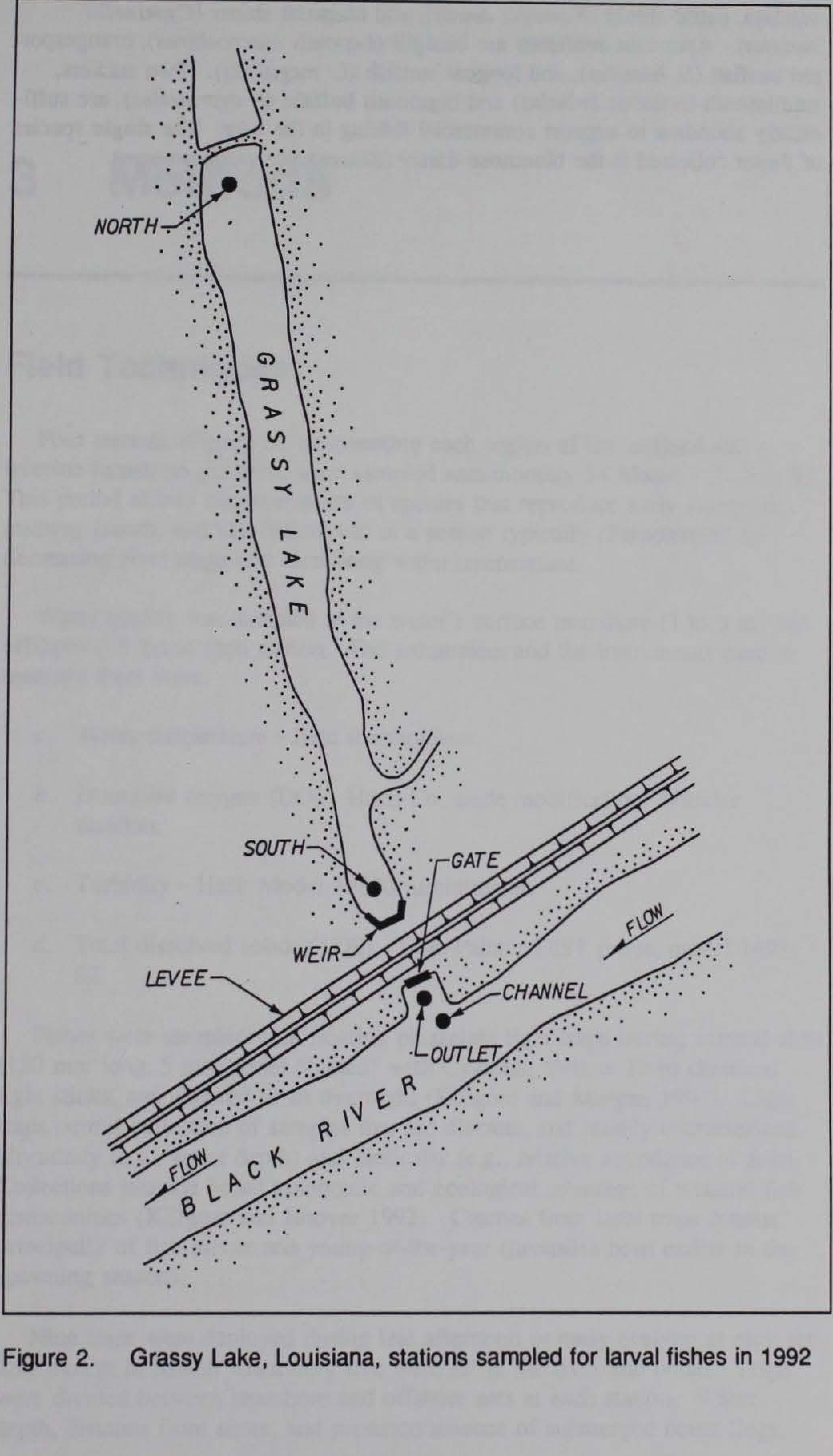

Figure 2. Grassy Lake, Louisiana, stations sampled for larval fishes in 1992

vigilax), pallid shiner (*Notropis amnis*), and blacktail shiner (*Cyprinella venusta*). Abundant sunfishes are bluegill (*Lepomis macrochirus*), orangespotted sunfish (*L. humilus*), and longear sunfish (*L. megalotis*). Two suckers, smallmouth (*Ictiobus bubalus*) and bigmouth buffalo (*I. cyprinellus*), are sufficiently abundant to support commercial fishing in the lake. The single species of darter collected is the bluntnose darter (*Etheostoma chlorosomum*).

3 Methods

Field Techniques

Four stations (Figure 2), representing each region of the wetland and a riverine-lacustrine gradient, were sampled semimonthly 24 March - 23 July 92. This period allows documentation of species that reproduce early (suckers), midway (shad), and late (minnows) in a season typically characterized by decreasing river stage and increasing water temperature.

Water quality was sampled at the water's surface nearshore (1 to 3 m) and offshore (>5 m) at each station. The parameters and the instruments used to measure them were:

a. Water temperature - field thermometer.

b. Dissolved oxygen (DO) - Hach Co. azide modification, Winkler titration.

c. Turbidity - Hach Model 16800 turbidimeter.

d. Total dissolved solids (TDS) - Cole-Palmer DiST probe, model 1491-62.

Fishes were sampled with floating plexiglass light traps having vertical slots (150 mm long, 5 mm wide) "baited" with Cyalume Yellow 12-hr chemical light sticks, and allowed to sit overnight (Killgore and Morgan 1994). Light traps permit collection of samples that are discrete, and readily characterized physically (e.g., water depth) and biotically (e.g., relative abundance of fish). Collections provide broad taxonomic and ecological coverage of wetland fish communities (Killgore and Hoover 1992). Catches from light traps consist principally of fish larvae and young-of-the-year (juveniles born earlier in the spawning season).

Nine traps were deployed during late afternoon or early evening at each station, except in March when only five were set at the river and outlet. Traps were divided between nearshore and offshore sets at each station. Water depth, distance from shore, and presence/absence of submerged cover (logs, macrophytes) were recorded for each trap. Traps were recovered the following morning. Fishes were filtered through plankton netting of 505-µm mesh and preserved in 5-percent formalin. In the laboratory, fishes were identified to the lowest possible taxon and then counted. Six traps were lost during the course of the study so samples totaled 347.

Physical data associated with each trap (water quality, depth, distance, and cover) were used to characterize habitats sampled at the four stations and to describe conditions associated with spawning. Physical data do not represent habitat availability, but they do indicate differences in microhabitats sampled among stations. Correlations between physical parameters and larval fish abundance suggest factors that operate as environmental cues regulating spawning success.

Analytical Techniques

Habitats are described using principal components analysis (PCA) ordinating 40 observations (10 dates by 4 stations) of 10 variables: temperature, DO, turbidity, TDS (means of nearshore and offshore measurements), river stage, percent cover, mean depth, coefficient of variation in depth, mean distance from shore, and coefficient of variation in distance from shore (Hintze 1991). PCA provides data reduction by plotting points (i.e., samples), originally projected in high-dimensional space (i.e., 10 variables), into space of lower dimensions (i.e., 2 components) while preserving as much of the original configuration as possible. An ordination based on the first two principal components is presented (PCI, PCII). Each component has an eigenvalue >2.00 and collectively accounts for 51 percent of the data set variance. Variables associated with components are identified as those with the three highest "loadings" on PCI and two highest loadings on PCII. Guidelines for application and interpretation of PCA vary and are available at different levels of expertise, including technical (Gaugh 1982, Ludwig and Reynolds 1988), semitechnical (Gaugh 1993), and popular (Gould 1981).

Fish abundance was quantified as the number of fish collected per trap-night and assemblages described from cumulative species-abundance data. Similarity between wetland and riverine fish assemblages was expressed using qualitative and quantitative coefficients. Jaccard's index J,

$$J = \frac{C}{A + B - C} \tag{1}$$

in which

C = number of taxa that co-occur in wetland and river

A = number of taxa that occur in wetland

B = number of taxa that occur in river

provides a numerical expression of taxonomic similarity, based on presence-absence of individual taxa.

Values of J range from 0.00 (no taxa in common) to 1.00 (all taxa shared). Schoener's (percent similarity) index S,

$$S = \sum_{i=1}^{n} \min\ [p_i w,\ p_i r] \tag{2}$$

in which

n = total number of taxa occurring in the wetland and river

p_i = proportion of taxon i occurring in wetland (w) and in the river (r)

provides a numerical expression of compositional similarity, based on relative abundance on individual taxa. Values of S range from 0.00 (fewer than 1 percent of individuals in each list belong to co-occurring taxa) to 1.00 (more than 99 percent of all individuals belong to co-occurring taxa). Compared with other binary and abundance-based similarity measures, Jaccard and Schoener indices are responsive, interpretable, and exhibit relatively low influence from sample size and diversity (Linton, Davies, and Wrona 1981; Hubalek 1982, Ludwig and Reynolds 1988).

Abundance of fish larvae vary by several orders of magnitude and are log-transformed: $\log_e$[mean number fish/trap-night + 1]. Transformed larval abundances describe spawning chronologies of four nonperciform and four perciform taxa: threadfin shad, gizzard shad, minnows, buffalo, sunfishes, black basses, crappie, and darters. For comparison, abundance of mosquitofish was used to characterize temporal abundance and movements of a small, obligate surface-dwelling fish. Mosquitofish are livebearers in which newborn individuals, comparable to post yolk-sac larvae of other species, are more advanced possessing scales and a full complement of fins and rays (Wallus et al. 1990).

Log-transformed fish abundance (z-coordinate) was plotted by Julian date (x-coordinate) and by water temperature (y-coordinate) to describe spawning chronology. Modal abundance and coincident water temperatures were used to define peak spawning periods and tentatively separate taxa not morphologically distinguishable as larvae into species. Periods of modal abundance were used to describe shoreline affinities of larvae. Percentage of traps set and percentage of fish caught (y-coordinates) were plotted against trap distance from shore (x-coordinate). Disparities in traps set and fish caught do not truly quantify selectivity for specific distances from shore since they do not represent habitat availability. The data represent gross patterns of inshore-offshore occurrence.

Relationships between individual habitat parameters (independent variables) and transformed abundance of individual taxa (dependent variable) were quantified using linear correlation analyses. Initial analyses were univariate (Pearson product moment correlation coefficients) and included young-of-the-year; these are summarized in Hoover, Konikoff, and Killgore (1993) and were used to screen variables for subsequent analyses. Multivariate fish-habitat relationships are described with multiple regression models of two to four physical variables. The trap distance from shore and water depth were colinear ($r = 0.52$, d.f. = 345, $p < 0.001$) so the distance from shore was excluded to minimize autocorrelation. Depth was retained because it better represented a limited area of attraction presented by a light trap. River stage was excluded from further analysis because it was constant for most of the spawning season and because it could not be used to represent changes in water elevation in the lake.

Data for the sampling period were partitioned by taxa and by station. Variables (depth, cover, temperature, DO, TDS, turbidity) in each partitioned data set were excluded if observed variability was negligible (coefficient of variation <15 percent) and if univariate correlations with the catch were low ($-0.30 < r < 0.30$). Partitioned data sets consisted of three or more station dates, each station date representing more than 5 percent of the total catch for that taxon. This was done to minimize statistical bias of large numbers of zero values (which can artificially generate significant correlations) and would misrepresent fish-habitat relationships by including dates when those taxa do not spawn. Outliers (single samples with extraordinarily high abundance) creating a correlation that otherwise would not exist were identified and excluded from final analyses.

4 Results

Physical Habitat

Riverine and lake habitats were similar early in the spawning season, but water quality diverged after river stage decreased and temperature increased (Figure 3). River stage was highest (39.0 ft NGVD) at the onset of sampling in late March and declined to minimum river stage (34.0 ft NGVD) by mid-April, which persisted for the remainder of the study. Temperature ranged from 15 to 32 °C. Outlet and lake temperatures were typically 2 to 5 °C warmer than the river through April, similar among all stations thereafter. TDS values ranged from 20 to 110 ppm and were consistently higher in the river and outlet than in the lake, with pronounced differences observed in late May and early June. Turbidity ranged from 11 to 69 Nephelometric Turbidity Units (NTU's); differences among stations were slight through mid-May, but from late May through July, turbidity was higher in the outlet and river than in the lake.

DO ranged from 3.5 to 9.5 ppm, but 86 percent of the observations were $\geq$5.0 ppm. The percentage of traps in the cover varied. Approximately 44 percent of Grassy Lake traps and 22 percent of outlet traps were set in or near cover with little temporal variation (CV $\leq$ 10 percent); the mean percentage of traps set in or near cover in the river was also 44 percent, but temporal variation was high (CV = 52 percent). Mean water depths at which the traps were set were comparable among the four stations (62 to 96 cm), but variability at North Grassy Lake (CV = 6 percent) was lower than at the other three stations (CV = 22 to 32 percent). The mean distance from shore at which traps were set was greatest at North Grassy Lake (7.9 m); it then declined longitudinally and was lowest at the river (1.7 m). Temporal variability was high (CV = 20 to 39 percent). The data reflected seasonal and longitudinal declines in the width of the shallow (wading depth) littoral zone among the four stations.

Larval Fish Assemblages

Over 17,000 fishes were collected, dominated by minnows, sunfishes, livebearers, shad, and buffalo (Table 1). Silversides, darters, and topminnows

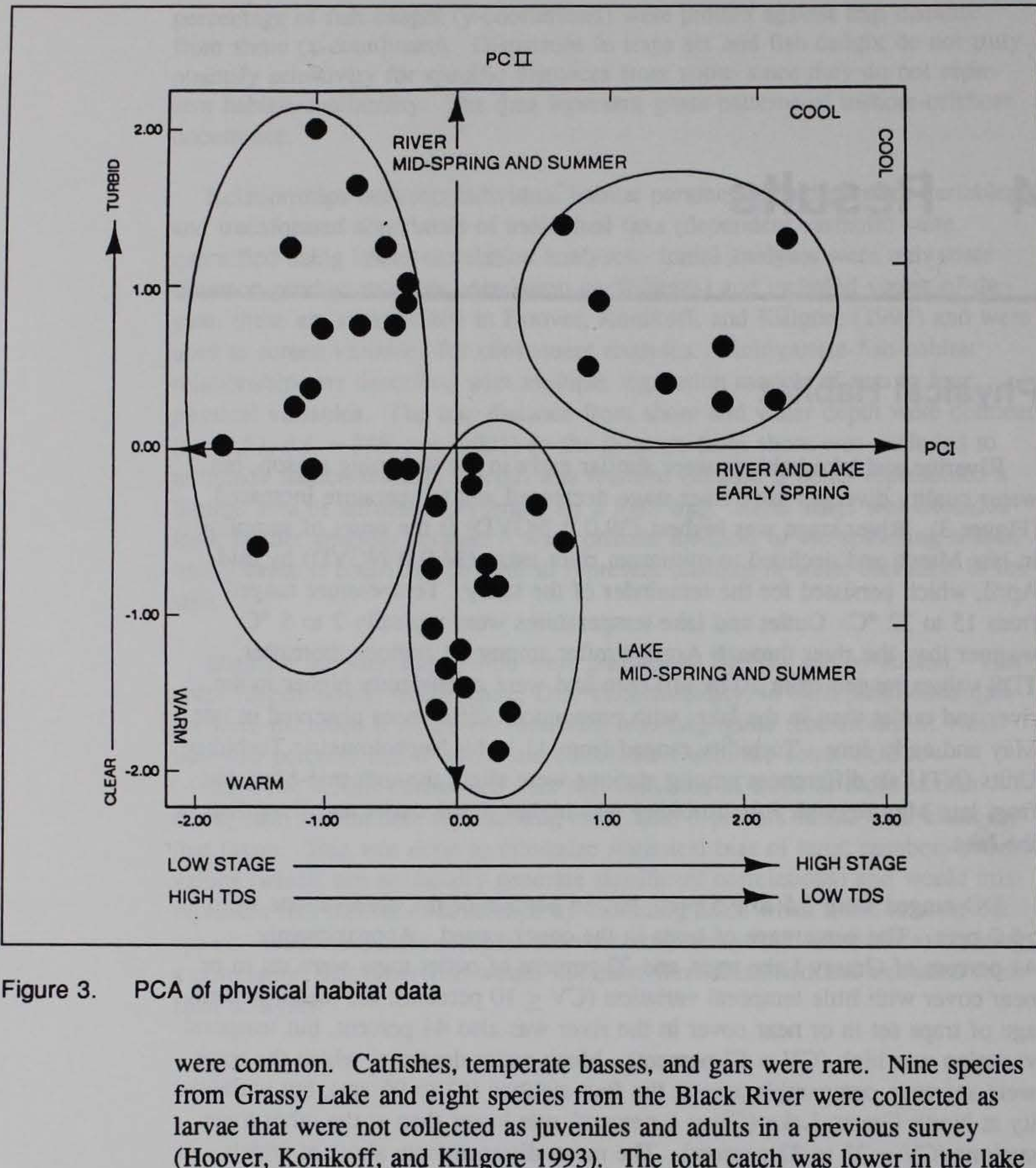

Figure 3. PCA of physical habitat data

were common. Catfishes, temperate basses, and gars were rare. Nine species from Grassy Lake and eight species from the Black River were collected as larvae that were not collected as juveniles and adults in a previous survey (Hoover, Konikoff, and Killgore 1993). The total catch was lower in the lake (14.7 fish/trap-night) than in the river (88.2 fish/trap-night), although river densities were inflated by a single occurrence (12 June 92) of very large numbers of minnows (1,185.2 minnows/trap-night) in the outlet. When these data are excluded, river catch rates (25.3 fish/trap-night) are less disparate from those of the wetland. Larvae predominated in the wetland and stream. For all egg-laying species, larvae comprised 88 percent of the catch from Grassy Lake and 97 percent of the catch from the Black River.

Wetland and riverine assemblages were qualitatively and quantitatively different (Table 1). Only half of all taxa co-occurred in Grassy Lake and the

Table 1
Larval (LRV) and Juvenile (JVS) Fishes Collected by Light Traps from Grassy Lake, Louisiana, March-July 1992

Species of Fish	Lake, n = 181		River, n = 166	
	LRV	JVS	LRV	JVS
Gars, Lepisosteidae				
Spotted gar, *Lepisosteus oculatus*	1	*		
Herrings, Clupeidae				
Gizzard shad, *Dorosoma cepedianum*	18	3*	150	
Threadfin shad, *D. petenense*	387	34*	36	16
Unidentified herring	22	1	36	23
Carps and minnows, Cyprinidae				
Grass carp, *Ctenopharyngodon idella*			560	*
Blacktail shiner, *Cyprinella venusta*			577	2
Common carp, *Cyprinus carpio*		8*		8
Bighead/silver carp, *Hypophthalmichthys* sp.			12	*
Shiners with >10 anal rays,[1] "*Notropis*" spp.			84	42
Pugnose minnow, *Opsopoeodus emiliae*			1	1
Bullhead minnow, *Pimephales vigilax*		1*	3	4
Unidentified minnows[2]	5	1	10,552	11
Suckers, Catostomidae				
Buffalo, *Ictiobus* spp.	3		289	1*
Spotted sucker, *Minytrema melanops*			5	*
Bullhead catfishes, Ictaluridae				
Channel catfish, *Ictalurus punctatus*		1*		
Yellow bullhead, *Ameiurus natalis*		5*	4*	
Killifishes, Cyprinodontidae				
Golden topminnow, *Fundulus chrysotus*	5	6		
Blackstripe topminnow, *F. notatus*				4
Blackspotted topminnow, *F. olivaceus*				3*
Unidentified topminnow, *F.* spp.			30	3
Livebearers, Poeciliidae				
Western mosquitofish, *Gambusia affinis*	1	1,106	2	115
Silversides, Atherinidae				
Brook silverside, *Labidesthes sicculus*	1	66	8	20
Inland silverside, *Menidia beryllina*	11	23*	2	12
Unidentified silversides	4		8	
Temperate basses, Percichthyidae				
White bass, *Morone chrysops*			1	*
Yellow bass, *M. mississippiensis*			1	*
Unidentified temperate bass			1	

(Continued)

Note: Asterisks (*) indicate species not collected in previous survey of juveniles and adults (Hoover, Konikoff, and Killgore 1993).
[1] Includes ribbon shiner, *Lythrurus fumeus*; emerald shiner, *Notropis atherinoides*; bluehead shiner, *Notropis hubbsi*.
[2] May include species listed previously and other taxa: pallid shiner, *Notropis amnis*; golden shiner, *Notemigonus crysoleucas*; weed shiner, *Notropis texanus*; red shiner, *Cyprinella lutrensis*; taillight shiner, *Notropis maculatus*; mimic shiner, *Notropis volucellus*.

Table 1 (Concluded)

Species of Fish	Lake, n = 181		River, n = 166	
	LRV	JVS	LRV	JVS
Sunfishes, Centrarchidae				
Banded pygmy sunfish, *Elassoma zonatum*		1		
Sunfishes, *Lepomis* spp.[3]	532	539	1,338	24
Black basses, *Micropterus* spp.[4]	96	15	19	11
Crappie, *Pomoxis* spp.[5]	262	7	87	11
Perches, Percidae				
Unidentified darters[6]	1	*	121	
Damaged, unidentifiable fishes	2	4	293	175
Total number of fish	1,359	1,313	14,228	478
Minimum number of taxa	16		23	
Taxa newly documented	9		8	

[3] Includes bluegill, *Lepomis macrochirus*; green sunfish, *L. cyanellus*. Probably includes orangespotted sunfish, *L. humilis*; longear sunfish, *L. megalotis*. May include warmouth, *L. gulosus*; dollar sunfish, *L. marginatus*; redear sunfish, *L. microlophus*; bantam sunfish, *L. symmettricus*.
[4] Largemouth bass, *Micropterus salmoides*. May also include spotted bass, *M. punctulatus*.
[5] Probably white crappie, *Pomoxis annularis*, and black crappie, *P. nigromaculatus*.
[6] Probably bluntnose darter, *Etheostoma chlorosomum*.

Black River ($J = 0.48$), and only a third of all fishes collected belonged to co-occurring taxa ($S = 0.32$). In Grassy Lake, minnows were rare (0.1/trap-night), consisting of three taxa; in the Black River, minnows were abundant (7.5/trap-night, excluding outlet data from 12 June 92), consisting minimally of seven taxa. Buffalo and darters were rare in the wetland (<<0.1/trap-night) and common in the river (1.8 and 0.7/trap-night, respectively). Threadfin shad were more abundant in Grassy Lake (2.3/trap-night) than in the Black River (0.3/trap-night); gizzard shad were less abundant (0.1/trap-night) than in the river (0.8/trap-night). Crappie and black bass were more abundant in the wetland (1.5 and 0.6/trap-night, respectively) than in the river (0.5 and 0.2/trap-night, respectively). Sunfishes were abundant, less so in the wetland (3.1/trap-night) than in the river (8.2/trap-night). Mosquitofish were also abundant in both locations, but more so in the wetland (6.1/trap-night) than in the river (0.6/trap-night). Brook and inland silversides were twice as abundant in the wetland (0.4 and 0.2/trap-night, respectively) as in the river (0.2 and 0.1/trap-night, respectively). Two topminnows, two temperate basses, and the spotted sucker are rare in the river and unknown in the wetland.

Temporal-Spatial Occurrence of Larval Fishes

Distinctive temperature-associated chronologies of peak larval abundance were evident (Figure 4). Black bass, buffalo, and darters spawned early in the season (Julian date <100), in cool water (15 to 19 °C); shad and minnows spawned late (Julian date ≥150), in warm water (25 to 31 °C). Crappie spawned earlier in the season and at cooler temperatures than sunfishes. Threadfin and gizzard shad exhibited peak spawning at the same time; threadfin densities were higher during this abbreviated peak, but gizzard shad also spawned earlier in the season when threadfin shad did not. Mosquitofish were collected only late in the season (Julian date 164 to 205).

Polymodal peaks of crappie, sunfishes, and minnows (Figure 4) corresponded to the order of, but were 2 to 3 °C warmer than, spawning temperatures of different species within those taxa from higher latitudes (Carlander 1977; Stanley, Miley, and Sutton 1978; Heins and Dorsett 1986; Robison and Buchanan 1988). The abundance of crappie was bimodal, approximating spawning temperatures of white and black crappie as follows:

Crappie peak I	15 to 16 °C	White crappie	13 °C
Crappie peak II	22 to 24 °C	Black crappie	18 to 20 °C

The abundance of sunfishes was trimodal, also corresponding to spawning temperatures of three species common in this system as follows:

Sunfish peak I	22.5 °C	Bluegill	20 °C
Sunfish peak II	25 °C	Longear sunfish	21 to 24 °C
Sunfish peak III	29 to 31 °C	Orangespotted sunfish	27 °C

The abundance of minnows was bimodal. Although species-level identifications were usually impossible, an Asian (grass) carp and blacktail shiner were conclusively identified in large numbers for two collections, respectively:

Minnow peak I	25 °C	Crass carp	23 °C
Minnow peak II	30.5 °C	Blacktail shiner	29 °C

Three lacustrine fishes spawned earlier than their riverine counterparts, and this was associated with the lake warming more rapidly than the river (Figure 4). Early spawned sunfishes, presumably bluegill, appeared in the lake and outlet 1 month earlier than in the river where water temperatures were up to 1.5 °C cooler. Middle peaks in sunfish abundance, presumably longear sunfish, appeared 2 weeks earlier in the north lake than at the outlet, but at identical

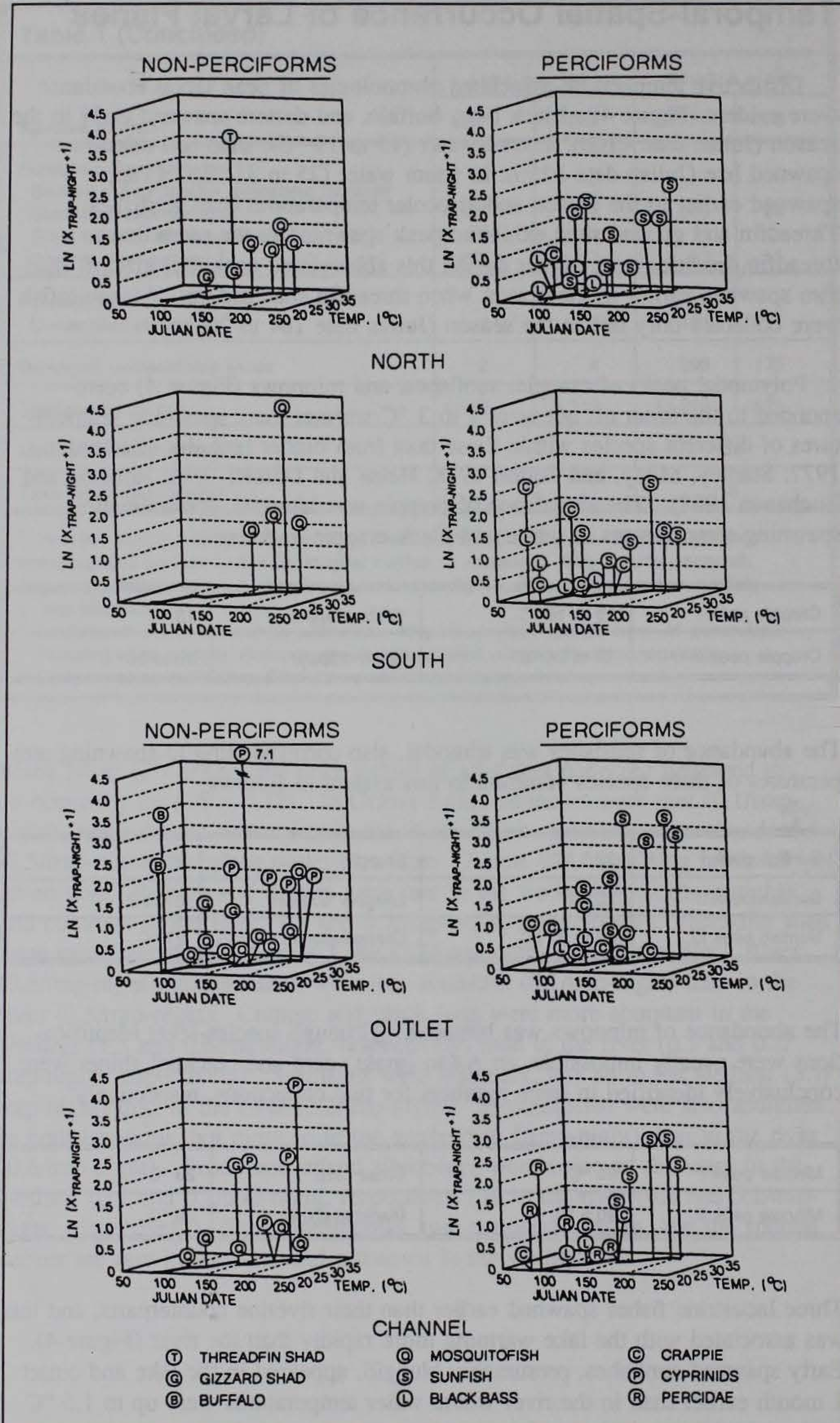

Figure 4. Larval fish abundance as a function of time and temperature

water temperature. Late spawned sunfish, presumably orangespotted sunfish, peaked 2 weeks earlier in the lake than in the outlet where water temperatures were up to 3 °C warmer. Early and late spawned crappie, presumably white and black crappie, appeared 2 weeks earlier in the lake than in the outlet which was 3 to 4 °C cooler and 3 °C warmer during these times, respectively. First modal abundance of gizzard shad larvae co-occurred in the lake and outlet when temperatures were comparable; the second mode coincided with a unimodal abundance of threadfin shad in the river. Absence of early spawned gizzard shad in the river cannot be attributed to temperature, since outlet and river temperatures were the same.

Larvae of different taxa were segregated by distance from the shore (Figure 5). Larvae in their order of proximity to the shore were darters and sunfishes (closest to shore), gizzard shad and minnows, black bass and crappie, buffalo, and threadfin shad (farthest from shore).

Larval Fish-Habitat Relationships

Every habitat variable tested was significantly correlated with abundance of more than one taxa, but temperature, turbidity, and TDS were more frequent correlates for riverine fishes (Table 2). Larval gizzard shad and crappie inhabited deep, turbid waters. Abundance in the wetland was positively correlated with depth (relationship nonsignificant for gizzard shad), and abundance in the outlet with turbidity (gizzard shad also correlated with depth). Larval minnows in the outlet and channel inhabited waters with high TDS. Minnow abundance in the outlet was positively correlated with turbidity; abundance in the channel negatively correlated with turbidity. Larval sunfishes inhabited warm water. Abundance in the lake, outlet, and channel was positively correlated with temperature (relationship nonsignificant in the outlet), whereas abundance in the outlet was correlated negatively with DO, positively with cover and TDS. Black bass were positively correlated with DO, darters with cover. Limited occurrence of threadfin shad and buffalo made habitat modeling impossible.

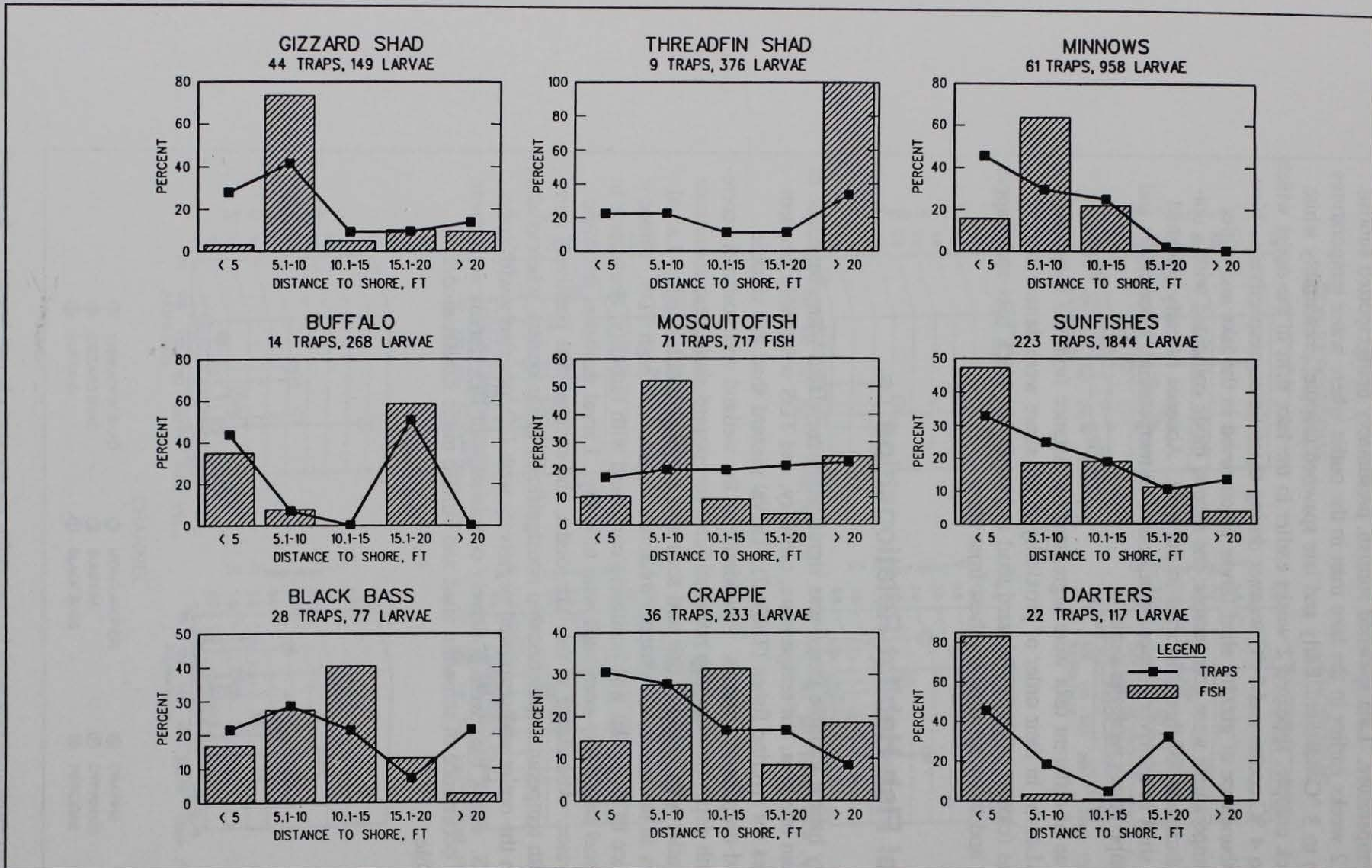

Figure 5. Relative sampling effort and larval fish abundance as a function of distance from shore. Data are for peak spawning periods

Table 2
Multiple Regression Models for Log-Abundance of Grassy Lake Fishes Caught in Surface Light Traps

Gizzard shad$_{North}$	= 0.996 + 0.222(Depth) - 0.033(Cover) - 0.036(TDS) - 0.067(DO)	r^2 = 0.254	df = 26	p = 0.150
Gizzard shad$_{Outlet}$	= -13.859 + 0.596(Depth) + 0.152(Turbidity) + 0.256(Temperature)	r^2 = 0.567	df = 26	p = 0.000
Minnows$_{Outlet}$	= -12.657 + 0.136(Turbidity) -1.262(Cover) + 0.027(TDS) + 0.227 (Temperature)	r^2 = 0.708	df = 42	p = 0.001
Minnows$_{Channel}$	= 0.736 + 0.036(TDS) - 0.047(Turbidity)	r^2 = 0.215	df = 34	p = 0.021
Mosquitofish$_{Lake}$	= 7.013 + 1.151(Cover) - 0.220(TDS)	r^2 = 0.392	df = 69	p = 0.000
Crappie$_{South}$	= - 0.165 + 0.435(Depth)	r^2 = 0.220	df = 26	p = 0.014
Crappie$_{Outlet}$	= -2.484 + 0.121(Turbidity) - 0.050(TDS)	r^2 = 0.299	df = 25	p = 0.017
Sunfishes$_{Lake}$	= 1.010 - 0.013(Turbidity) + 0.019(Temperature)	r^2 = 0.044	df = 125	p = 0.062
Sunfishes$_{Outlet}$	= -2.372 -0.373(DO) + 0.191(Temperature) + 0.717(Cover) + 0.021(TDS)	r^2 = 0.649	df = 61	p = 0.000
Sunfishes$_{Channel}$	= -5.757 + 0.264(Temperature)	r^2 = 0.247	df = 44	p = 0.001
Black bass$_{All\ sites}$	= -0.946 + 0.124(DO) + 0.009(Turbidity)	r^2 = 0.116	df = 131	p = 0.000
Darters$_{Outlet}$	= 3.778 + 1.493(Cover) - 0.157(Temperature)	r^2 = 0.527	df = 21	p = 0.001

Note: Variables are listed in descending order of correlation with fish abundance; significant correlates (p < 0.050) are underlined.

5 Discussion

Larval Fish Assemblages

Numerical dominance by sunfishes observed in Grassy Lake is typical of larval fish assemblages of riverine backwaters. Grassy Lake, however, exhibits lower fish abundance and diversity than other backwater wetlands of the Mississippi River. Total fish abundance (15/trap-night) was two to three times lower than that recorded for backwaters of the upper Mississippi (45/trap-night), Cache (33/trap-night), and Tallahatchie (60/trap-night) Rivers (Dewy and Jennings 1992, Baker and Killgore 1994, Turner et al. 1994). In the lower Mississippi Basin, fish densities are substantially higher in backwaters than in channels (Baker and Killgore 1994, Brown and Coon 1994, Turner et al. 1994), but Grassy Lake densities were lower than densities in the Black River (Table 1). Darters and minnows in Grassy Lake were less abundant and less diverse than those taxa in other backwaters of the lower Mississippi, and some characteristic taxa, such as pirate perch, were absent (Baker and Killgore 1994, Turner et al. 1994). Grassy Lake assemblages may be different from those previously studied because of local differences in fish-habitat relationships or because of continued isolation from its parent river.

Catches from light traps confirm abundance of certain fishes collected by seining but indicate higher biodiversity by documenting the occurrence of taxa not susceptible to that technique (Table 1). The abundance of mosquitofish, larval sunfishes, and larval crappie in light-trap catches corresponds to their numerical dominance in juvenile and adult assemblages (Hoover, Konikoff, and Killgore 1993).

Of nine species newly collected for the Black River site, five are small, inshore species represented by only a few specimens; four are large, mobile, offshore forms consisting of two native suckers and two Asian minnows (Table 1). Grass carp and bighead/silver carp, once presumed incapable of reproduction in small North American streams (Stanley, Miley, and Sutton 1978; Robison and Buchanan 1988), are unlikely to survive to maturity in this system, but juveniles are occasionally encountered.[1] Of ten species newly documented for Grassy Lake, seven are rare, nearshore forms. Threadfin shad, gizzard shad, and inland silverside often migrate to deep water or offshore, rendering them less susceptible to seining. Sympatric occurrence of brook and inland silversides in Grassy Lake is exceptional. Since competitive exclusion by the latter is demonstrated for lentic systems (McComas and Drenner 1982), continued occurrence of the former within the wetland may depend on riverine connection.

Wetland-riverine disparities in taxonomic richness and abundance of certain species indicate that nursery functions of Grassy Lake are underutilized when isolated from the river. Nine nearctic minnows (*Cyprinella* spp., *Notemigonus crysoleucas*, *Notropis* spp.) and the bluntnose darter utilize floodplain wetlands as spawning and rearing habitat (Robison and Buchanan 1988, Baker and Killgore 1994). Some species (e.g., weed shiner) may require flooding and access to backwaters for successful recruitment (Ross and Baker 1983). No riverine minnows and only a single darter larvae are known from Grassy Lake. Long-term persistence of wetland populations is probably limited by predation (high densities of gamefishes) and specialized habitat affinities of juveniles and adults. Likewise, low abundance of larval buffalo in the wetland emphasize that spawning adults in the river are unlikely to exploit this floodplain environment. The continued commercial fish harvest of buffalo in Grassy Lake, then, may be limited by reproductive capabilities of a dwindling, lentic subpopulation.

Temporal-Spatial Occurrence of Larval Fishes

Larvae of eight taxa are separated along multiple gradients: temporal (chronological, thermal), longitudinal (riverine-wetland), and latitudinal (inshore-offshore). This is partially attributable to spatial differences in juvenile-adult fish communities and is exacerbated by isolation of the wetland from the river. It also results from different habitat affinities among species of larval fish (or among spawning adults).

Larval Fish-Habitat Relationships

The community structure of larval fishes in backwaters of the Mississippi River is correlated with several physical factors and combinations of factors. In the upper Mississippi, the abundance of individual species was associated with submersed vegetation and water quality (Dewey and Jennings 1992). In the lower Missouri River, a gradient from small- to large-stream assemblages corresponded to a gradient in channel morphometry and substrate size (Brown

1 Personal communication, 1994, Neil Douglas, Museum of Zoology, and Department of Biology, Northeast Louisiana University, Monroe, LA.

and Coon 1994). In the Tallahatchie River, relative abundances were associated primarily with velocity, secondarily with suspended solids and temperature (Turner et al. 1994). In the Cache River (Arkansas), abundance was associated with duration and magnitude of floods (Baker and Killgore 1994). Relative abundances of Grassy Lake fishes were correlated, individually or in concert, with combinations of cover (including vegetation), morphometry (depth, distance from shore), temperature, and water quality (TDS, turbidity). Substrates and velocity in the Grassy Lake system were not evaluated, but the concentration of riverine fishes in the outlet and disparities in abundance between the north and south stations in the lake suggest that these variables may also influence spawning success.

Observed spawning chronology conforms to a generic pattern: darters and crappie early, shad mid-season, sunfishes and minnows late (e.g., Floyd, Hoyt, and Timbrook 1984; Turner et al. 1994). Buffalo spawn early in the reproductive season when temperatures are <20 °C (Johnson 1963, Carlander 1969, Burr and Heidinger 1983), but dates of larval appearance relative to other taxa are not well documented. Gizzard shad typically spawn earlier than threadfin shad (Allen and DeVries 1993) and at cooler temperatures (Carlander 1969). Black bass larvae may appear late in the season (Floyd, Hoyt, and Timbrook 1984) but are usually presumed to be early spawners (Carlander 1977). In areas with prolonged spawning seasons and speciose assemblages, well separated peaks of larval abundance may represent responses to fluctuations in water level and changes in temperatures that partition resources among potential competitors (nesting adults, feeding larvae) and separate prey from potential predators (Floyd, Hoyt, and Timbrook 1984). Such a process could be important in Grassy Lake where low TDS and turbidity indicate low primary productivity, and much of the invertebrate biomass is represented by large prey (e.g., decapod shrimp) unavailable to larval fishes (unpublished data).

Specific habitat variables previously associated with larval fish abundance are confirmed by Grassy Lake data (Figure 5, Table 2). In other systems, abundance of larval sunfishes and nearctic minnows are correlated positively with temperature, DO, and vegetation (Paller 1987, Dewey and Jennings 1992, Turner et al. 1994). In Grassy Lake, sunfishes were correlated positively with temperature, but DO and cover were important only at the outlet, and the correlation with DO was negative. Minnow larvae are correlated positively with temperature (in the outlet), but moreso with turbidity and TDS. In other systems, gizzard shad larvae predominate in open water (Dewey and Jennings 1992) but not necessarily offshore, sometimes congregating near cover or at the surface during high turbidity (Allen and DeVries 1993, Van den Avyle 1988, Matthews 1984). Gizzard shad in Grassy Lake are abundant nearshore in deeper water; in the wetland, abundance was negatively correlated with cover and TDS. In the outlet, abundance was positively correlated with temperature and turbidity.

Mosquitofish typically occur near shore; inhabit warm, shallow, vegetated backwaters; and tolerate very high temperatures, high levels of dissolved substances, and very low DO (Pflieger 1975, Laerm and Freeman 1986, Robison and Buchanan 1988); in the laboratory they actively select submersed cover (Casterlin and Reynolds 1977). In a southwestern stream, mosquitofish predominated in shallows, at low DO, but in cool water with little shelter (Matthews and Hill 1980). In Grassy Lake, mosquitofish were abundant 5 to 10 ft (or farther) from shore (Figure 5). Abundance was correlated positively with submersed cover but negatively with TDS (Table 2). The absence of samples prior to June (Julian Date < 164) suggests that population levels are low early in the season or that nocturnal movements are not significant at water temperatures <28 °C (Figure 4). Supporting these contentions are observations that mosquitofish have limited tolerance of cold and that only a few survive over winter (Cross and Collins 1975).

Larval Fishes and Riverine Backwaters

Riverine wetlands in the lower Mississippi Basin are distinctive habitats presenting an array of potential spawning cues. The utilization of backwater wetlands at higher latitudes may be governed more by vegetation complexity (Dewey and Jennings 1992) due to clearer water or to hydraulics and geomorphic variables (Turner et al. 1994, Brown and Coon 1994) due to more pronounced variation in ground elevation. In low gradient systems of the southern Mississippi Basin, spawning and larval fish aggregations may respond to channel/slough disparities in water chemistry, especially dissolved solids and turbidity, which in turn will influence primary and secondary productivity (Baker, Killgore, and Kasul 1991). Observed differences in habitat correlates of Grassy Lake fishes are certainly the result of parameters chosen for measurment in different studies, but may be attributable to local populations, and possibly subpopulations, responding to different environmental cues. This is supported by documentation of Grassy Lake fishes spawning at warmer temperatures than indicated in the literature, and by variation among sites in correlates associated with larval abundance (Table 2).

Larval Fishes as Indicators of Wetland Value

The analysis of fish-habitat relationships in Grassy Lake requires additional data to quantify spawning and rearing value for individual fish species. Limited information on larval fish systematics, especially minnows and sunfishes dominating the lower Mississippi Basin, necessitate indirect identification of most species, based on the time of spawning, relative abundance of adult fishes, and water temperature (Holland-Bartels, Littlejohn, and Houston 1990; Wallus, Simon, and Yeager 1990). Inferring habitat preferences of a single species within a polytypic taxon, then, requires intensive sampling during individual periods of modal abundance and the sometime erroneous assumption that spawning is temporally discrete. Typically, wetland biologists treat taxa conservatively and quantify habitat requirements for the lowest practical taxon (e.g., genus), overrepresenting spawning conditions or larval preferences than probably realized by individual species (Paller 1987, Dewy and

Jennings 1992, Turner et al. 1994, Brown and Coon 1994). Surveys conducted for more than 1 year will provide a sufficiently robust database which can be partitioned by "species" (modes within a taxon) while retaining sufficient sample sizes for statistical analyses, and representing a broader range of environmental conditions. It will also allow effects of density to be evaluated for individual taxa by allowing fish-habitat relationships to be quantified during periods of high and low abundance.

Management of Grassy Lake for Fishery Enhancement

Typically, winter and spring river stages (e.g., 1990, 1991) are sufficiently high to permit the exchange of water between river and wetland (Figure 6). The Black River rises substantially in January, subsides slightly, rising again in May, but water elevations during the entire period usually exceed maximum weir crest, 41.0 ft NGVD. If the gate remains open throughout this period, fish could enter the wetland, even with stoplogs in place, by passing over the weir. The removal of stoplogs, however, would reduce velocities over the crest, enhancing water exchange and fish passage. River stages decline rapidly in June-July to pool maintenance level, 34.0 ft NGVD. Fish passage would require removal of stoplogs, although increased water velocities through the

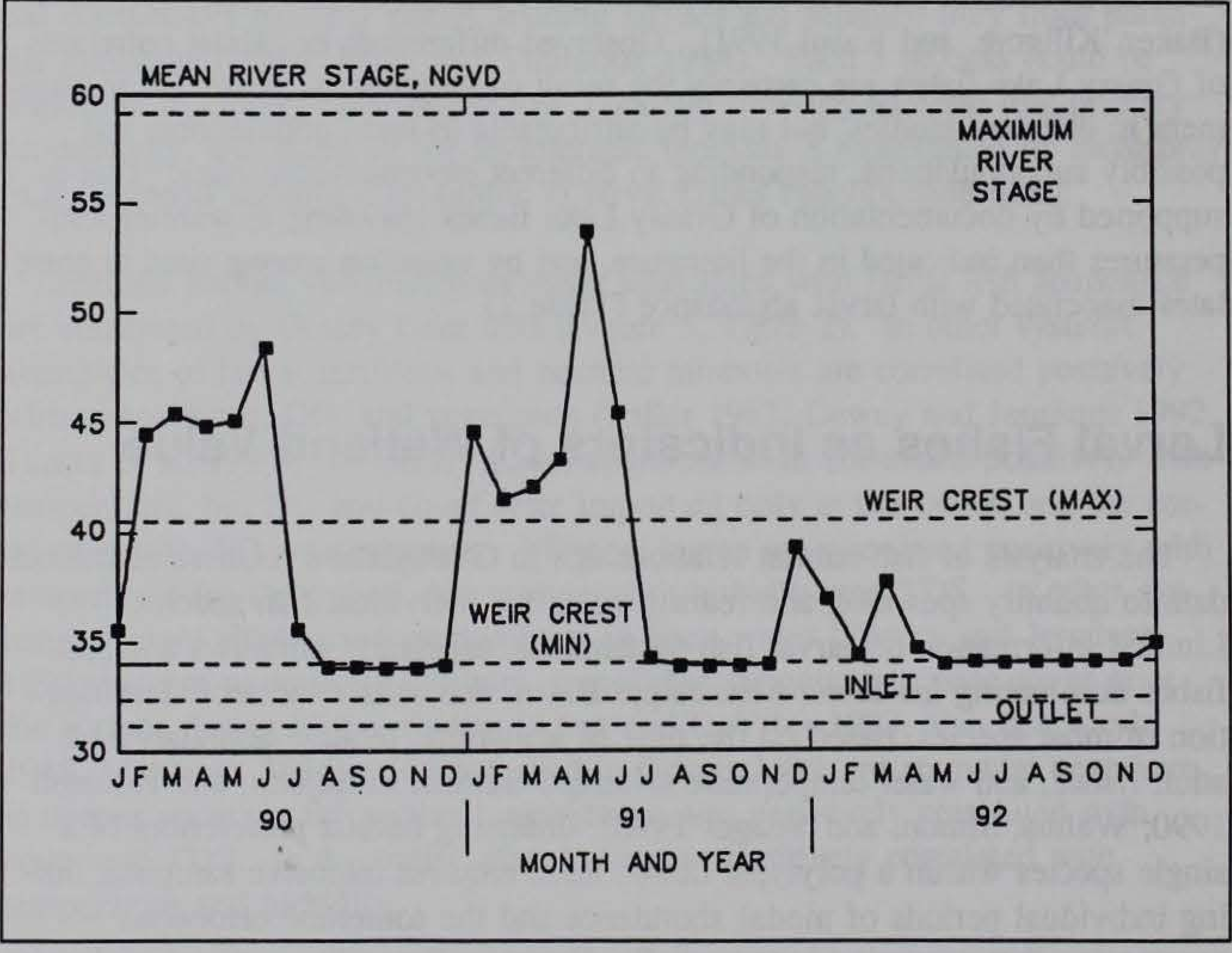

Figure 6. Water levels of Black River at Jonesville lock and dam, 1990-1992

structure and reduced wetland habitat from dewatering will take place if substantial disparities exist between lake and river elevations. To maximize the likelihood of fish passage through the structure, maximum number of stoplogs should be removed during high water immediately preceding spawning seasons of desirable species and then replaced to maximize extent of the nursery habitat. To minimize the likelihood of fish passage, all stoplogs should remain in place with the gate closed.

Chronology of larval fish abundance (spawning seasons) identifies optimal times for connection and isolation. Connection early in the reproductive season, March through mid-April, provides spawning and nursery grounds for four important species: buffalo, black bass, black crappie, and bluntnose darter (Figure 4). Subsequent isolation, mid-April through mid-May, reduces the influx of bluegill and white crappie, which are already abundant in the lake and prone to overcrowding (Carlander 1977), and gizzard shad, which attain sizes too large for many predatory fishes to consume (Carlander 1969). Reconnection, late-May through July, provides habitat for minnows and threadfin shad, important forage for recreational fisheries, and for longear sunfish and blacktail shiner, currently undocumented from the lake. Many of the minnows spawned in early June were Asian carps, but these typically are channel spawners; therefore, establishment within a lentic wetland is unlikely (Robison and Buchanan 1988).

6 Conclusions

Larval and young-of-the-year fishes of Grassy Lake are relatively low in abundance and diversity but are numerically dominated by species of economic importance (sunfishes, crappie, black bass) and desirable forage (threadfin shad). A seasonal connection of this wetland to the river would provide habitat for stream fishes that utilize floodplains as spawning grounds and nurseries, but which are now absent or rare in the wetland (nearctic minnows). Commercial fishing (buffalo) would be enhanced; the forage base for recreational fisheries (shiners) would be diversified, and habitat for characteristic species (bluntnose darter) would be provided.

Physical habitat of Grassy Lake is distinct from that of the Black River, especially late in the reproductive season, when waters are warmer, clearer, and lower in dissolved solids. Monitoring variables correlated with spawning of individual taxa will allow wetland managers to identify advantageous periods of wetland connection (or isolation) from the river.

Collections of larval fishes made with light traps permit identification of nurseries, spawning chronology, and environmental conditions associated with reproduction. These collections enhance the quantification of wetland biodiversity by detecting species uncommon as adults due to specialized habitat (topminnows, temperate basses), large size and high mobility (suckers), and/or catastrophic mortality (exotic carps).

Larval fishes of eight taxa were separated by pronounced differences in chronology (i.e., time-temperature of appearance), longitudinal distribution (e.g., wetland-riverine), shoreline affinities (e.g., distance to shore), and habitat correlates. This suggests that wetland fisheries can be effectively manipulated by the operation of the Grassy Lake structure to selectively allow fish passage and changes in physical habitat.

Connection (removal of stoplogs) in March-April, or when high water inundates terrestrial vegetation and DO is high in cooler water, will enhance reproduction by buffalo, black bass, and darters. Isolation (replacement of stoplogs) in May-June, when temperatures are uniformly warming and lake waters clear, will reduce the likelihood of invasion by gizzard shad, exotic carps, and bluegill. Reconnection (removal of stoplogs) in July, when lake waters have cleared and TDS have increased, will enhance reproduction of the blacktail shiner.

Habitat benefits exist from the structure irrespective of the operation. Riverine fishes benefit from the embayment of the outlet which supports dense populations of larval minnows, crappie, and sunfishes. Lacustrine fisheries could improve when high water in early spring (above maximum crest of weir) allows buffalo passage into the wetland, although this requires that the gate remain open.

Low diversity of wetland assemblages and the importance of water chemistry to reproduction of riverine fishes may reflect the wetland's historical isolation from the parent river, and low river stages that took place during the study period, respectively. Larval fish assemblages and fish-habitat relationships following wetland connection to the river and during higher stages may be substantially different from those observed in 1992 when it was continuously isolated.

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Physical habitat and more than 17,000 recently spawned fishes were sampled from a backwater and a stream in which connections are regulated through a water control structure. The backwater remained isolated for the duration of the spawning season, creating subpopulations of wetland and riverine fishes, allowing fish-habitat relationships to be described for discrete locations along a wetland-riverine gradient. Backwater assemblages were dominated by mosquitofish, sunfishes, threadfin shad, crappie, and black bass. Stream assemblages were dominated by minnows, sunfishes, buffalo, gizzard shad, and darters. Chronology of peak larval abundances was buffalo and black bass; darters; crappie, shad, and early spawning sunfishes; early spawning minnows including Asian carps; late spawning sunfishes; and late spawning minnows including blacktail shiner. Cover, depth, turbidity, total dissolved solids, dissolved oxygen, and temperature were each correlated with larval abundance of several taxa. Habitats differed among taxa and between subpopulations. Wetland-riverine connection prior to 1 May will enhance fisheries by providing habitat for spawning buffalo and black bass. Reconnection after 1 July will increase biodiversity by providing spawning habitat for nearctic minnows. Intervening isolation will reduce influx of exotic species, gizzard shad, and centrarchids already abundant in the lake.

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