The Effect of the Lake Chicot Renovation Project on the Fishery of a Mississippi River Oxbow Lake

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Abstract: A renovation project on Lake Chicot, a 1,417-ha Arkansas oxbow lake, was undertaken to improve water quality and fisheries productivity negatively impacted by surrounding agricultural land and ensuing drainage. A 1920s levee and drainage project that added 90,653-ha of catchment area to the inflow of Lake Chicot also increased agricultural acreage from 10% to 80% of the lake's watershed. This resulted in a substantial increase in turbidity in the lake (from 40 to 400 NTU), negatively affecting the sportfish populations, especially the largemouth bass. In the late 1980s, the Army Corps of Engineers and the Arkansas Game and Fish Commission initially aided lake water quality by drawing down the lake and seeding the exposed lake bottom. A fish population adjustment using rotenone was also conducted by the Arkansas Game and Fish Commission to bring back a desirable lake fishery. In excess of 70,500 kg of fish, mostly shad, stunted catfish, carp and buffalo, were removed from the lake. The Corps of Engineers constructed a multimillion dollar diversion system and pumping plant to divert turbid and polluted water from an agricultural watershed from entering the lake. This cooperative program reduced turbidity, total solids and suspended solids significantly. Better water quality resulted in positive changes to key species in the lake's fishery, especially largemouth bass, bluegill, and channel catfish. As a result, the state's largest natural lake is once again a productive sport fishery attracting in-state and out-of-state recreationists.

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Lake Chicot is a 600-year-old oxbow lake of the Mississippi River located in the extreme southeast corner of Arkansas. The lake is 1,417 ha in area, making it the largest natural lake in Arkansas, with a maximum depth of 9.2 m and a mean depth of 4.2 m. Up until the early 1900s, Lake Chicot was a productive channel scar lake with little pollution and a reputation as an excellent black bass fishery. In 1926, the local drainage district began a project to install a major portion of the Mississippi River mainline levee in the vicinity of Lake Chicot and to lower the level of Macon Lake, a system which lies north of Lake Chicot, by connecting the 2 lakes (Fig. 1). The drainage district then lowered the lake's natural spillway to enhance drainage. Water flow subsequently eroded the spillway, and Lake Chicot was lowered 2.1 m below its natural level.

In 1927, a major Mississippi River flood heightened drainage problems in the area. Because of this flooding, 2 canals were later excavated into Macon Lake and thus through Connerly Bayou into Lake Chicot, adding 90,653 ha of catchment area to the inflow of Lake Chicot (Fig. 1). Drainage projects, together with post-World War II machinery improvements, increased the amount of the lake's catchment area

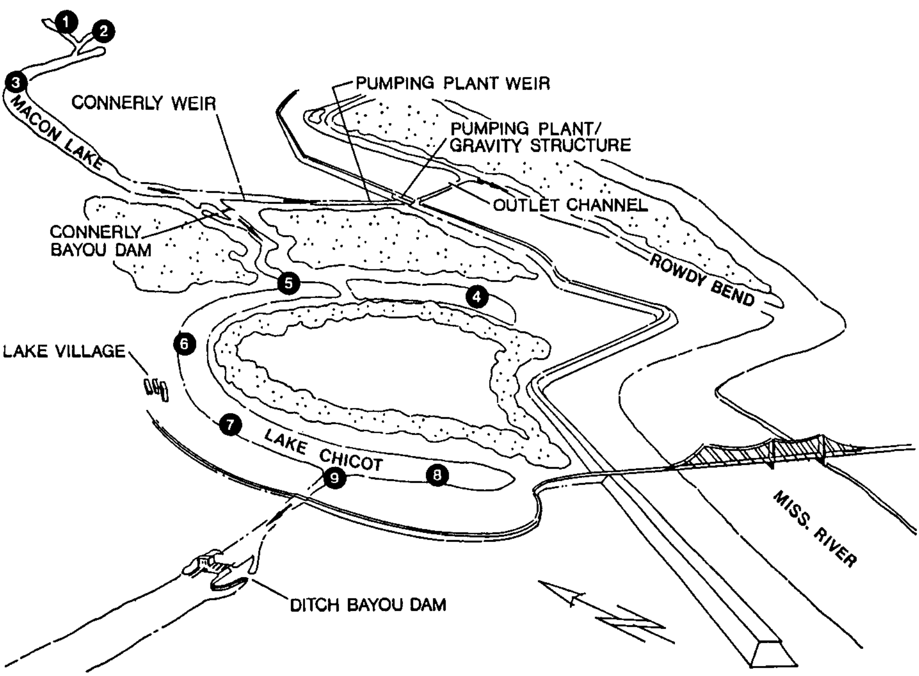

Figure 1. Map of Lake Chicot, Arkansas, showing project structures and sampling stations. Station 1 = canal No. 43, 2 = Clay Bayou, 3 = Macon Lake, 4 = Upper Lake Chicot, 5 = Connerly Bayou (inflow), 6 and 7 = mid Lower Lake Chicot, 8 = lower Lower Lake Chicot, 9 = Ditch Bayou (outflow).

used for agriculture. This resulted in a substantial increase of silt, nutrients, and biocides flowing into the lake.

This situation, combined with the fluctuations in the lake level due to inadequate flow control, resulted in a severe turbidity problem. While no turbidity readings were recorded in the 1920s, the upper lake's recent turbidity readings can be used as a surrogate for the lower lake's pre-drainage project turbidity levels because the upper lake was later isolated from the impacts of the levees on the lower lake by a dam. Using this value, turbidities increased from an average of 40 to 400 NTU in the lower lake following the 1920s drainage project. The lake's sport fishery declined (U.S. Fish and Wildl. Serv. 1954), and the regionally renowned largemouth bass (*Micropterus salmoides*) fishery became almost non-existent.

In 1948, the Arkansas Game and Fish Commission (AGFC) constructed a dam across Lake Chicot above the mouth of Connerly Bayou in order to isolate a portion of the lake from silt and pesticide loads and to enhance the water quality of this upper end of the lake. As a result, the upper one-fourth of Lake Chicot (hereafter referred to as Upper Lake Chicot) became and remains a relatively clear yet productive sport fishery (Fig. 1).

As a result of engineering studies by local, state, and federal agencies from 1940 to 1963 regarding the management of the lake (U.S. Fish and Wildl. Serv. 1954), the following conclusions were made:

1. Silt and pesticide pollution were hypothesized to be the factors limiting sport fish production in Lower Lake Chicot.

2. The federal government had an interest and legal obligation in mitigating project-related losses of recreation at Lake Chicot and in providing flood control benefits in the Bayou Macon Basin.

3. A pumping plant, water control dams, and diversion structure, that would divert high, turbid inflows from Lake Chicot into the Mississippi River, built on the levee east of the lower end of Macon Lake (Fig. 1) was the most feasible solution to the lake's problems.

4. The minimum lake elevation should be raised to further reduce the turbidity and to enhance boating and fishing.

5. The federal government would pay the majority of the costs for the construction of the pumping plant while local interests would be responsible for one-half of the recreational costs, plus all the operational and maintenance costs for the recreational facilities.

The objective of the renovation project was to improve the water quality of Lake Chicot and return the fishery to its previous status as a popular sport fishery. This project was initially authorized in 1968 by the U.S. Congress. Funding for the project was $67 million in federal funds, matched by $1 million of local sponsorship, $500,000 from Chicot County, and $500,000 provided by the AGFC.

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Methods

The Lake Chicot Pumping Plant was completed in 1985 and was designed to reduce pesticides, the heavy suspended sediment, and turbidity levels by diverting inflows into Lake Chicot from Connerly Bayou greater than 10.3 cms into the Mississippi River.

A 2-stage drawdown of Lake Chicot from 32 m above mean sea level (msl) to 30 m msl began in July 1985 with the final drawdown level of 29 m msl reached by August. The major purposes of this drawdown were to expose the bottom sediments to oxidation and precipitate out suspended solids and to concentrate the fish population of the lake for removal of stunted channel catfish (*Ictalurus punctatus*), abundant common carp (*Cyprinus carpio*), and buffalo (*Ictiobus* spp.) by rotenone. In order to expedite fish concentration and facilitate reduction, 1,818 kg of catfish feed, 455 kg of alfalfa pellets, and 455 kg of cottonseed meal were distributed in selected areas of the lake in early September. A rotenone fish population adjustment was conducted in late September with the application of 3,862 liters of 5% liquid rotenone. An estimated 800 boats and 3,000 people participated in the fish reduction. A total of 50 of these boats were randomly surveyed as they left the lake and the fish removed by the public identified, counted, and weighed. In addition, a shoreline estimate of fish killed but not removed by the public was conducted using the AGFC's rotenone subsampling methodology (Armstrong 1988).

Prior to and following the rotenone application, the AGFC seeded the lake bottom with 1,773 kg of winter wheat and 5,864 kg of sorghum sudan grass. This was done to establish a quick ground cover on the exposed lake bottom, solidify bottom sediments, and assist in the release of tied up bottom nutrients.

Since little open water centrarchid habitat was left in the lake, the AGFC installed 36 PVC pipe fish shelters (3 × 3 × 3 m) throughout the lake. Because fish concentration and angler utilization were 2 primary reasons for the placement of these structures, they were marked with readily visible buoys.

Since black bass were practically non-existent in the lake and to aid in the establishment of a diverse sport fishery, the AGFC stocked Lake Chicot with a variety of sport fish after the lake had detoxified. Over the period 1985–88, the following fish species were stocked into the lake: 73,935 Florida largemouth bass, 28,200 northern largemouth bass, 65,000 redear sunfish (*Lepomis microlophis*), 25,100 bluegill sunfish (*Lepomis macrochirus*), 10,000 crappie (*Pomoxis* spp.), 19,000 blue catfish (*Ictalurus furcatus*), and 25,675 channel catfish. The catfish were mostly catchable size (>308 mm TL) when stocked.

Water quality sampling was begun in July 1976 by the Vicksburg District Corps of Engineers. Nine stations were initially established for water quality analysis including inflow, main lake, and outflow (Fig. 1). Three of the sites (1, 2, and 8) were eliminated from the sampling program after 1 year since data analysis indicated no additional information was being collected from them that was not already covered with the other 6 sites. Eight water quality parameters were measured at these stations every 16 days from 1976–1987. These parameters were turbidity (NTU), secchi depth (m), total solids (mg/l), suspended solids (mg/l), nitrate (mg/l), chlorophyll A (ug/l), orthophosphorous (mg/l), and total phosphorous (mg/l). Procedures for determining these parameters conformed to standard methods used on all U.S. Army Corps of Engineers (USACE) projects (Am. Public Health Assoc. 1975, Environ. Protection Agency 1979). Differences in water quality parameters were tested for significance ($P < 0.05$) by performing an analysis of variance (ANOVA) on data from stations 3, 4, 7, and 9 (SAS Inst. 1982). All pre-project data (before 1985) were lumped together by station and post project data were lumped by station. This resulted in 8 separate sets of means and each were treated as independent stations or data sets and compared for similarities. Pre- and post-project means for each station were compared between years and between stations. These stations represented critical sites to monitor due to their location within project boundaries (Fig. 1). Results were tabulated and station means ranked and grouped using Duncan's multiple range test.

Cove rotenone samples were conducted (1/year) prior to (1973, 1981, 1984) and following (1986, 1987, 1988) the lake's renovation. Rotenone samples were carried out generally as described by the Reservoir Committee, Southern Division American Fisheries Society (Surber 1959) and the Arkansas Game and Fish Commission's standardized sampling procedures (Armstrong 1988). Data were compiled and analyzed using microcomputer programs that produce length frequency plots, biomass estimates, and available prey-predator relationships developed by Jenkins and Morais (1978) (Bivin et al. 1989). Significant differences in various components of the fishery before and after project completion were determined with *t*-tests. Differences in fish species structure before and after the project were tested using the Kolmogorov-Smirnov test. Shoreline seining was conducted to assess the relative abundance of young-of-the-year largemouth bass and to identify available small forage to determine the need for supplemental bass stocking. Sampling was conducted with the use of a 6.1 × 1.8 m beach seine with 3.2 mm mesh according to Arkansas' standardized sampling procedures (Armstrong 1988). Most sampling occurred between late May and mid June and permanent sampling sites were established when possible. A total of 12.2 m of shoreline at each of 5 different sites was sampled using quadrant seining and the fish sorted by species and size group.

An extensive monitoring of black bass tournaments held before versus after the renovation was conducted for 3 years before and 3 years after project completion. This included recording the numbers of bass tournaments reported in area newspapers as well as voluntary reports of bass tournament results by bass club members. A 2-sample Rank Sum test was performed on the data to detect differences. This analysis was used as an index to the number of bass tournaments held on the lake because it was realized that not all bass tournaments were monitored before or after the renovation. Statistical analyses for all of the above tests were done with SAS (SAS Inst. 1982).

Results

Water Quality

Analyses of pre-project and post-project Lake Chicot water quality data indicated marked changes (Table 1), some of which have been previously reported (Nix and Schiegbe 1984, Johnson 1988). Station means for turbidity were divided into 2 clearly different groups. Stations 3, 7, 9, and post-project 3, identified in Figure 1, were significantly higher ($P < 0.05$) than the means from station 4 and post-project 4, 7, and 9. The mean turbidity at station 7, lower Lake Chicot, dropped from 148 to 12 NTU. Results for total and suspended solids were similar for station 7, decreasing from 347 to 185 mg/l and 142 to 17 mg/l respectively. As with turbidity, post-project means for total and suspended solids from stations 7 and 9 grouped with the means from station 4 (pre- and post-) and were significantly lower than their pre-project means and the station 3 means. Looking at the map of the project area (Fig. 1), it can be seen that stations 3 and 4 represent the extreme conditions and are the stations that should be unaffected by the project. Stations 7 and 9 represent the stations where the greatest changes should be detected if the project was successful. Secchi transparency means grouped with stations 3, post-project 3, 7, and 9 being significantly lower than all other stations. Additionally, the post-project mean for secchi transparency at station 7 (lower Lake Chicot) was significantly higher than all other stations, indicating the water clarity was much greater at this station than all others. Spatial and temporal differences in the station means for nutrients and chlorophyll A were less evident. Significant decreases in both nitrate and orthophosphorous means in lower Lake Chicot and Ditch Bayou were recorded. Similarly, significant increases in the means of chlorophyll A at those stations were observed. A significant drop in nitrate at the inflow (Macon Lake-site 3) resulted in its post-project mean being grouped with the other post-project stations and the pre-project upper lake. Lower Lake Chicot and Ditch Bayou displayed significant differences for all 8 parameters tested for pre- and post-project conditions.

Fish Population Adjustment

Total biomass of fish removed during the rotenone adjustment was 70,588 kg (349 kg/ha), with shad (*Dorosoma* spp.), catfish, buffalo, and carp the most prevalent fish collected. Only 2 largemouth bass were observed from all the fish collected and reported.

Rotenone Sampling

Comparison of rotenone data of the before project samples with the post project samples demonstrated significant changes in the fish community, especially the largemouth bass component, total forage fish biomass, and the structure of several species. Table 2 illustrates numeric and biomass means on an areal basis for selected fish species in lower Lake Chicot. Standing stock of largemouth bass, virtually non-existent in the lake before project initiation, increased significantly at the 0.05 level after project initiation ($P = 0.02$). The size structure of bass is shown in Fig. 2.

Table 1. Results of the 1-way analysis of variance comparing the water quality at different sampling locations on Lake Chicot, Arkansas. The means at each station are ranked and grouped. The grouping was done using Duncan's multiple range test.

Turbidity (NTU)			Secchi depth (m)		
Group	Mean	Station[a]	Group	Mean	Station
A	235	7	A	0.59	7-P
A B	204	3-P	B	0.45	9-P
B	182	3	B	0.43	4
B	172	9	C	0.37	4-P
C	37	4	D	0.24	3
C	32	9-P	D	0.22	7
C	23	4-P	D	0.29	3-P
C	21.5	7-P	D	0.20	9

Total solids (mg/l)			Suspended solids (mg/l)		
Group	Mean	Station	Group	Mean	Station
A	517	3	A	254	7
A B	477	3-P	A	235	3
B	453	7	A B	202	3-P
C	284	9	B	148	9
D	200	9-P	C	41	4
D	189	7-P	C	33	4-P
D	171	4	C	29	9-P
D	171	4-P	C	20	7-P

Nitrate (mg/l)			Chlorophyll A (ug/l)		
Group	Mean	Station	Group	Mean	Station
A	0.487	9	A	66.267	4-P
A	0.474	7	B	44.457	4
A	0.450	3	B C	36.967	7-P
B	0.261	4	C	30.6	9-P
C	0.146	3-P	D	19.665	7
C D	0.088	4-P	D	19.128	3-P
D	0.045	7-P	D	14.011	3
D	0.032	9-P	D	10.975	9

Total phosphorus (mg/l)			Orthophosphorus (mg/l)		
Group	Mean	Station	Group	Mean	Station
A	0.428	3	A	0.087	7
A	0.474	7	A	0.077	9
A B	0.450	9	A	0.070	3-P
C B	0.261	3-P	A	0.069	3
C D	0.146	4	B	0.044	4
E D	0.088	4-P	B	0.037	7-P
E	0.045	9-P	B C	0.035	4-P
E	0.032	7-P	C	0.018	9-P

[a]Station 3 = Macon Lake, station 4 = Upper Lake Chicot, station 7 = Lower Lake Chicot, station 9 = Ditch Bayou, P = post project.

Table 2. *T*-test statistics for selected fish species means before (N = 3 years) and after (N = 3 years) the 1985 renovation project on Lake Chicot, Arkansas.

	Species	Mean N/ha	Mean kg/ha
Largemouth bass	Before	0.0	0.0
	After	255.4	29.4
	Prob. > t	0.17	0.02[a]
Bluegill sunfish	Before	953.5	11.1
	After	12,616.6	109.7
	Prob. > t	0.13	0.13
Channel catfish	Before	751.5	99.2
	After	241.8	93.3
	Prob. > t	0.16	0.17
Total all species	Before	17,196.1	376.7
	After	27,305.2	735.2
	Prob. > t	0.27	0.11

[a]Designates significant difference at 0.05 level.

Threadfin shad (*Dorosoma petenense*) structure shifted significantly (P = 0.001) after the renovation from most of the biomass being <75 mm TL to most of the population being >75 mm TL. (Fig. 3), perhaps a response to increased predation by largemouth bass. Bluegill structure improved significantly (Fig. 4) at the 0.10 level (P = 0.07) from very little biomass in any length group in 1981 (3 years before the renovation) to 57 kg/ha >150 mm TL in 1988 (3 years after the renovation). Other effects of the renovation and improvement in water quality and habitat included a significant increase (P = 0.000) in larger size groups (>375 mm TL) of channel catfish (Fig. 5). Total fish biomass doubled after project initiation, from 377 to 735 kg/ha. Most of the increase was in the forage fish component (*Dorosoma* spp., *Notropis* spp., young-of-year, and intermediate *Lepomis* spp.) of the system which showed a significant increase after the project at the 0.10 level (P = 0.10) (139 kg/ha vs. 516 kg/ha).

Shoreline Seining

Shoreline seining results were more qualitative than quantitative, giving an index to stocking and reproductive success of largemouth bass in Lake Chicot. Catch per unit effort data from the seining showed an increase in numbers of young-of-year (YOY) largemouth bass caught per seine haul from 0 in the pre-renovation years to 0.4 per haul in the post-renovation years. Intermediate largemouth bass also increased from 0/haul to 1.3/haul in pre- vs. post-project sampling. YOY sunfish were also more abundant after project initiation indicating a better forage base for the young largemouth bass after the renovation project. YOY sunfish increased from 1/seine haul in the pre-renovation years to 5.3/haul in the post-project years.

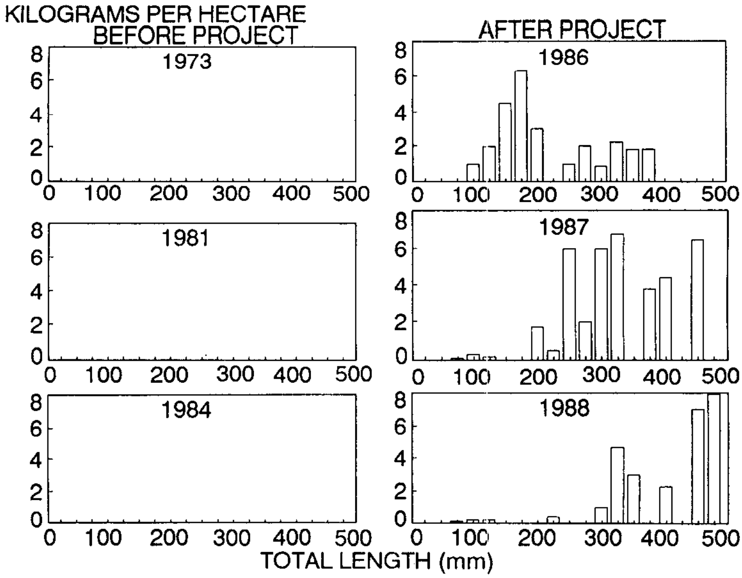

Figure 2. Largemouth bass biomass by length group before and after project initiation at Lake Chicot, Arkansas.

Bass Tournament Monitoring

There was an obvious and significant increase ($P = 0.05$) in the relative number of black bass tournaments held before versus after the renovation project on Lake Chicot. The mean number of bass tournaments held before project initiation was 0. After project completion, the mean number of bass tournaments had increased to 60/year. Since it was not possible to conduct creel surveys on Lake Chicot before or after project initiation, these data give an index to perceived and actual benefits to the largemouth bass fishery as a result of the renovation project.

Discussion

Improvements in water quality and fisheries have occurred due to the cooperative renovation/pumping plant project on Lake Chicot. The Lake Chicot Project consisted of several components that meshed together to make up the successful program. The first was the lake drawdown to expose large portions of the lake bottom to oxidation of bottom nutrients. This drawdown allowed seeding of the lake bottom for future nutrient release, compaction of bottom sediments, and flocculation of suspended solids from the water column, initially improving the lake's water quality. The second component of the project was the fish population reduction that thinned overabundant, stunted crappie, shad, sunfish, and catfish and, along with fish stockings, brought the fish population back to a more desirable state. The third

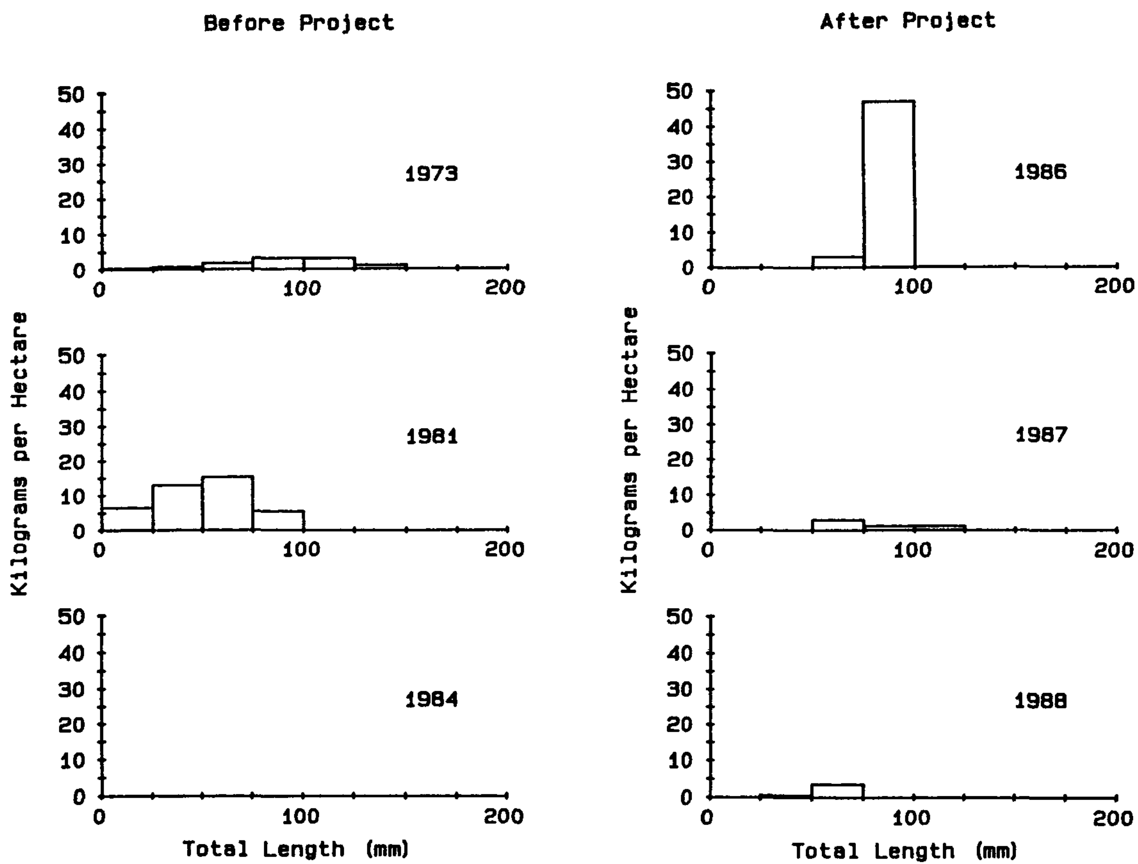

Figure 3. Threadfin shad biomass by length group before and after project initiation at Lake Chicot, Arkansas.

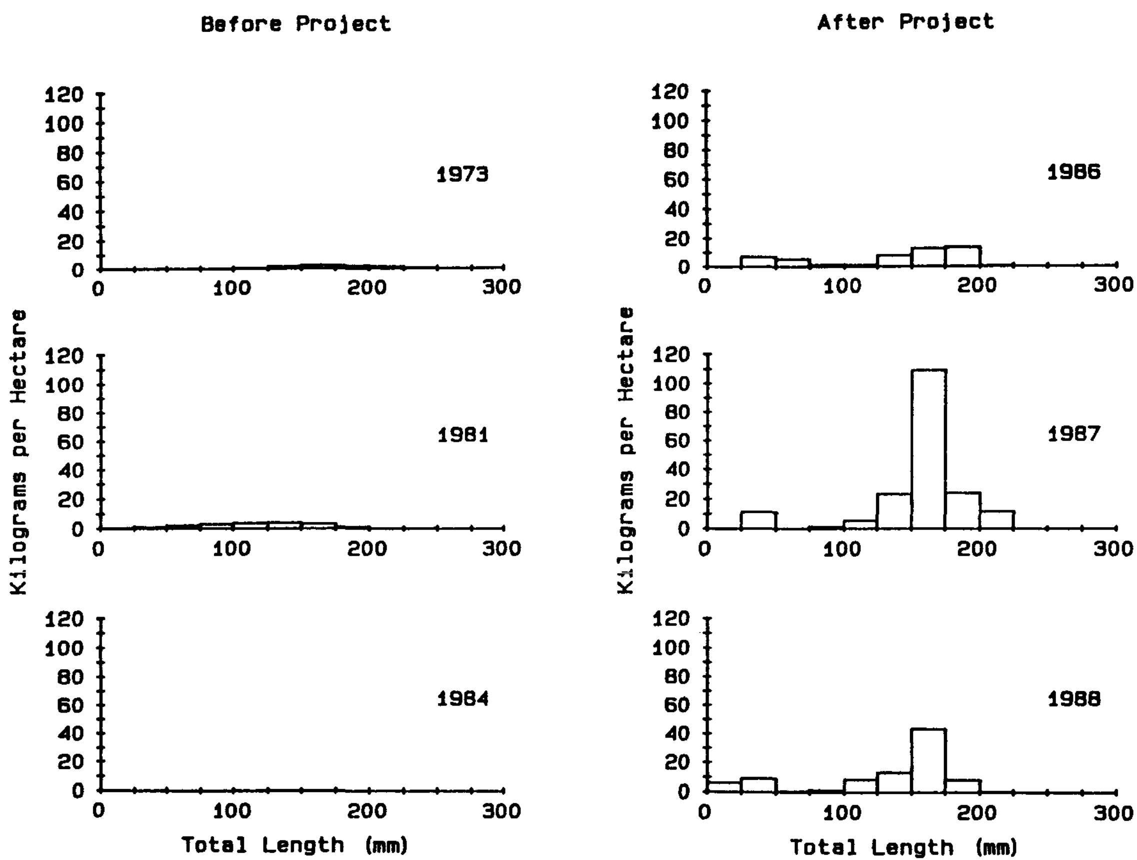

Figure 4. Bluegill biomass by length group before and after project initiation on Lake Chicot, Arkansas.

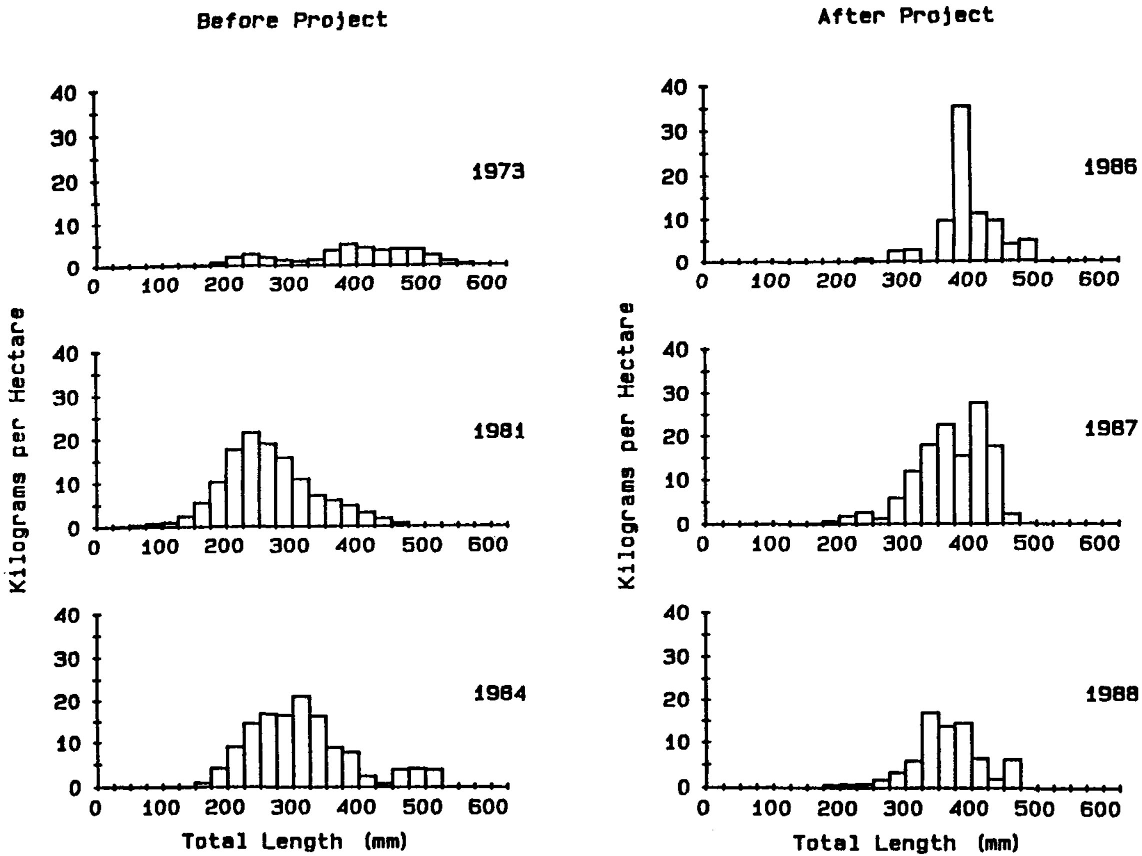

Figure 5. Channel catfish biomass by length group before and after project initiation on Lake Chicot, Arkansas.

project component was the construction and operation of the pumping plant that diverted turbid and polluted water away from the lake and maintained improved water quality (Price et al. 1984). The pumping plant was the most costly link in the plan. However, all 3 components were essential for a successful lake rehabilitation. For example, previous work in Arkansas and other states has shown drawdowns and rotenone renovations to substantially benefit lake fisheries (Mathis and Hulsey 1959, Lennon et al. 1971, Rider and Limbird 1978, Filipek 1980). However, these benefits can be relatively short-term in effect (3–5 years), and a lake may revert to the original unbalanced condition if the problems causing the original fishery imbalance are not ameliorated. One of the major advantages of the Lake Chicot Project is that the problems causing the initial imbalance in the sport fishery, the influx of silt and pesticide runoff from watershed development and associated land uses, could be controlled and diverted to the Mississippi River without affecting the lake. The Mississippi River was the final destination of water flowing out of Lake Chicot before so there has been little net increase in siltation to the Mississippi.

The rejuvenation of the lake's largemouth bass population can be attributed to improved water quality, an increase in available forage, and corrective stockings of the lake. The other adjustments to other portions of the fish population, and especially to their individual population structures, can be at least partially attributed to increased predation by the growing largemouth bass population.

While not scientifically based, monitoring of the public's response to the Lake Chicot Project has been interesting. Renovation of the lake has brought a large number of bass tournaments to the lake and it has not been unusual for these events to be won by heavy stringers of largemouth bass. This kind of news is the best type of public relations for an area and the vast improvement in the lake's fishery has attracted in-state and out-of-state publics, creating an improved housing and land market. In fact, land values around the lake have doubled since the renovation project and there has been an increase in tourism in Chicot County (Johnson 1988). The scope of work accomplished at Lake Chicot may not be feasible on a large number of similarly degraded lakes due to financial constraints. The cost:benefit ratio on such a project is difficult to ascertain. If nothing else, the high costs involved in remediation work on Lake Chicot reinforce the need for the use of Best Management Practices (Haugen 1983) for both point and non-point pollution problems. Nevertheless, the Lake Chicot project stands out as a noteworthy example of the benefits to a lake that can be derived from state and federal agencies cooperating towards a mutually beneficial goal both for the public and the resource.

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