Red River Waterway Project
Shreveport, LA, to Daingerfield, TX, Reach
Reevaluation Study In-Progress Review

APPENDIX 6
AQUATIC RESOURCES

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SHREVEPORT, LA, TO DAINGERFIELD, TX
REEVALUATION STUDY IN-PROGRRSS REVIEW

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<u>**Item**</u>

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INTRODUCTION

1. Ichthyofauna of the Cypress Bayou and Twelvemile Bayou system is diverse and unusual. Over 80 species are documented from Big Cypress Bayou and its principal tributaries, many of which are rare and/or at the westernmost limits of their distribution (Hoover et al., in press). Fish communities of Twelvemile Bayou are poorly documented, but are potentially complex because of the high species richness of the Lower Red River (Cross et al., 1986).

2. Evaluating impacts of the proposed Red River Waterway, Shreveport to Daingerfield Reach, on fish habitat required a priority consideration of faunal complexity and composition, as well as availability of quantitative habitat models. Local fish assemblages are taxonomically dominated by darters and minnows, and to a lesser extent by sunfishes, exploiting a wide variety of habitats and microhabitats. In lowland streams of the southeast, and especially in blackwater systems, these habitats are defined primarily by hydraulic parameters (velocity and depth) and instream structure (vegetation and woody cover), and fishes exhibit a high degree of habitat specialization (e.g., Baker and Ross, 1981; Meffe and Sheldon, 1988). Quantitative models, like the Habitat Suitability Index (HSI), however, are unavailable for the majority of species characteristic of this system.

3. To determine best methods of habitat assessment, meetings were held in August and December 1992 among cooperating agencies: Texas Parks and Wildlife; Louisiana Wildlife and Fisheries Commission; U.S. Fish and Wildlife Service (FWS); and U.S. Army Corps of Engineers, Vicksburg District (CELMK), and Waterways Experiment Station (CEWES). Decisions of the interagency team were: (1) reservoirs would be modeled separately from streams using regression equations developed by the National Reservoir Research Program, WS; (2) streams would be modeled using Instream Flow Incremental Methodology; (3) evaluation species would be chosen from different ecological guilds to broaden representation of the fish community; (4) existing models of stream fish-habitat relationships (i.e., suitability indices) would be used, with modifications based on field data from this study.

4. Ecological guilds were constructed for the known ichthyofauna based on spawning and velocity preferences of individual species (Table 6-1), providing the principal basis for selecting evaluation species. Additional criteria considered included: commercial and recreational importance, sensitivity to environmental disturbances, and availability of existing habitat models (e.g., Killgore and Hathorn, 1987). Habitat assessments were conducted separately for

Table 6-1

Habitat guilds for Cypress and Twelvemile Bayou fishes, based on preferred velocities (horizontal axis! and spawning substrate (vertical axis). Evaluation species for reservoirs (*) and streams (**) are indicated.

	LACUSTRINE/GENERALISTS	SLACK WATER	SWIFT WATER
OPEN	Gizzard shad Mosqultoflsh	American eel * Threadfin shad Cypress minnow Silvery minnow Ribbon shiner	Skipjack herring Emerald shiner Mimic shiner Freshwater drum
SAND AND GRAVELS	Red shiner Green sunfish Orangespotted sunfish * Bluegill Redear sunfish * Lsrgemouth bass White Crappie Black crappie	Redfin shiner Pallid shiner Bluehead shiner Pugnose minnow River carpsucker Creek chubsucker ** Spotted sucker Blacktail redhorse Golden topminnow Flier Warmouth Redbreast sunfish Dollar sunfish Longear sunfish Spotted sunfish Bantam sunfish ** Spotted bass Mud darter	Chestnut lamprey Blackspot shiner Striped shiner ** Ironcolor shiner Sand shiner Weed shiner Yellow bass White Bass Scaly sand darter Harlequin darter Goldatripe darter Redfin darter River darter ** Blackside darter Dusky darter
VEGETATION	Bowfin Common carp Golden shiner Brook silverside	* Spotted gar Shortnose gar Alligator gar ** Grass pickerel ** Chain pickerel Taillight shiner Lake chubsucker Smallmouth buffalo Bigmouth buffalo Starhead topminnow Blackstripe topminnow Blackspotted topminnow Inland silverside Banded pygmy sunfish ** Bluntnose darter Swamp darter Slough darter	Longnose gar Black buffalo
CREVICE	Bullhead minnow Black bullhead Yellow bullhead * Channel catfish	Blue catfish Tadpole madtom ** Flathead catfish Pirate perch Cypress darter	** Blacktail shiner

streams and lakes. Data arc summarized for three navigational reaches: Twtlvcmile Bayou (I), Big Cypress Bayou below Jefferson, Texas including Caddo Lake (II), Big Cypress Bayou above Jefferson, Texas including L&t 0' the Pints (III).

5. The objectives of this report art: (1) establish baseline conditions for ichthyofauna and physical habitat; (2) apply habitat evaluation techniques and quantify impacts of the proposed waterway on fish habitat.

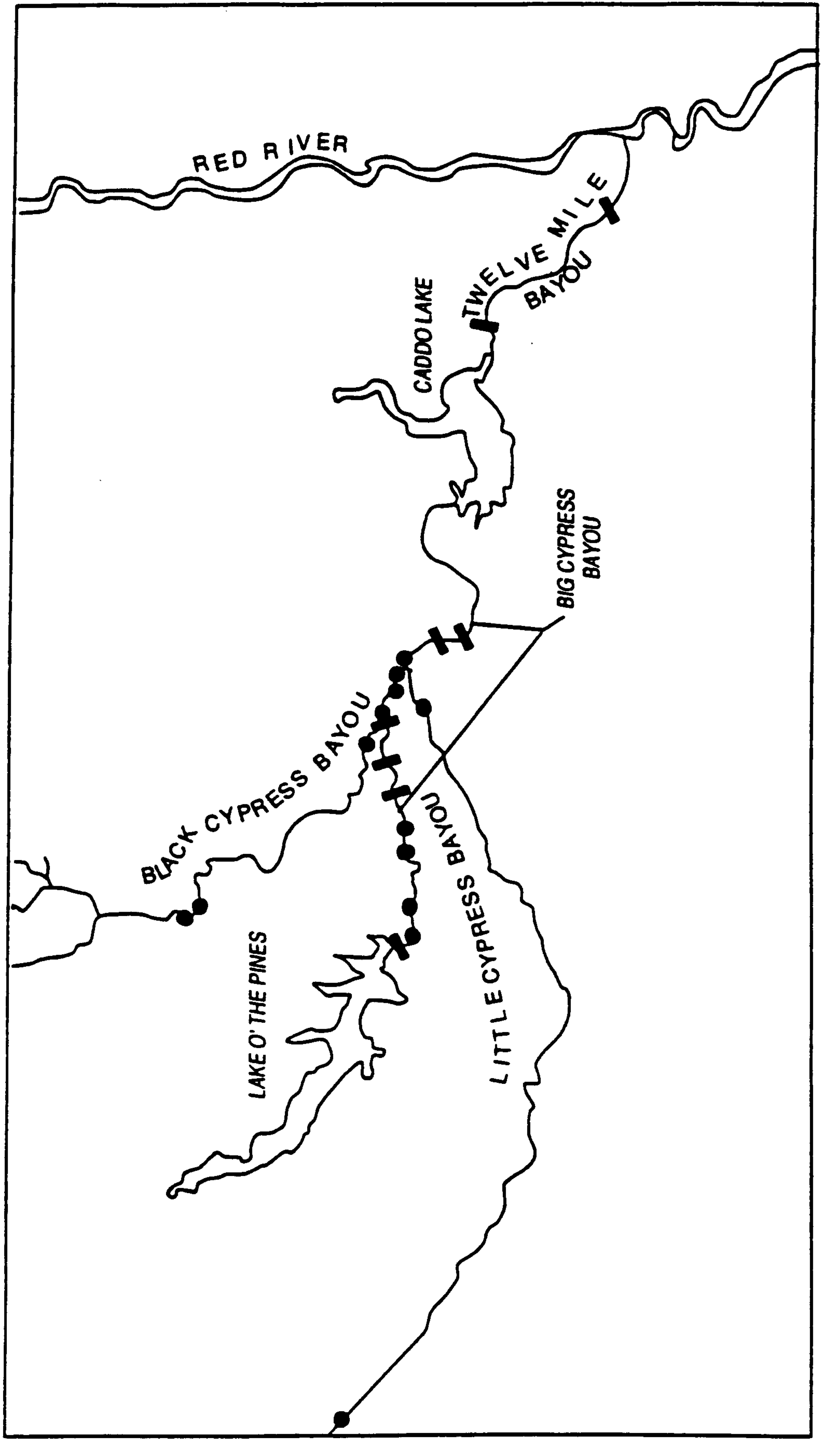
STUDY AREA

6. The study area extends from the mouth of Twelvemile Bayou to the upper reaches of Lake 0' The Pints (Figure 1). The system consists of blackwater streams, lakes, and swamps located in Cass, Marion, Harrison, Morris, Titus, and Upshur Counties, Texas, and Caddo Parish, Louisiana. Soils art alluvial, mainly loamy sand with low-to-moderate organic matter. Dominant riparian vegetation includes bald cypress (*Taxodium distichum)*, button bush (*Cephalanthus occidentalis)*, common alder (*Alnus serrulata*), water elm (*Planera aquatica)*, and black willow (*Salix nigra)*. In the rivers, aquatic plants art patchy in distribution. Water moss (*Fontinalis* sp.) is attached to submerged tree bases and fallen trees. Water lilies *(Nymphaea odorata) occur* during the summer in wide, shallow backwaters in the lower reaches. Substrate in the rivers ranges from clayey sand to silty clay. Allochthonous material (primarily leaf litter) usually overlays the sediment in slackwater.

7. Lake 0' The Pints was initially impounded in 1957 for flood control, recreation, and water supply. Water supply pool area is 18,700 acres. Maximum depth is 45 feet. Inundated brush and timber art common in the middle and upper areas of the lake, and shorts art shallow and sandy; lower reaches have steep rock outcroppings or sloping banks of clay or sandy loam with growths of button bush and black willow. Aquatic vegetation is moderately abundant, comprised mainly of American lotus *(Nelumbo lutea)* and water-weed (*Elodea* sp.).

8. Big Cypress Bayou,between Lake 0' The Pints and Caddo Lake, is 40 milts long. Discharge is largely controlled by releases from Lake 0' the Pints with input from tributaries and local runoff after heavy rains. The lower reach below Jefferson, Texas, has been channtlized and was historically navigable by steamship. The channtliztd reach of Big Cypress Bayou is wide (125-300 feet), deep (to 40 ft), with little instream cover except cypress knees. The upper reach is shallow, meandering, with submerged logs and riparian vegetation. The principal tributaries of Big Cypress Bayou art two blackwater streams: Black Cypress Bayou and Little Cypress Bayou.

9. Caddo Lake was formed by a log jam on the Red River during the 19th century. In 1914, an earthen dam was constructed which was replaced by a concrete structure in 1971. Conservation pool area is 26,800 acres with an average depth of about 6 feet. Over 30 species of aquatic plants occur in the lake; water hyacinth (Eichomia crassipes), coontail (Ceratophyllum demersum), and Eurasian watermilfoil (Myriophyllum spicatum) dominate the upper portion of the lake. Cypress trees form extensive stands throughout.


RED RIVER
TWELVE MILE BAYOU
CADDO LAKE
BIG CYPRESS BAYOU
BLACK CYPRESS BAYOU
LITTLE CYPRESS BAYOU
LAKE O' THE PINES

10. Twelvemile Bayou is 23 miles long. It is wide (250-300 feet), deep (16 feet) and was historically navigable. Shorelines are sandy with steep, wooded bluffs. Banks are highly erodible, compared with Big Cypress Bayou. Instream cover consists of fallen trees and debris. Aquatic plants are rare.

RESERVOIR IMPACT ANALYSIS

11. Five evaluation species were selected: spotted gar (Lepisosteus oculatus), threadfin shad (*Dorosoma petenense*), channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), and largemouth bass (*Micropterus salmoides*). These species represent four different ecological guilds comprised-of 34 species (Table 6-l). Habitat models used are regressions developed from field data conducted for National Reservoir Research Program (Ploskey et al., 1986). In these models, observed standing crops of fishes (dependent variable) are significantly correlated with physical variables such as water quality, lake morphometry, and growing season (independent variables).

METHODS

12. Regression models were used to calculate estimated standing crops of fish (Ploskey et al., 1986). Several models were available, but since lake morphometry will not change appreciably as a result of the proposed waterway, models were selected that equated standing crops with physical (water quality) and nutrient data:

Gar = -13.627 - 1.288 Log(Secchi depth) - 2.571 log(Nitrogen) + 5.882 log(Growing season) r2 = 0.31

Threadfin shad = 2.016 + 1.109 Log(Secchi depth) + 1.639 log(Phosphorous) r2 = 0.11

Catfish = 0.987 + 0.350 log(Phosphorus) I 0.275 log(Alkalinity) r2 = 0.12

Bluegill = 1.519 I 0.942 log(Secchi depth) + 0.668 Log (Phosphorus) - 0.162 log(Storage ratio) r2 = O.-I9

Largemouth bass= -4.109 I 0.326 log(Secchi depth) I 0.548 Log (Chlorophyll a) I 1.869 log(Growing season) r2 = 0.29

13. Water quality data from CELMK were used to calculate estimated standing crops of fish. Preproject standing crops were calculated from mean values for water quality parameters sampled in 1991-1992. Long-term changes in water quality attributable to the project were not anticipated based on the water quality data collected by CELMK.

	Caddo Lake	Lake 0' The Pines
Secchi depth (ft)	2.1	2.2
Nitrogen (ppm)	.702	.810
Phosphorus (ppm)	.056	.060
Growing season (days)	230	230
Alkalinity (ppm)	14	20
Chlorophyll a (ppb)	29	9
Storage ratio (yp)	.10	.44

ASSUMPTIONS

14. Spotted gar and channel catfish are the dominant representatives in their families. Regression models were available for gars and catfishes, but not for individual species (Ploskey, et al., 1986). The models have the greatest chance of representing habitat of individual species, then, when a single species is numerically dominant. Reservoir surveys indicate that spotted gars are substantially more abundant than longnose gars, and that channel catfish dominate biomass more than flathead catfish and bullheads (Dorchester, 1959: Toole and Ryan, 1981; Toole, 1983).

RESULTS AND DISCUSSION

15. Calculations based on water quality and regression models are summarized below:

ESTIMATED STANDING CROPS (LBS/ACRE)

	Spotted Gar	Threadfin Shad	Channel Catfish	Bluegill	Largemouth Bass
Caddo Lake	0.24	0.51	1.11	1.15	1.21
Lake 0' The Pines	0.06	0.60	0.92	1.08	0.94

16. Regression equations identified relevant variables associated with .habitat value, and estimated standing crops provided indices of relative abundance and habitat quality for individual species. In the southeast, secchi depth (i.e., transparency) and/or phosphorus were significantly correlated with standing crops of each of the five evaluation species (Ploskey et al., 1986), suggesting that habitat quality of Caddo Lake and Lake 0'The Pines will be influenced by primary productivity. Estimated standing crops indicated higher abundances (and habitat quality) in both reservoirs for channel catfish, bluegill, and largemouth bass, than for gar or threadfin shad. Rotenone surveys of the two lakes confirm this pattern in relative abundance, although observed standing crops were substantially higher than estimated standing crops (Toole and Ryan, 1981; Toole, 1983; unpublished data of Texas Parks and Wildlife Department). Because no long-term, project-related changes in water quality are anticipated, changes in fish habitat were undetectable.

STREAM IMPACT ANALYSIS

17. Eight evaluation taxa were selected: pickerels (Esox spp.), blacktail shiner *(Cyprinella venusta),* ironcolor shiner (*Notropis chalybaeus*), spotted sucker (Minytrema melanops), flathead catfish *(Pylodictis olivaris),* spotted bass (*Micropterus punctulatus),* bluntnose darter (*Etheostoma chlorosomum*), and blackside darter *(Percina maculata). These* species represent five ecological guilds comprised by 56 species (Table 6-l). Habitat models were previously developed from field data on local populations of five species (Killgore and Hathorn, 1987) Literature-based models are available for flathead catfish (Killgore and Hathorn, 1987; Lee and Terrell, 1987). A non-regional model is available for the slough darter (*Etheostoma gracile),* a species with habitat requirements similar to the bluntnose darter (Edwards etal., 1982; Kuehne and Barbour, 1983). Limited unpublished data exist for the blackside darter (Thorn Hardy, pers. comm.).

METHODS

18. Fish-habitat relationships - Physical habitat and relative abundance of fishes were sampled at 21 stations April-August 1992 (Figure 1). Four stations were sampled on four occasions, 13 stations on three occasions, and five stations once. During sampling, stream width, dissolved oxygen, Ph. turbidity, conductivity, and temperature were measured from a single position representative of that station; measurements were made with a Lietz rangefinder, Hydrolab, and Hach 2100 turbidimeter. Depth and velocity were measured at 10 points along a cross-sectional transect; depth was measured using a stadia rod (< 15 feet) or Hummingbird boat mounted depth-finder (> 15 feet); velocity was measured using a Marsh-McBirney velocity meter, the probe at 0.6 depth (< 3 ft.) or 0.2 and 0.8 depth (> 3 feet). If substantial longitudinal variation existed at a site, additional transects were used.

19. Fishes were collected using a seine (10 X 8 ft., 3/8" mesh); a representative effort consisted of 10 hauls through all apparent habitats. When depths were sufficient (> 6 feet), experimental gillnets (6 X 90 feet, .75, 1.5, 2.0, 2.5, 3.0, 3.5" mesh) were set out overnight.

20. Because habitat models did not exist for the blackside darter, and because this species is uncommon locally, 10 individuals collected from Big Cypress Bayou were transported to a 4- by B-foot laboratory stream (265 gallons) at Northeast Louisiana University, Department of Biology. The stream created a mosaic of velocities ranging from O-l.3 feet/second. A hydraulic map was constructed **from** approximately 100 velocity measurements along cross-sectional transects throughout the stream. Measurements were made 0.2 inches from the bottom (height occupied by a darter resting on the bottom) using a Nixon 422 velocity meter and probe. Contours were constructed for ranges at 2 inches/s intervals. Observations of darter position were made 10 times/day for 6 weeks and used to infer occupied velocities.

21. Suitability indices (SI's) for physical habitat variables were confirmed, modified, or generated by plotting standardized number of observations (i.e., fish) for each measured value of a variable (i.e., velocity, depth, cover). Observed SI's were compared with existing SI curves. Because few flathead catfish were collected, previously developed curves were used for stream habitat (Killgore and Hathorn, 1987). SI curves were distributed to all members of the interagency fish-habitat team for comment.

22. Instream Flow Incremental Methodology (IFIM) - Direct effects of the waterway on channel habitat were evaluated by simulating changes in habitat that would occur at different discharges. Standard field surveys (Bovte and Milhous, 1978; Bovee, 1982) of water surface elevation, bottom contours, water velocity, and occurrence of instream cover were conducted along l-4 transects at seven sites: preproject rivermiles 11.0, 22.5, 55.0, 56.0, 62.5, 66.5, 71.0, 82.5 (Figure 1). These represented homogeneous lengths of fish habitat, based on gross river morphometry, and were determined by field reconnaissance.

23. The model was implemented using these cross-sectional data (preproject) and cross-sections based on waterway specifications (post-project) provided by CELMK PHABSIM generated quantitative simulations of physical habitat for a wide range of discharges: 5-5,000 cfs in upper Big Cypress Bayou; 5-8,000 cfs in lower Big Cypress Bayou; 900-36,000 cfs in Twelvemile Bayou (see Bovee., 1982 for computational methodology). For each length of stream, data from simulations (velocity depth, cover) were weighted with corresponding SI's to calculate Weighted Usable Area (WUA) for each species.

24. Discharges used to calculate impacts were those for a "typical" water year (1985). Data provided by CELMK showed median (or near median) discharge for 1985 at all three gages for which the period of record is greater than 25 years. Differences in WUA were calculated for each species, each month (based on mean monthly discharge for that reach); annual means of the differences in WUA for each habitat reach were combined to express overall changes in habitat in each navigational reach.

ASSUMPTIONS

25. Stage-Discharge Ralationships provided by CELMK were used for all analyses. Elevations in NCVD were adjusted to IFI survey elevations. Post-project stage-discharge relationships, provided by CELMK, were derived by adjusting the pre-project relationships by regression for common stage-discharge points on the pre- and postproject curves.

26. Postproject cross sections (HEC-2) and alignment map, provided by CELMK, were used to locate corresponding IFIH stations. At each IFIM station, all HEC-2 cross-sections within +1 mile were utilized in analysis.

27. Cross-section weightings were based on number of transects available for each site (e.g.,a site with 3 cross-sections would have each individual cross-section weighted 33.33% for that length of stream). Cross-sectional data represented a "theoretical" lOO-ft. section of stream.

28. Two-channel conditions were assumed for all cross-sections in which simulated water surface elevation indicated depth in either channel.

29. Velocity profiles from IFIM field surveys were utilized for calibration of pre-project conditions. For measured discharge at each station, velocities were used to estimate Manning's n for each vertical. Manning's n was assumed constant for all other simulated discharges.

30. For postproject HEC-2 cross-sectional data,Manning's n values were assumed and used to simulate velocities. It was assumed that Manning's n did not change as a function of discharge. Calibration discharges and starting water surface elevations were taken from postproject stage-discharge relationships. IFIM data sets contain approximately 2-3 times more verticals versus postproject discharges derived from HEC-2 data sets. This means that preproject velocity simulations will have greater variation in velocity profiles compared to postproject simulations.

31. Reproject cover observed at each vertical was used in all simulations. "No cover" was assumed for postproject cross sections (i.e., conservative assumption).

32. Horizontal extension of IFIM cross-sactfonal field measurements were based on preproject cross-sectional profiles and were used to simulate higher discharges.

33. Habitat simulations used geometric means of depth, velocity, and cover Suitability Indices. This option in the IFIM habitat modeling represents compensatory analysis and was considered the best approach given the uncertainty in the assumed stage-discharge relationships and velocity simulations.

34. Physical habitat is assumed to be of primary importance, whereas temperature and water quality are not limiting.

35. Two-year Flood Impacts - Indirect effects of waterway operation were evaluated by predicting reductions in flood plain habitat. Pre- and postproject water elevations for a 2-year frequency flood (i.e., a flood with a 50 percent chance of occurring in any given year), and river stage-area relationships were _ provided by CELMK. These data were used to generate estimates of changes in flooded acreage. Suitability indices for flood.plains in each navigational reach were created for seven species using the following formula:

$$\mathrm{SI} - \frac{\text{Mean Relative Abundance in Reach}}{\text{Mean Relative Abundance in System + One Standard Deviation}}$$

Flathead catfish were not collected in sufficient numbers to determine flood plain SI in this manner, so a value established by expert consensus was used (Killgore and Hoover, 1992). Impacts to fish habitat were determined by multiplying preproject and postproject flooded acres with SI's for each species.

ASSUMPTIONS

36. Two-year flood determines ecological success (e.g., survival, growth, reproduction) of fish. Less frequent (more severe) flooding may be associated with pronounced changes in certain fisheries, but fast-growing and short-lived fishes require more frequent (less severe) flooding for sustained production. Of the eight evaluation species, two are known to be long-lived (≥ 5 years): spotted bass and flathead catfish (Carlander, 1969; Pflieger, 1975; Robison and Buchanan, 1988). Both species, however, may mature by Age 3. Pickerel and spotted sucker do not usually live more than 3-4 years, and the shiners and darters probably _ live only 2-3 years.

37. Flood plain habitats do not differ among the reaches. Flood plain habitats consist almost exclusively of bottomland hardwood wetlands (Hans Williams, pers. comm.. Flooded agricultural land,fallow land, etc. is negligible.

38. All species utilize flood plain. Quantification of flood plain use by southeastern stream fishes is not well-documented in literature, although some species are known to be "exploitative" and others are considered "quiescent" (Ross and Baker, 1983). Flood plain utilization is known for the majority of evaluation species (Kwak, 1988; Killgore and Hoover, 1992). Flood plain use is not documented for spotted bass or blackside darter, although we have encountererd the last species in qualitative collecting. Assumptions that all species use flood plains equally, though, provides a worst-case scenario of possible habitat impacts (i.e., conservative assumption).

39. In-stream relative abundance will reflect primary habitat value of flood plains. We expressed this as a ratio of a typical value (mean) for that reach to a high value for that system (mean + 1 standard deviation). Since flood plain habitats consist of one principal kind, use of that habitat should be dependent on the number of fishes available for lateral migration. i.e., fish

density within that segment of the stream. Physical characteristics of flood plains, chronology, and duration of flooding are presumed secondary in importance. Homogeneity of flood plain habitats, and the prolonged breeding seasons of fishes in this area (e.g., Hubbs, 1985) support this contention.

RESULTS AND DISCUSSION

40. Stations sampled at Twelvemile Bayou had greater velocities and depths than those at Cypress Bayou (Figure 2). Variation in hydraulic parameters within locations and between stations and time was greater for velocity (Coefficient of variation 86-227 percent), than for depth (CV - 46-81 percent) or width (CV- 19-64 percent).

41. Evaluation species were highly variable in abundance. Numbers collected of each evaluation species by seining were:

Pickerels	138
Ironcolor shiner	222
Blacktail shiner	94
Spotted sucker	24
Flathead catfish	2
Spotted bass	45
Bluntnose darter	158
Blackside darter	71

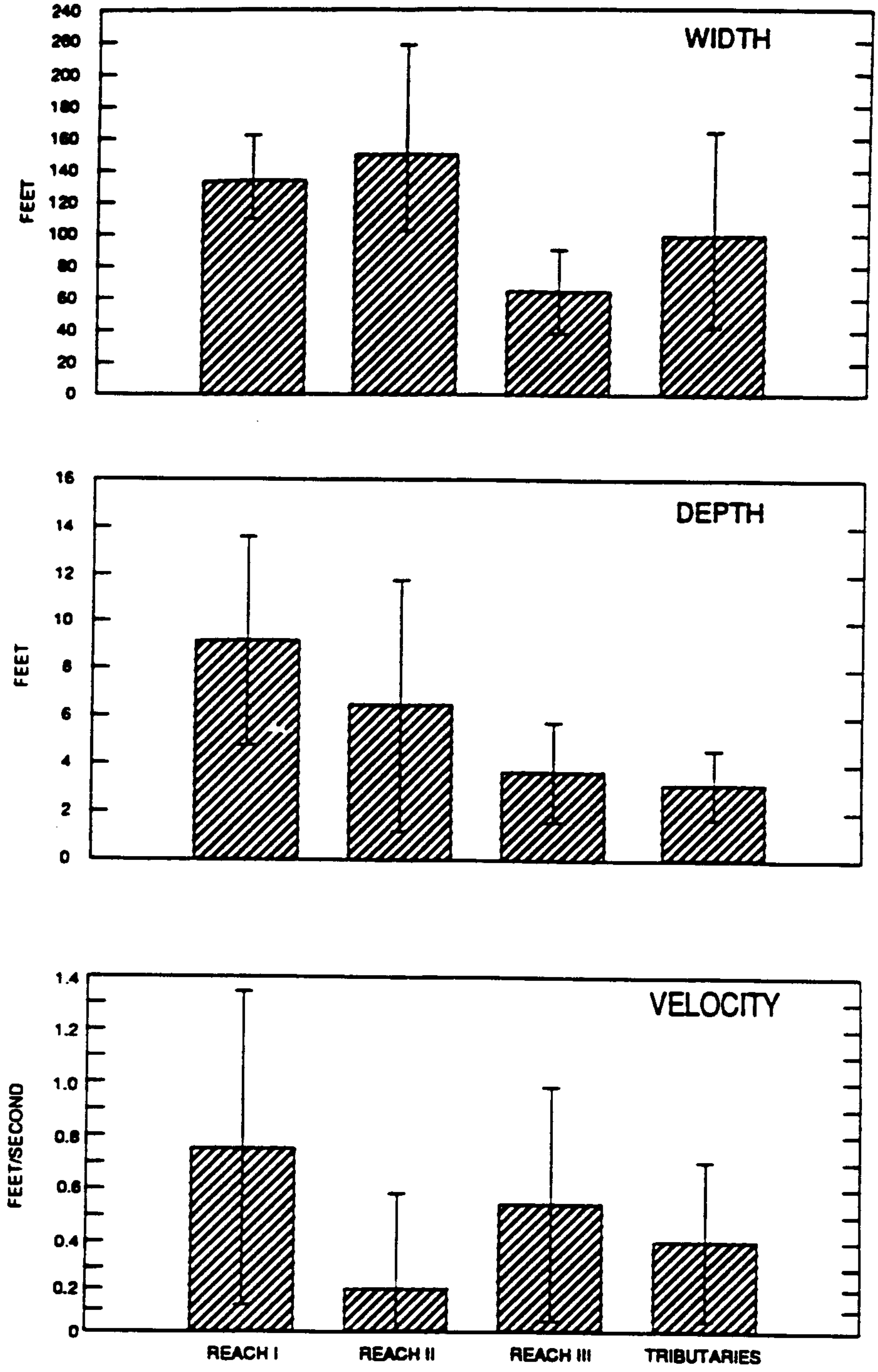
42. Numbers of evaluation species collected by gillnetting were low (< 30) but locations where large fishes were gillnetted corresponded to those where smaller individuals of the same species were seined. High SI's for most species were observed for slow, shallow water with cover (Figure 3) and wetlands of Big Cypress Bayou (Figure 4).

Changes in acres of stream fish habitat based on Instream Flow Incremental Methodology:

ACRES OF STREAM HARITAT

Reach	PICKERELS	SPOTTED BASS	SPOTTED SUCKER	IRONCOLOR SHINER	BLACKTAIL SHINER	BLACKSIDE DARTER	BLUNTNOSE DARTER	FLATHEAD CATFISH
I*	83	243	257	150	133	123	95	114
II	- 21	129	463	453	48	238	203	567
II	146	243	245	198	143	166	122	198
TOTAL	208	615	965	801	324	527	420	679

1 Bared on discharges ≥ 900 cfs; post- ,preproject differences in acres assumed zero for lower discharges (*Jul-Oct*).



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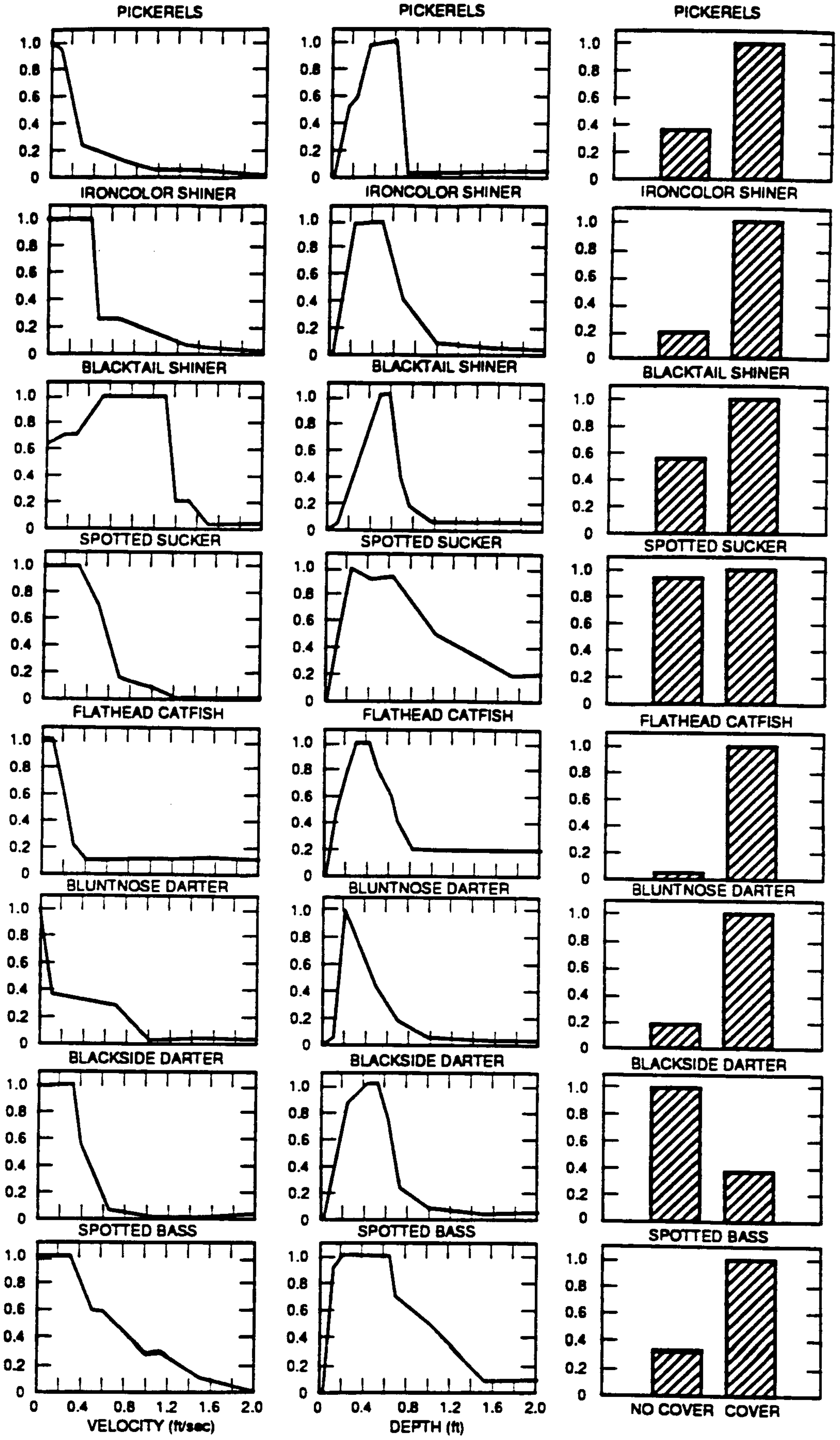
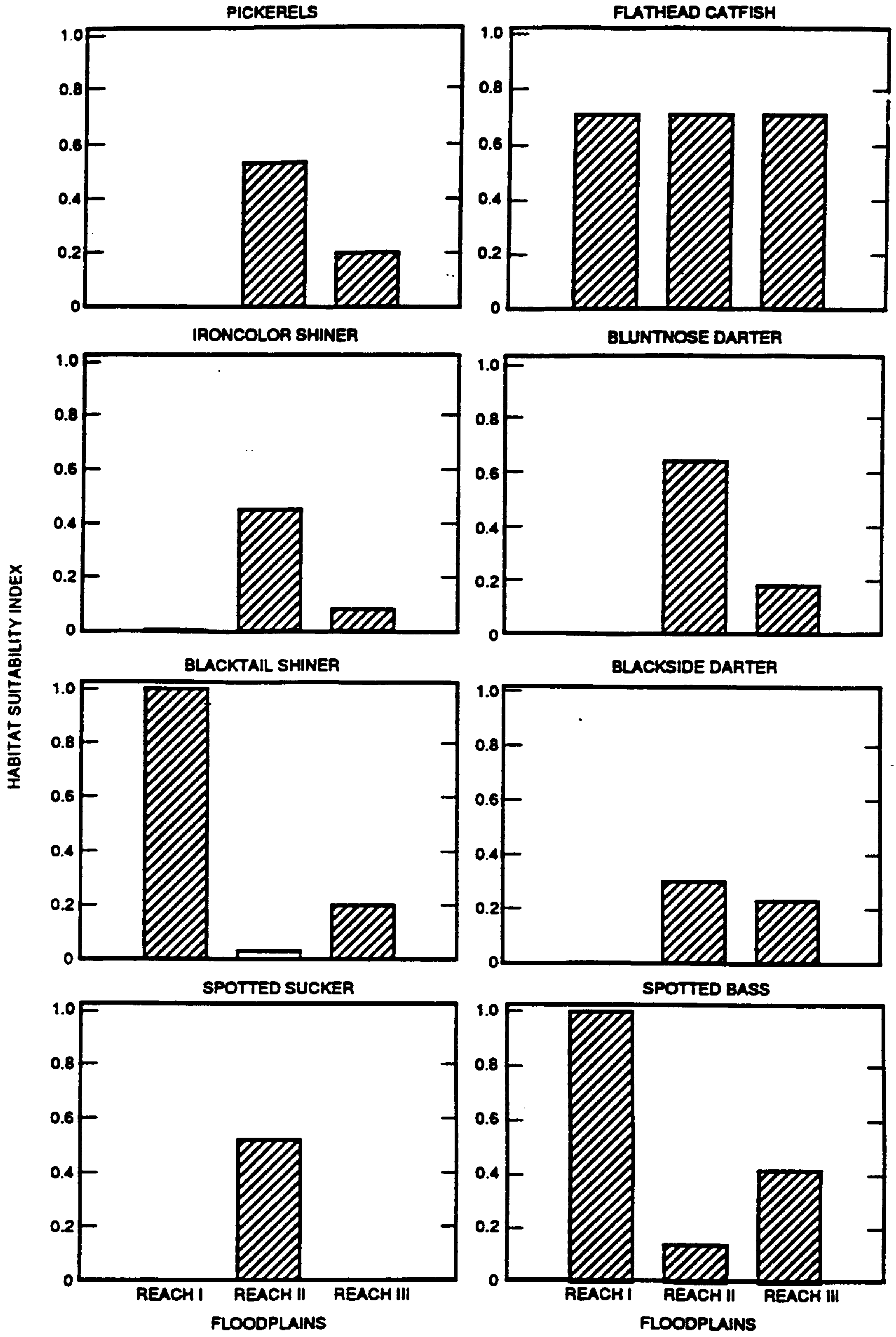

PICKERELS
IRONCOLOR SHINER
BLACKTAIL SHINER
SPOTTED SUCKER
FLATHEAD CATFISH
BLUNTNOSE DARTER
BLACKSIDE DARTER
SPOTTED BASS
1.0
0.8
0.6
0.4
0.2
0
0
0.4
0.8
1.2
1.6
2.0
VELOCITY (ft/sec)
DEPTH (ft)
NO COVER
COVER



PICKERELS

FLATHEAD CATFISH

IRONCOLOR SHINER

BLUNTNOSE DARTER

BLACKTAIL SHINER

BLACKSIDE DARTER

SPOTTED SUCKER

SPOTTED BASS

43. Slight reductions in pickerel habitat occurred in Reach II, and these were confined exclusively to the fish habitat reach represented by the station at RM 55 (Marshall Pump Station). Habitat losses here were attributable to channelization within the original channel, and projected removal of extensive shallows and cover from the right shore. Habitat gains for most species reflect increases in habitat volume with minor, if any, reductions in habitat quality. The creation of a double channel in Reach II, and channel enlargement in other areas will more than offset reductions in cover and increases in depth.

44. Changes in flood plain fish habitat for a typical year (1985) are summarized below:

ACRES OF FLOW PLAIN HABITAT

Reach	PICKERELS	SPOTTED BASS	SPOTTED SUCKER	IRONCOLOR SHINER	BLACKTAIL SHINER	BLACKSIDE DARTER	BLUNTNOSE DARTER	FLATHEAD CATFISH
1*	D	-1768	0	0	-1768	D	0	-1255
II	-859	- 227	-842	-729	- 49	-486	-1037	-1150
III	- 205	-431	0	- B2	-205	-236	- 185	-728
TOTAL	*-1064*	- **2426**	**- 842**	**- -**	**- 2022**	**-722**	**-1222**	**-3133**

• Based on river stages- flood plain area **curves** for pre- and postproject conditions.

45. Because flood plain was reduced in all navigational reaches, habitat reductions occurred for all species. High habitat reductions (> 3,000 HU's) for flathead catfish resulted from the high SI (.71) applied to flood plains in all reaches; although few flathead were collected in this study, presence of this species was confirmed from all reaches. Habitat losses were high (> 2,000 HU's) for blacktail shiner and spotted bass since they occurred throughout the system but attained disparate abundance in the lower reach; habitat losses for the remaining species were lower because they were confined to the upper two reaches (< 1,300 HU'S). Zero values indicate that those species were not collected in that reach during the course of this study, and potential for wetland utilization is negligible.

MITIGATION REQUIREMENTS

46. Requirements for mitigation of fish habitat losses are based on maximum losses for any species, in any of the three principal habitats for each reach.

ACRES REQUIRED

REACH	RESERVOIR	**STREAM**	FLOOD PLAIN
I	0	0	1,768
II	0	21	1,150
III	0	0	728
TOTAL	0	21	3,646

47. Assuming no long-term, project-related changes in reservoir water quality, habitat losses were unmeasurable and mitigation will not be required. In streams, habitat losses occurred for pickerel only. Complete mitigation will be accomplished if 21 acres of channel habitat are created in Reach II with optimal conditions for this taxon (SI's - 1.00): no velocity, 3-6 feet depths, and abundant instresm cover. Sub-optimal conditions will require greater acreage. If considering the entire study area, however, mitigation for pickerel will be unnecessary since habitat gains in Reaches I and III overcompensate for the losses in Reach II. Flood plain habitat losses in Reach I occurred for blacktail shiner and spotted bass only; 1,768 acres provide complete mitigation for both species. In Reaches II and III, flood plain losses were greatest for flathead catfish; 1,878 acres will provide complete mitigation for all evaluation species.

MULTIVARIATE ANALYSES OF STREAM FISH DATA

48. Multivariate analyses were conducted to identify relationships between fish community structure and physical habitat. These techniques used data collected from stream surveys &scribed above. Unlike the IFIM, data from all species and for all habitat parameters were utilized. Such an approach allows direct habitat assessments for a greater number of species and objective determination of relative importance of different physical habitat factors.

49. Species diversity of fishes is positively associated with habitat quality (Gorman and Karr 1978; Foltz 1982) and water quality(Barbour and Brown 1974; Jackson and **Harvey** 1989; Keller and Crisman 1990), but the measurement of species diversity is problematic (Magurran, 1988). Typically "diversity" involves some evaluation of species richness (i.e., the number of species) and evenness (i.e., equitability of abundance among those different species). These components may be expressed separately or incorporated into a single measure (i.e., heterogeneity index). All assessments of diversity are influenced by ssmple-size, and for comparative purposes, sample effort or number of individuals should be the same.

50. Relationships between fish diversity and physical habitat are determined by correlating site-specific measures of fish diversity with habitat measurements. Those factors exhibiting high or significant correlations are presumed to influence the occurrence (richness) or abundance (evenness) of the greatest number of fish species, while those with low or nonsignificant correlations are presumed to influence fewer kinds of fish.

METHODS

51. Field methods were those described above. Fish abundance was expressed as the number of fish collected per 10 seine hauls.per site. Species-richness (S) was quantified as the number of fish species collected in 10 seine hauls at a site. A heterogeneity index,the Shannon function (H') was calculated that is sensitive to differences in species richness and evenness (Magurran, 1968). H' can range from 0.00, when a single species is present, *to* ln[total number of species], when species are all equally abundant. Although H' does not have an absolute upper limit, sample sizes and composition of small fish communities impose some constraints on observed values; for single collections of small stream fishes, usually H'< 3.00. Evenness (E) is the ratio of observed H' to maximum H' (for the observed number of species); values range from 0.00, when a single species is numerically dominant, to 1.00, when all species are equally abundant. For diversity and habitat measures, significant differences among locations or between seasons were determined using Student-Newman-Keuls test. Factors that were most closely associated with species diversity were identified by multiple regression, 0.15 significance level (SAS 1987).

RESULTS AND DISCUSSION

52. Water quality of Twelvemile Bayou differed from that of Cypress Bayou; mean pH and conductivity were higher (Figure 5). Variation in water quality parameters within locations and across time was lower for dissolved oxygen (Coefficient of variation - 6-22 percent) and Ph (CV - 6-26 percent) than for conductivity (CV -13-42 percent) and turbidity (38-89 percent). Mean Ph can be somewhat misleading since values represent a logarithmic scale, but it indicated a trend for more alkaline waters in the lower reach.

53. Sixty-four species were collected during this study (Table 6-2). Most were rare; 50 species were individually represented by fewer than 2 percent of all fishes collected. Numerically dominant species in order of abundance were: mosquitofish *(Gambusia affinis),* brook silverside *(Labidesthes sicculus)*, bullhead minnow *(Pimephales vigilax),* bluegill *(Lepomis macrochirus), the* weed shiner *(Notropis texanus),* red shiner *(Cyprinellalutrensis),* threadfin shad (*Dorosoma petenense),* blackstripe topminnow *(Fundulus notatus),* longear sunfish *(Lepomis megalotis),* and ironcolor shiner *(Notropis chalybaeus*) . These species cumulatively comprised over 65 percent of 10,014 fish collected. Mosquitofish, brook silverside, bluegill, and blackstripe topminnow were common throughout the system. Threadfin shad and longear were less common in the tributaries. Weed and ironcolor shiners were absent from Twelvemile Bayou: red shiners were found only Twelvemile Bayou.

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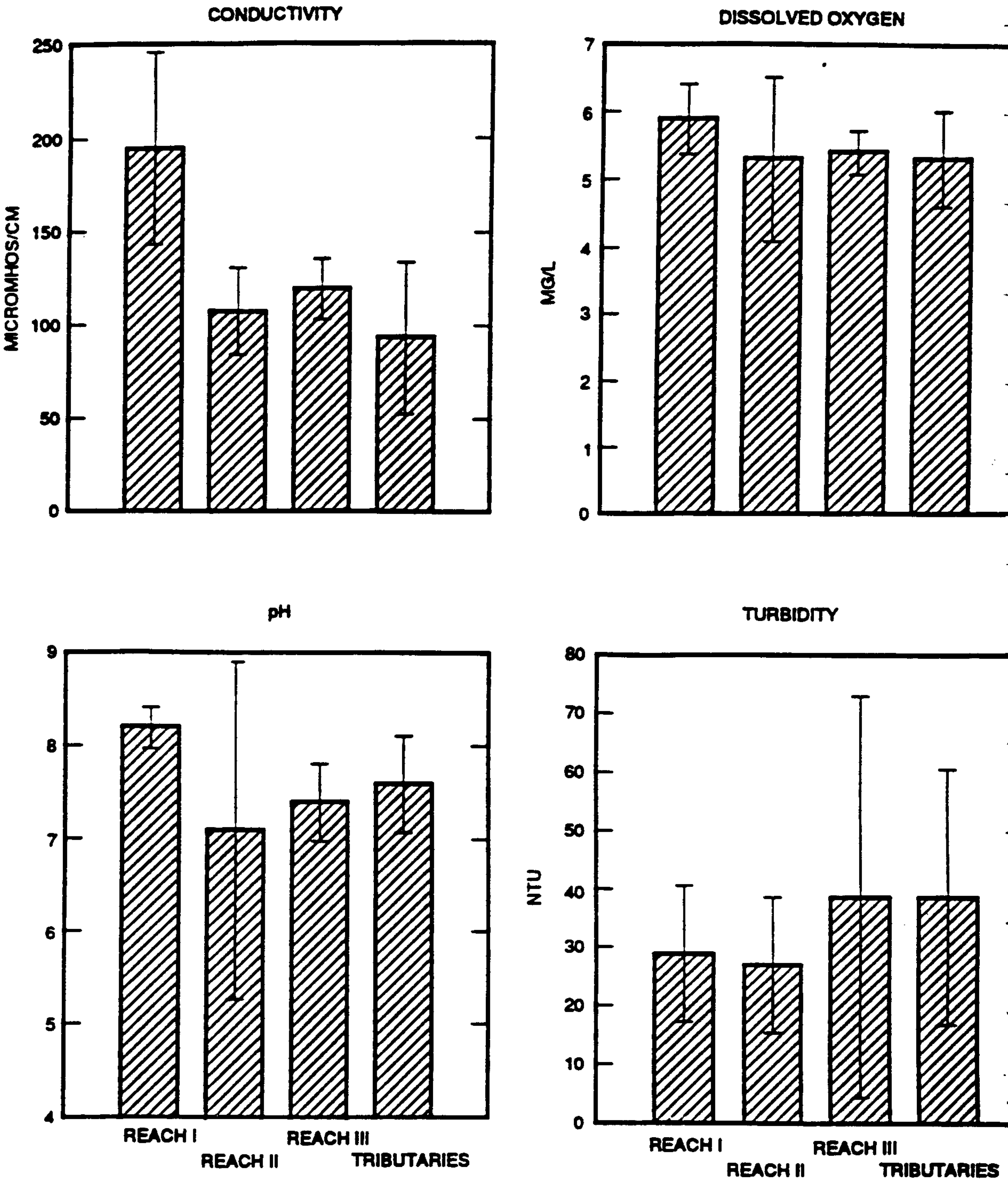


Table 6-2

Relative abundance of Cypress Bayou and Twelvemile Bayou fishes, April-August 1992: mean number/10 seine hauls/station. All species known are listed, including those not collected during this study.

Family/Species	Navigational Reach I	II	III	Tributaries
N -	7	19	12	15
Family Petromyzontidae				
Ichthyomyson castaneus, chestnut lamprey				
Family Lepisosteidae				
Lepisosteus oculatus, spotted gar		0.16		
L. osseus, longnose gar				
L. platostomus, shortnose gar				
L. spatula, alligator gar				
L. sp., juvenile		0.05		
Family Amiidae				
Amia calva, bowfin				
Family Anguillidae				
Anguilla rostrata, American eel				
Family Clupeidae				
Alosa chrysochloris, skipjack herring				
Dorosoma cepedianum, gizzard shad	0.43	0.05		
D. petenense, threadfin shad	13.43	5.21	13.92	0.07
Family Hiodontidae				
Hiodon alosoides, goldeye				
H. *tergisus*, mooneye				
Family Cyprinidae				
Cyprinella lutrensis, red shiner	53.85			
C. *venusta*, blacktail shiner	10.14	0.37	1.25	0.07
C. *lutrensis* X C. *venusta,* hybrid shiner	2.28			
Cyprinus carpio, common carp	0.14			
Hybognathus hayi, cypress minnow		0.05		0.07
H. *nuchalis,* silvery minnow	0.14			
Luxilis chrysocephalus, striped shiner	0.14			
Lythrurus fumeus, ribbon shiner	0.57	1.21	1.50	10.07
L. umbratilis, redfin shiner		0.16	0.17	0.40
Notemigonus crysoleucas, golden shiner		0.42		0.07
Notropis amnis, pallid shiner		0.05		1.27
N. atherinoides, emerald shiner				
N. *atrocaudalis,* blackspot shiner				
N. *chalybaeus,* ironcolor shiner		6.84	1.25	5.13
N. *hubbsi,* bluehead shiner		6.95	0.08	
N. maculatus, taillight shiner			0.08	0.13
N. *stramineus*, sand shiner				
N. *texanus,* weed shiner		6.89	16.00	9.73
N. *volucellus, mimic* shiner				
Opsopoeodus emiliae, pugnose minnow		2.89	1.25	2.93
Pimephales vigilax, bullhead minnow	107.57	0.74	0.17	4.73

Table 6-2 (Con't)

Family/Species	Navigational		Reach III	Tributaries
	(7)	(19)	(12)	(15)
Family Catostomidae				
Carpiodes carpio, river carpsucker				
Erimyzon oblongus, creek chubsucker				
E. *succetta*, lake chubsucker		0.05		
Ictiobus bubalus, smallmouth buffalo				
I. *cyprincllus,* bigmouth buffalo				
I. niger, black buffalo				
Minytrema melanops, spotted sucker		0.63		0.80
Moxostoma poecilurum, blacktail redhorse				
Family Ictaluridae				
Ameiurus melas, black bullhead		0.26		
A. natalis, yellow bullhead		0.05		0.07
Ictalurus furcatus, blue catfish				
I. punctatus, channel catfish		0.95		0.07
Noturus gyrinus, tadpole madtom		0.21	0.08	0.93
N. nocturnus, freckled madtom				0.13
Pylodictis olivaris, flathead catfish	0.14			0.07
Family Esocidae				
Esox americanus, grass pickerel		0.95	0.75	0.60
E. niger, chain pickerel		3.16	0.92	2.07
Family Aphredoderidae				
Aphredoderus sayanus, pirate perch		2.95	0.83	2.07
Family Cyprinodontidae				
Fundulus chrysotus, golden topminnow		1.73		0.07
F. dispar, starhead topminnow		3.79	0.08	0.27
F. notatus, blackstripe topminnow	1.29	6.47	10.50	6.27
F. olivaceus, blackspotted topminnow				
Family Poeciliidae				
Gambusia affinis, mosquitofish	62.57	30.21	9.58	24.60
Family Atherinidae				
Labidesthes sicculus, brook silverside	59.86	20.47	40.83	11.60
Henidia beryllina, inland silverside	21.00			
Family Percichthyidae				
Morone chrysops, white bass				
M. *mississippiensis*, yellow baas				
M. *saxatilis*, striped bass				
M. *chxysops X saxatilis,* hybrid				

Table 6-2 (Cont)

Family/Species	Navlgatfonal	Reach		Tributaries
	I		III	
	(7)	(19)	(12)	(15)
Family Ccntrarchidae				
Cencrarchus macropcerus, flier				
Elassoma zonacum, banded pygmy sunfish		0.74	0.08	0.07
Lepomis auritus, redbreast sunfish				
L. cyanellus, green sunfish			0.08	0.07
L. gulosus, varmouth		2.00	0.17	0.67
L. humilis, orangespotted sunfish	0.57			
L. macrochirus, bluegill	3.14	22.89	17.75	2.87
L. margInatus, dollar sunfish		3.10	3.25	1.40
L. megalotis, longear sunfish	6.43	8.84	3.83	0.87
L. microlophus, redear sunfish	1.29	3.63	6.58	2.27
L. puncTatus, spotted sunfish	0.43	4.16	3.25	5.00
L. symmeTricus, bantam sunfish		1.10		0.27
L. punccacus X megalotis, hybrid sunfish		0.32	0.25	
L. SPP., juvenile sunfishes		34.53	8.33	2.47
icropterus punctulatus, spotted bass	3.14	0.42	0.92	0.27
M. salmoides, largemouth bass	1.43	5.84	3.33	0.80
Pomoxis annularis, white crappie		0.10	0.08	
P. nigromaculatus, black crappie			0.42	0.07
Family Percidae				
Ammocrypta vivax, scaly sand darter	0.29	0.63	1.50	1.33
Etheostoma asprigene, mud darter		0.37	0.92	0.33
E. chlorosomum, bluntnose darter		2.63	1.33	5.60
E. fusiforme, swamp darter				
E. gracile, slough darter.				
E. hiscrio, harlequin darter		0.16	1.17	0.67
E. parvipinne, goldstripe darter				
E. proliare, cypress darter	0.29	3.26	1.33	7.47
E. whipplei, redfin darter				
Percina caprodes, logperch		1.47	2.00	1.00
P. maculata, blackside darter		1.63	1.08	1.80
Percina sciera, dusky darter	0.43		0.83	0.20
P. shumardi, river darter				
P. spp., juvenile darters		0.16		0.33
Family Sciaenidae				
Aplodinocus grunniens, freshwater drum				

54. Spotted sunfish *(Lepomis puncatus)*, ribbon shiner *(Lythrurus fumeus),* cypress darter (*Etheostoma proeliare*), bluntnose darter (E. chlorosomum), pickerel (*Esox spp.)* blackside darter (*Percina maculata*), and logperch (P. *caprodes)* were moderately abundant (Table 6-2). These species cumulatively comprised 9 percent of fish collected but were common only in Cypress Bayou.

55. Abundance and community structure of fish assemblages were highly variable among sites, but significant differences among locations were not pronounced. Total number of fish/sample ranged from 25-1,025 individuals: richness ranged from 7-29 species, Shannon functions from 0.95-2.89, and evenness from 0,43-0.94 Abundance was significantly higher in the lower reaches than in upper Big Cypr Bayou and the tributaries (Figure 6). There were no significant differences among locations in species richness, but Twelvemile Bayou exhibited significantly lower diversity and evenness.

56. The wide ranges of community metrics, with few differences among locations reflected the substantial temporal changes in composition of the fish community. To compensate for this, we partitioned data into spring and summer data sets. Water temperature was significantly lower in spring (22° C) than summer (270 C), and total numbers of fishes were significantly lower in spring (124/sample) thar summer (290/sample).

57. Multiple regression analyses generated the following habitat-based models for richness and evenness components of species diversity:

Richness

Spring S = 26.243 + 0.167(Turbidity) l 0.027(Width) - 3.726(Velocity) - 0.922(Temperature) R2 = 0 .

Summer S = 21.583 + 0.033(Width) = 1.739(Dissolved oxygen) R2 = 0

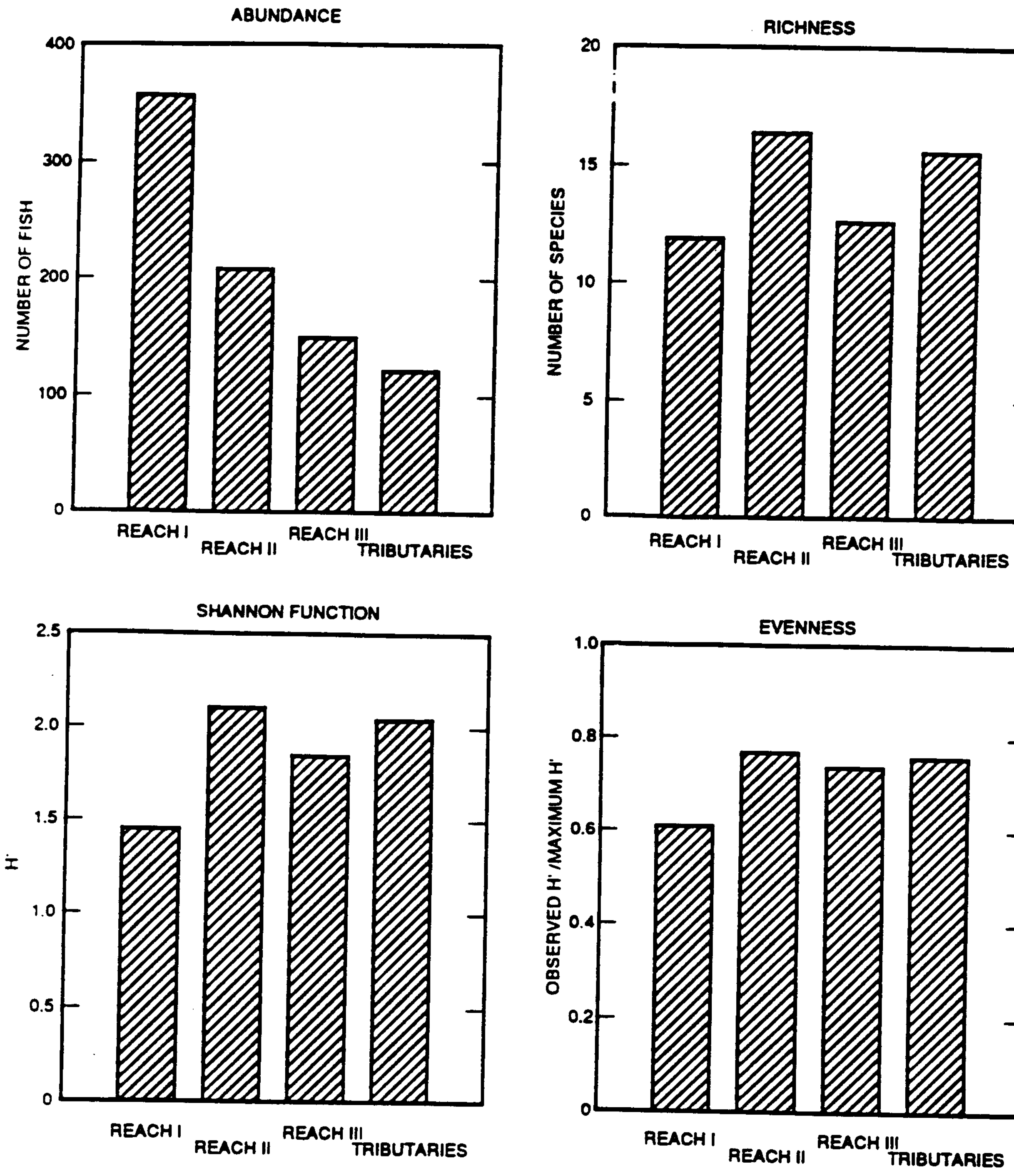
Evenness

Spring E = 0.866 - 0.001(Conductivity) R2 = 0

Summer E = 0.692 - 0.039(pH) -0.001(Conductivity) - 0.019(Depth) R2- 0,

58. These equations indicate that, in spring, greater numbers of species were found at turbid, wider channels in slower, cooler water: species were more equally abundant in waters of low conductivity. In summer, greater numbers of species were found at wider channels with lower dissolved oxygen; species were more equally abundant in waters of lower pH and lower conductivity, and at wider channels.

59. It appears counter-intuitive to find, during summer, greater numbers of species at lower concentrations of dissolved oxygen, and greater equitability in abundance at lower pH. Hypoxia (Dissolved oxygen < 4 ppm) and strongly acidic


ABUNDANCE
NUMBER OF FISH
400
300
200
100
0
REACH I
REACH II
REACH III
TRIBUTARIES
RICHNESS
NUMBER OF SPECIES
20
15
10
5
0
REACH I
REACH II
REACH III
TRIBUTARIES
SHANNON FUNCTION
H'
2.5
2.0
1.5
1.0
0.5
0
REACH I
REACH II
REACH III
TRIBUTARIES
EVENNESS
OBSERVED H'/MAXIMUM H'
1.0
0.8
0.6
0.4
0.2
0
REACH I
REACH II
REACH III
TRIBUTARIES

conditions (Ph < 6.5) were not recorded during this time. Also, it seems likely to assume that fish assemblages are adapted to these seasonally occurring conditions.

60. Different factors may influence diversity during different times of the year, but it is interesting to note that the models consistently identified a positive correlation between species richness and stream width, and a negative correlation between evenness and conductivity. If the proposed project does not affect the water quality parameters listed, and since width will increase, it is unlikely that species diversity would be adversely affected.

61. Channelization frequently results in higher turbidity (e.g., sediments washed in from unstable banks). In the Cypress Bayou and Twelvemile Bayou, turbidity is typically low to moderate (15-60 NTU's), but is an important correlate of fish community structure (this study; also see Killgore et al., 1991). Consequently, local fish assemblages could be particularly susceptible to any project-induced changes in turbidity, and impacts would be significant. If changes in any water quality parameter, especially turbidity, are predicted, a model incorporating hydraulic and water quality factors should be implemented (Killgore et al., 1991).

CONCLUSIONS

62. Ichthyofauna of the study area consists of more than 80 species and assemblages at individual stations are frequently complex. Diversity is correlated with hydraulic and water quality parameters.

63. Habitat losses for reservoir species are not anticipated.

64. Negative impacts to fish habitat in streams will be negligible. Evaluation species prefer slow, shallow water with cover. Although, channelization will increase depth and reduce cover within the navigation channel, the creation of a double channel in Reach II and channel enlargement in Reaches I and III will preserve high quality habitat and increase total habitat volume. Gross habitat gains were demonstrated for all species, presuming no significant change in **other** physical parameters (e.g., temperature, water quality).

65. Negative impacts to flood plain habitat will be substantial. Evaluation species mature in three years or less, so 2-year flood frequencies affect all generations; most actively exploit flood plains as spawning and rearing habitat..

66. Impacts on fish habitat are presumed irreparable for life of project. Mitigation requirements for the system are:

Reservoir	0 acres
Flood plain	3,646 acres
Stream	0 acres

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