A Classification of Louisiana Lakes Based on Historical Rotenone Data

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Abstract: Fish standing crop data from rotenone surveys of 43 Louisiana lakes from 1969 to 1989 were analyzed in an effort to classify them for fisheries management purposes. Total fish, largemouth bass (*Micropterus salmoides*), and >30-cm largemouth bass standing crops averaged 207.7, 11.8, and 7.7 kg/ha, respectively. Results from these rotenone surveys were compared to those of similar studies in the 1950s when Louisiana lakes were placed into habitat categories. Standing crops were compared to various water-quality parameters; they were positively correlated to chlorophyll-*a* levels. Standing crops of fish were affected by the location of the lake within land resource areas in Louisiana. Higher fish biomass occurred more often in lakes associated with the fertile soils of the Southern Mississippi Valley Alluvium than with the Southern Coastal Plain region of the state.

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Louisiana fisheries biologists have sampled fish populations in the state's natural lakes and impoundments using rotenone since the 1950s. Lambou and co-workers reported survey results in a series of papers for backwater lakes, tributary impoundments, oxbow lakes and alluvial floodplain lakes of Louisiana (Lambou 1959*a,b,* 1961; Lambou and Geagan 1961).

Many impoundments have been constructed in the intervening years, including the state's only mainstream impoundment, the 74,500-ha Toledo Bend Reservoir, between Louisiana and Texas. In 1959, Louisiana had only 15 impoundments (35,563 ha) whereas by 1991 there were 36 impoundments >200 ha for a total of 143,617 ha. Thus, we felt that an analysis of Louisiana's historical rotenone data was timely.

The purpose of this study was to classify Louisiana lakes and impoundments as to their productivity and fishery potential through analyses of rotenone sample data. A primary intent of this study was to update and expand upon the lake classification scheme of Lambou in the 1950s because so many impoundments have been constructed since then. Lambou found differences in fish abundance among various lake categories (i.e., backwater lakes, tributary impoundments, oxbow lakes, and alluvial floodplain lakes). He speculated that these difference were related to lake fertility, among other factors. Therefore, another purpose of this study was to relate fish standing crop to lake fertility and water quality. The overall intent of the study was to provide the Inland Fisheries Division of the Louisiana Department of Wildlife and Fisheries (LDWF) with a sound basis upon which to make informed fisheries management decisions such as the stocking of Florida largemouth bass and application of length-limit regulations. Intensive management for specific fisheries (e.g., trophy largemouth bass) should be directed at lakes having the greatest potential for success.

We acknowledge the efforts of the many LDWF field biologists and co-workers who took the fish samples over the 21-year period covered by this study, and we thank the fisheries administrators, especially Mr. Gary Tilyou, who allowed us to analyze this historical, statewide database.

Methods

Fisheries data used in these analyses were collected by fisheries biologists of the LDWF in 94 lakes from 1969 to 1989. Rotenone samples were taken in late summer according to the procedure described by Lambou and Stern (1958). One ppm emulsifiable rotenone was applied to 0.4-ha sites contained by blockoff nets. Fish were collected over a 2-day period, sorted by species and were sorted into the following size-length classes 0–3.80, 3.81–6.34, 6.35–8.88 cm, etc., and then weighed in lots or individually. The dataset included over 130,000 records of fish weighed by 2.54-cm classes; this amounted to 512 lake-year combinations. The data were manipulated and analyzed with PC SAS (SAS Inst. 1988).

Because of large annual fluctuations in standing crops for some lakes, we used geometric means of annual values for computing average lake standing crops. Geometric means, hereafter referred to as means or averages, were computed for total fish standing crops (all species), largemouth bass standing crops, and the standing crops of largemouth bass $>$29.2 cm total length (herein referred to as $>$30 cm). Average largemouth bass values only included years with $>$30-cm largemouth bass in the sample. Due to the variation in fish catch possible with rotenone sampling, we considered samples lacking $>$30-cm largemouth bass potentially unrepresentative of the lake.

We decided to restrict our study lakes to those which typified lakes in north and central Louisiana capable of supporting a substantial largemouth bass fishery. Lakes used in these analyses were selected according to the following criteria: (1) lakes must be $\geq$200 ha; (2) average largemouth bass standing crops must be $\geq$3 kg/ha; and (3) there must be multiple years of data for that lake, including more than 1 year with $>$30-cm largemouth bass in the sample. There were 43 lakes and 346 lake-year combinations which met these selection criteria; this amounted to 46% of the available lakes and 68% of the total lake-year combinations. Locations of the study lakes are shown in Figure 1.

The lakes were assigned to the categories described by Lambou (1959*a,b,* 1961) and Lambou and Geagan (1961) and the average standing crops of lakes in this study were compared to their findings. Total and >30-cm largemouth bass standing crops in this study were related to various water-quality parameters measured in Louisiana lakes in 1984 by the Louisiana Department of Environmental Quality (Malone and Burden 1985). Of the 30 lakes monitored in their study, 27 were common to this study. Water-quality parameters included total organic carbon (mg/liter), total phosphorus (mg/liter), total Kjeldahl nitrogen (mg/liter), chlorophyll *a* (μg/liter), Secchi disk transparency (m), and Carlson's Trophic State Index (TSI; Carlson 1977). Carlson's TSI is based upon Secchi disk transparency as related to algal biomass and further correlated to both chlorophyll a and total phosphorus concentrations (Carlson 1977, 1980). The TSI values used in this study were those for chlorophyll *a.* Water-quality parameters were measured 12 times over a 6-month period in 1984 in each of the lakes. Average water quality values for 1984 were compared with average standing

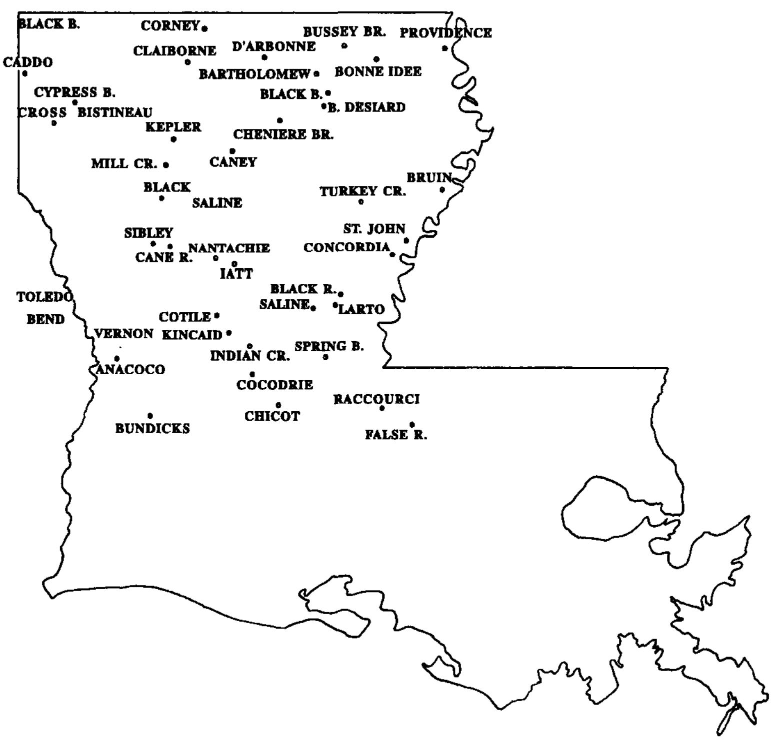

Figure 1. Location of study lakes in Louisiana.

crops of fish over the period 1979 to 1989. We restricted comparison of the fish sampling time frame to within 5 years of the 1984 water-quality samples to reduce the effects of any long-term changes in water quality. The 1-year results of water-quality parameters provided no information regarding annual or long-term variability.

Previous research in reservoirs indicates that fish biomass is related to water quality and fertility of the watershed (Jones and Hoyer 1982, Yurk and Ney 1989), and we are aware that soil fertility and surface water quality varies substantially in Louisiana. Soil types, forest types, crop production, and wildlife harvests all attest to this. Therefore, we sought to relate fish biomass to some measure of soil or habitat type in Louisiana. The measure we chose was the major land resource areas of Louisiana designation as depicted on a map (4-L-19104) by the Soil Conservation Service, U.S. Department of Agriculture. The basis for the land resource areas is soil type and topography. We plotted total standing crops and >30-cm largemouth bass standing crops on this map of land resource areas in Louisiana.

Statistical methods included Pearson's simple correlations to assess relations among total, largemouth bass, and >30-cm largemouth bass standing crops plus least squares quadratic regressions to assess relations of total and >30-cm largemouth bass standing crops to chlorophyll-*a* concentration. Because of the unbalanced nature of these survey data among lake categories (N = 3–25), we were concerned about violating distribution assumptions required by the parametric 1-way analysis of variance. Therefore, comparisons of total and >30-cm largemouth bass standing crops among lake categories were made using non-parametric Kruskal-Wallis and Dunn procedures (Zar 1984). The mainstream impoundment, Toledo Bend Reservoir, was not included in these statistical comparisons among lake types because it was the sole lake in its category. Alpha levels of 0.05 were used for all statistical procedures, but actual P values are reported.

Results and Discussion

Initial Findings

Average standing crop information for all species, largemouth bass, and >30-cm largemouth bass are given for each lake in Table 1. Simple averages of lake geometric means by lake for total, largemouth bass, and >30-cm largemouth bass standing crops were 207.7, 11.8, and 7.7 kg/ha, respectively. The 75th percentile values for each parameter were 293.0, 14.1, and 9.1 kg/ha, respectively.

We found a weak, positive relationship between largemouth bass and total standing crop (Fig. 2). Therefore, total standing crop alone appears to be a poor index of largemouth bass standing crop. In contrast, the correlation of >30-cm largemouth bass to total largemouth bass standing crop was strong and linear, as expected (Fig. 3).

Table 1. Geometric mean fish standing crops (kg/ha), by Lambou's lake categories, for 43 Louisiana lakes, 1969–1989. Lambou's arithmetic mean total standing crops are shown for comparison. LMB = largemouth bass.

Lake name	All species	All LMB	>30-cm LMB	Lambou[a]
Mainstream				
Toledo Bend Reservoir	270	25.8	15.9	
Tributary				
Anacoco Lake	55	4.1	1.9	
Black Bayou Lake (Caddo)	56	5.5	2.0	
Black Lake (Natchitoches)	110	4.6	2.9	
Bundick Lake	192	8.2	5.7	
Caddo Lake	130	3.7	2.5	
Caney Lake	114	11.2	1.7	
Cheniere Brake	131	14.1	9.0	
Chicot Lake	283	8.8	5.8	
Cocodrie Lake (Rapides)	204	4.5	3.2	
Corney Lake	80	6.2	3.4	
Cotile Lake	141	11.9	2.1	
Cross Lake	188	6.0	4.0	
Cypress Lake	144	7.6	3.5	
Darbonne Lake	160	11.0	6.5	
Indian Creek Lake	96	4.3	1.5	
Kepler Lake	80	10.1	3.2	
Kincaid Lake	214	11.5	4.0	
Lake Bistineau	146	6.7	5.0	
Lake Claiborne	141	11.3	6.5	
Lake Iatt	84	5.3	3.6	
Lake Nantachie	100	10.2	6.4	
Lake Vernon	60	11.6	2.9	
Mill Creek Lake	86	6.2	1.8	
Saline Lake (Winn)	36	4.3	3.1	
Sibley Lake	174	12.5	6.6	
Mean	128	8.1	4.0	82
Backwater				
Larto Lake	106	7.2	5.8	
Saline Lake (LaSalle)	208	4.7	3.0	
Turkey Creek Lake	293	6.0	4.4	
Mean	202	6.0	4.4	445
Alluvial Floodplain				
Bartholomew Lake	347	16.4	13.6	
Bayou Desiard	407	15.1	11.4	
Black Bayou Lake (Ouachita)	254	18.4	14.3	
Bonne Idee	245	15.9	12.5	
Bussey Brake	293	14.1	6.6	
Cane River Lake	432	18.6	13.1	
Spring Bayou	417	4.5	2.8	
Mean	342	14.7	10.6	494
Oxbow				
Black River Lake	211	10.4	9.0	
False River	318	30.9	22.8	
Lake Bruin	202	11.0	9.1	
Lake Concordia	440	56.6	50.1	
Lake Providence	328	7.1	5.0	
Lake St. John	440	25.8	21.4	
Raccourci Old River	513	15.9	10.0	
Mean	350	22.5	18.2	226

[a]Data from Lambou (1959*a*, *b*, 1961) and Lambou and Geagan (1961).

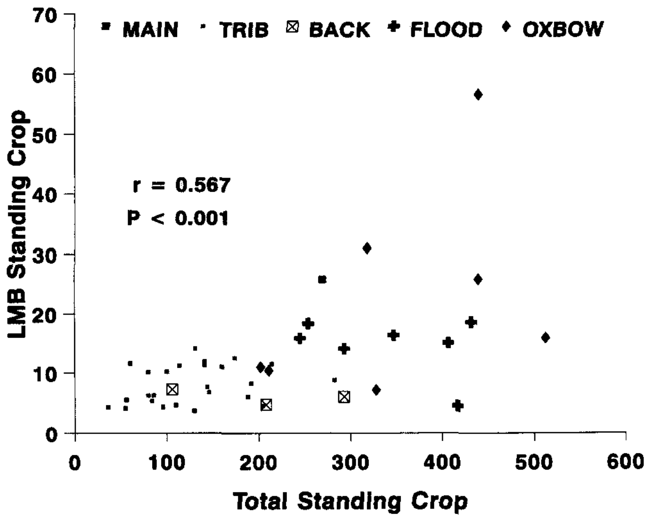

Figure 2. Relation of largemouth bass standing crop to total standing crop, both in kg/ha, for 43 Louisiana lakes. Lakes were categorized as backwater (BACK), tributary (TRIB), oxbow (OXBOW), alluvial floodplain (FLOOD), or mainstream (MAIN).

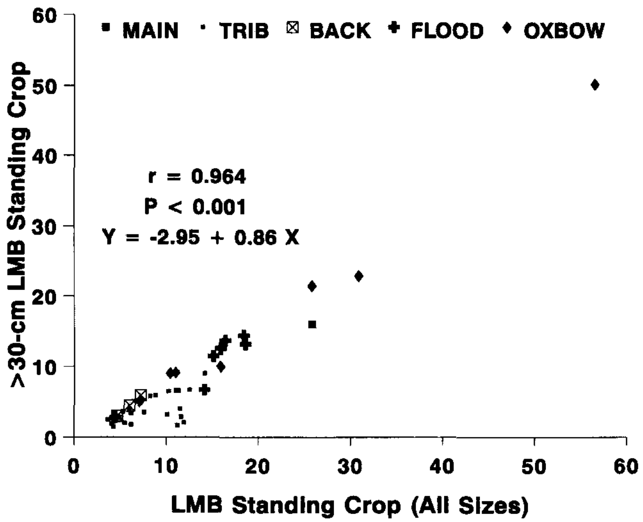

Figure 3. Relation of >30-cm largemouth bass standing crop to total largemouth bass standing crop, both in kg/ha, for 43 Louisiana lakes. Lakes were categorized as backwater (BACK), tributary (TRIB), oxbow (OXBOW), alluvial floodplain (FLOOD), or mainstream (MAIN).

Relation to Lake Category

Standing crop values from this study were compared to those reported by Lambou (Lambou 1959*a,b,* 1961; Lambou and Geagan 1961) in the 1950s for lakes of various categories. Direct comparisons were not always possible, however, due to construction of impoundments since that time and the fact that Lambou did not report individual lake information in many instances. Also, we may not have categorized each lake as he would have. Louisiana's mainstream impoundment, Toledo Bend Reservoir, was constructed after Lambou's studies, as were most of the state's tributary impoundments.

The following classifications of Louisiana lakes are as per those of Lambou. We tried to follow his scheme in categorizing the lakes used in this study. Backwater lakes are shallow, gently-sloping lakes generally <2,000 ha which receive periodic backwater from rivers and streams; aquatic vegetation is variable in these lakes, and crawfish are important in the diet of predaceous fish such as largemouth bass (Lambou 1959*a*). Alluvial floodplain lakes are shallow with gentle bottom slopes; they are <600 ha and have stable water levels (Lambou and Geagan 1961). Mississippi River oxbow lakes are deeper lakes <2,000 ha which no longer receive backwater or floodwater from the Mississippi River due to the construction of levees (Lambou 1961). These lakes have relatively steep slopes, sparse submersed aquatic vegetation, and abundant phytoplankton. Tributary impoundments are shallow reservoirs constructed in rolling to hilly topography; they are slightly acid lakes with calcium carbonate alkalinity <25 mg/liter and are characterized as generally clear with abundant submersed aquatic vegetation (Lambou 1959*b*).

We found high total fish biomass (about 350 kg/ha) in floodplain and oxbow lakes, but biomass in tributary impoundments averaged only 128 kg/ha (Table 1). Total standing crop was intermediate for backwater lakes and the mainstream impoundment (202 and 270 kg/ha, respectively). Differences in total standing crop among lake types in this study were significant ($P = 0.001$). Total standing crops were higher in floodplain and oxbow lakes than in tributary impoundments ($P < 0.001$), while backwater lakes were statistically similar to the other lakes.

Lambou reported total fish biomass was about 450–500 kg/ha in backwater and floodplain lakes (Lambou 1959*a,* Lambou and Geagan 1961), only about half that in oxbow lakes (Lambou 1961), and only 82 kg/ha for tributary impoundments (Lambou 1959*b*). Direct comparisons to Lambou's findings are of limited benefit because of differences in individual lakes studied and the use of slightly conservative geometric means here vs. arithmetic means by Lambou. What is valuable to the present study is Lambou's lake categorization scheme. In general, we conclude that total standing crops are similar for floodplain and oxbow lakes, whereas they are much lower for tributary impoundments; backwater lakes are intermediate.

We suspect that differences in total standing crops among lake categories are due to fertility of the watershed and retention time of water in the various lake types. Backwater, floodplain, and oxbow lakes are all located in watersheds with rich alluvial deposits, whereas the tributary impoundments drain relatively infertile soil areas of Louisiana. These are the same basic findings and conclusions reported by Lambou and Geagan (1961). Toledo Bend Reservoir is a mainstream impoundment on the moderately fertile Sabine River watershed, and its total fish biomass is only slightly lower than those of the alluvial lakes.

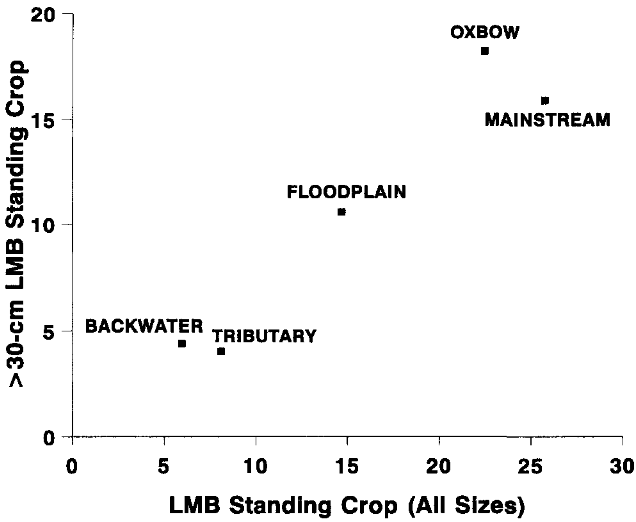

Figure 4. Lake category averages of >30-cm largemouth bass standing crop vs. total largemouth bass standing crop in 43 Louisiana lakes.

Standing crops of largemouth bass and >30-cm largemouth bass by category revealed a basically similar pattern (Table 1). Largemouth bass biomass was highest for Toledo Bend Reservoir and oxbow lakes, intermediate for floodplain lakes, and lowest for tributary impoundments and backwater lakes. Statistical comparisons were made only for the >30-cm largemouth bass because they were so closely related to total largemouth bass standing crops (Fig. 3). Overall differences were significant ($P = 0.001$). Floodplain and oxbow lakes had higher >30-cm largemouth bass standing crops than did tributary impoundments ($P < 0.01$), but backwater lakes were statistically similar to the other lakes.

A plot of the lake category averages for >30-cm largemouth bass vs. total largemouth bass standing crop indicates a linear relationship between these 2 factors (Fig. 4). Toledo Bend Reservoir and oxbow lakes are high on the graph, backwater lakes and tributary impoundments are lower on the graph, and floodplain lakes are intermediate. This clearly demonstrates the differences in both largemouth bass and >30-cm largemouth bass standing crops among the lake categories.

Relation to Water Quality

No other water quality parameter provided a more consistent relation to fish standing crop than chlorophyll *a*. Thus, only relationships to chlorophyll *a* are presented below. Total standing crop was positively correlated to chlorophyll *a* concentration in a quadratic fashion (Fig. 5). The relation between >30-cm largemouth bass standing crop and chlorophyll *a* also was positive and quadratic (Fig. 6), although the relationship was more variable than that for total standing crop.

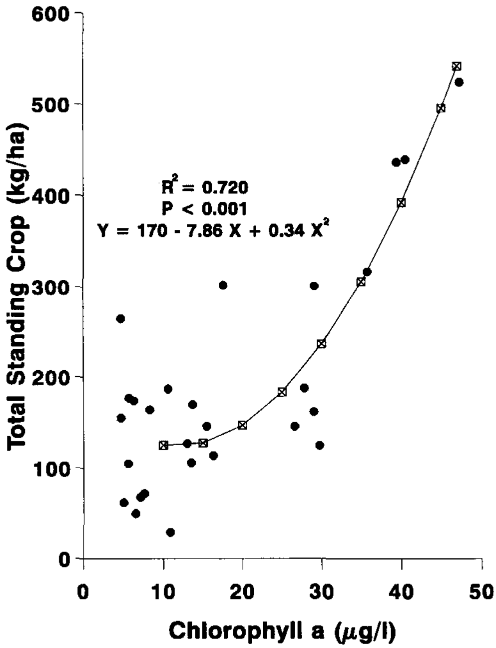

Figure 5. Relation between total fish standing crop and chlorophyll-*a* concentration for 27 of the study lakes. Chlorophyll *a* values are from 1984; fish survey data are from 1979–1989.

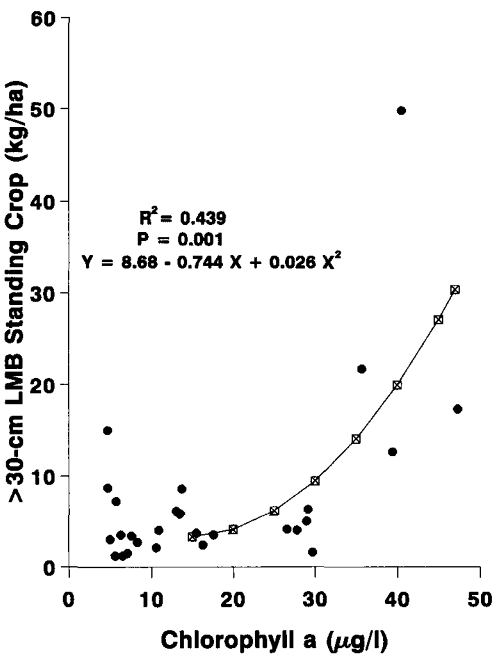

Figure 6. Relation between >30-cm largemouth bass (LMB) standing crop and chlorophyll-*a* concentration for 27 of the study lakes. Chlorophyll *a* values are from 1984; fish survey data are from 1979–1989.

Overall, chlorophyll *a* was positively related to both total standing crop and >30-cm largemouth bass standing crop. This indicates that lakes with higher phytoplankton chlorophyll *a* are capable of producing greater fish biomass. Jones and Hoyer (1982) reported a linear correlation between angler harvest and summer chlorophyll-*a* concentration in 25 lakes and reservoirs of Missouri and Iowa. Lakes with high chlorophyll-*a* concentrations tend to be located in fertile areas and have low non-algal turbidity and sufficient retention time to permit high phytoplankton production as the basis for fish production. Lake chlorophyll-*a* levels are related to the concentration of nutrients such as phosphorus (Jones and Bachmann 1976) as well as to zooplankton biomass (McCauley and Kalff 1981). Yurk and Ney (1989) found a positive relationship between fish biomass and total phosphorus concentration in a Virginia reservoir. Obviously, fish production and biomass are related to lake fertility. This study indicates that the relationship to chlorophyll *a* is stronger for all fish species combined than for largemouth bass alone. One might expect other species to be more closely tied to primary production than a top predator such as largemouth bass.

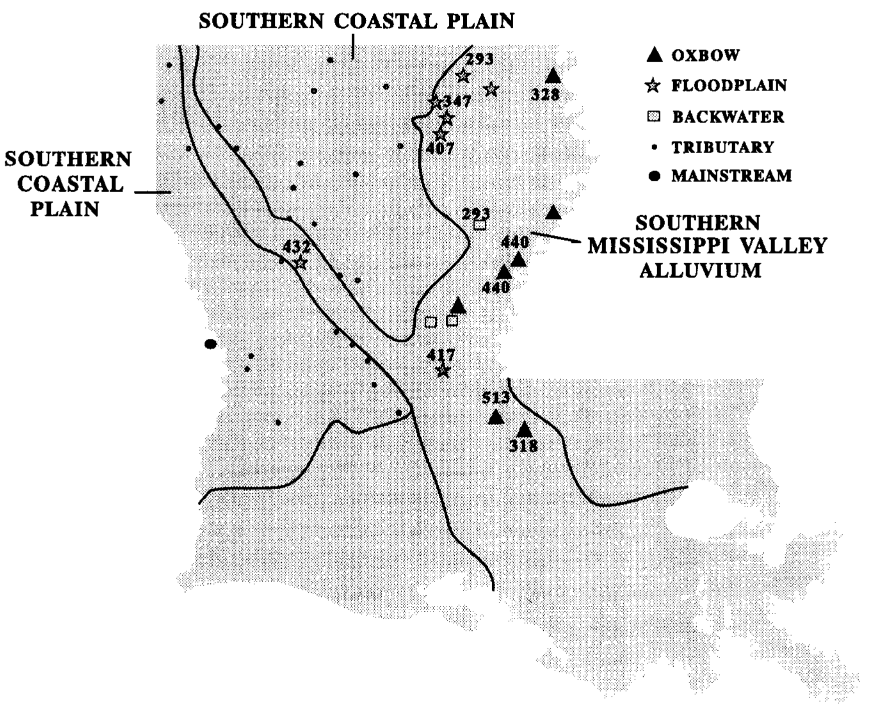

Figure 7. Distribution of lakes with high (upper quartile) total fish standing crops among major land resource areas of Louisiana. Values are in kg/ha.

Relation to Land Resource Area

All lakes with high total standing crops (the top quartile) were located in the Southern Mississippi Valley Alluvium resource area (Fig. 7). This area has fertile bottomland soils and generally shallow slopes. It encompasses the floodplains of the Mississippi, Ouachita, Red, and Atchafalaya rivers, among others. None of the lakes with high total standing crops were located in the Southern Coastal Plain resource area; this area is rolling to hilly, has lower fertility soils, and contains the tributary impoundments. Distribution of lakes with the highest >30-cm largemouth bass standing crops was similar (Fig. 8). All lakes having high biomass of >30-cm largemouth bass, except for Toledo Bend Reservoir, were within the Southern Mississippi Valley Alluvium.

Conclusions

The results indicate that lake category, watershed soils, water quality, and other factors such as topography all may have strong effects on fish biomass and fishery potentials from these water bodies. Fisheries managers should con-

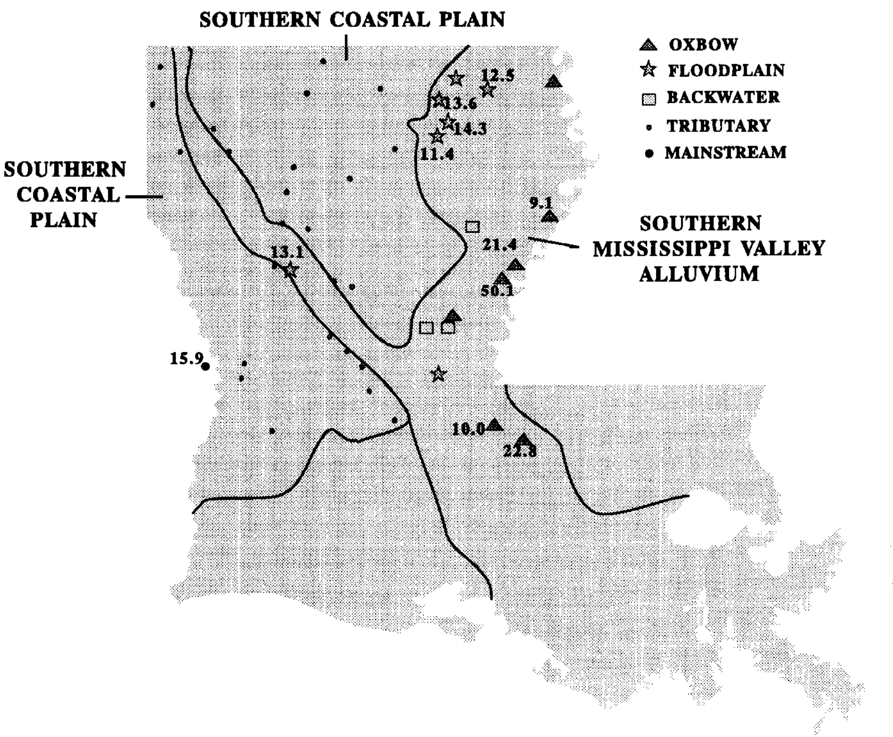

Figure 8. Distribution of lakes with high (upper quartile) >30-cm largemouth bass standing crops among major land resource areas of Louisiana. Values are in kg/ha.

sider these factors when estimating potential fishery yields and when developing statewide and individual fisheries management plans for Louisiana lakes. Management objectives of desired numbers, weights, and size ranges of target species (e.g., largemouth bass) may be influenced by lake category and basic fertility of its drainage area.

Findings of this study could be used in classifying Louisiana water bodies that provide the best potential for management strategies such as successful introduction of Florida largemouth bass and establishment of length-limit regulations. In Louisiana, oxbow lakes and the mainstream impoundment (Toledo Bend Reservoir) appear to have the most potential for substantial largemouth bass fisheries, floodplain lakes have intermediate potential, and backwater lakes and tributary impoundments have less potential. Alternately, Louisiana lakes in the Southern Mississippi Valley Alluvium and the Sabine River Valley have more potential for substantial largemouth bass fisheries than those in the Southern Coastal Plain. Beyond using these 2 classification schemes, fisheries managers should also consider other factors such as basic fertility when assessing individual lake fishery potential.

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