

# Potential Effects of Double-crested Cormorants on Largemouth Bass in Lake Chicot, Arkansas

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*Abstract:* Fisheries managers and anglers are concerned about the effects that increasing over-wintering populations of piscivorous double-crested cormorants *Phalacrocorax auritus* have on sport fishes across North America. We estimated the mortality of the largemouth bass *Micropterus salmoides* population due to predation by cormorants on a 2024-ha oxbow lake in southeastern Arkansas. Cormorants consumed an estimated 0.05%–6.20% of the largemouth bass population in 2001. Consumption ranged widely because of the variability associated with our estimates of the number of days per year that cormorants spent on the lake and the instantaneous estimate of number of cormorants feeding on the lake. Potential for competition between cormorants and largemouth bass was examined by determining diet overlap for fall, winter, spring, and all seasons combined. Diet overlap was greater than 60% only in the fall, but cormorant and largemouth bass diets were never significantly correlated. Managers concerned with cormorant-sport fish interactions should focus their efforts on obtaining accurate cormorant counts, as opposed to elaborate and expensive diet studies.

*Key words:* double-crested cormorant, diet, largemouth bass, Lake Chicot

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Double-crested cormorant (*Phalacrocorax auritus*) populations have increased in many areas of North America since the 1970s (Wires et al. 2001). They are efficient piscivores that have been linked with economic losses in aquaculture (Stickley et al. 1992, Glahn and Brugger 1995). Although cormorant predation may negatively affect the aquaculture industry, influences on natural fish populations are less certain

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(Schramm et al. 1984, Stickley et al. 1992, Glahn and Brugger 1995). Some studies indicate that cormorants can negatively affect sport fish populations (Schneider et al. 1998, Simmonds et al. 2000), or only negatively affect populations during episodes of unnaturally high fish densities, including stocking events (Modde et al. 1996, Derby and Lovvorn 1997, Ross and Johnson 1999). Conversely, other studies have found that cormorant diet is composed largely of non-game fish, such as shad *Dorosoma* spp. (Campo et al. 1993, Glahn et al. 1996). The inconsistency of these findings may be attributed to site-specific variations. The regional density of available prey species or foraging cormorant populations represents potential variations.

Annual bird counts suggest that over-wintering cormorant populations increased dramatically in the Mississippi River Delta region from 1981 to 1988 (Glahn and Stickley 1995, Jackson and Jackson 1995, Glahn et al. 2000). Cormorant diet studies have been conducted at natural lakes and reservoirs in this region (Campo et al. 1993, Glahn et al. 1996), but predation effects on fish populations have not been evaluated adequately. Cormorant and largemouth bass *Micropterus salmoides* interactions have rarely been investigated in natural systems (Simmonds et al. 2000).

We examined population dynamics of largemouth bass and increasing numbers of over-wintering cormorants on Lake Chicot in southeastern Arkansas. The diets of over-wintering cormorants were comprised largely of non-game fish in Lake Chicot (Fenech et al. 2004), but the interactive effects between largemouth bass and cormorants are unknown. Our objectives were to: 1) examine the direct effect of cormorants on the largemouth bass population by quantifying the mortality of largemouth bass due to predation by cormorants, and 2) examine the potential for an indirect effect of cormorants on largemouth bass growth by calculating the diet overlap of the two species.

## Methods

### Study Area

Lake Chicot is a 2024-ha natural oxbow lake (Robison and Buchanan 1988) of the Mississippi River located in southeastern Arkansas. Lake Chicot has a maximum depth of 9.2 m and a mean depth of 4.2 m. The lake is eutrophic with an average chlorophyll *a* concentration of approximately 37 µg/L (Filipek et al. 1991).

### Largemouth Bass Predation Mortality

The number of largemouth bass consumed (*X*) by cormorants per year in Lake Chicot was estimated by

$$X = B * C * D * E * F$$

where *B* was the number of days per year cormorants were on the lake, *C* was the number of cormorants on the lake, *D* was the grams of fish consumed per cormorant per day, *E* was the grams of largemouth bass per gram of fish consumed by a cormorant, and *F* was the number of largemouth bass per gram of largemouth bass. The

**Table 1.** Parameters used to estimate consumption of largemouth bass (LMB) by double-crested cormorants in Lake Chicot, Arkansas.

Parameter	Highest value	Lowest value	Average (SD)
Days/year	260	55	158 (74)
Cormorants	1534	148	841 (1904)
Fish (g)/cormorant/day	521	487	504 (30)
LMB (g)/fish (g)	0.0075	0.0075	0.0075
<i>N</i> LMB/LMB (g)	0.004	0.004	0.004

number of largemouth bass consumed by cormorants per year was estimated once using the mean value for all input parameters.

Parameters of this equation were estimated using a variety of data. The number of days per year that cormorants were on Lake Chicot and the number of cormorants on the lake (Table 1) were both estimated from Lake Chicot aerial surveys conducted by the U.S. Department of Agriculture, Aquaculture Research Service (A. A. Radomski, H.K. Dupree Stuttgart National Aquaculture Research Center, unpublished data). Aerial surveys were conducted biweekly on two consecutive days during the over-wintering period. The over-wintering period was January to April and October through December 2001. Surveys were conducted during the last two hours before sunset. It was assumed that the number of cormorants counted in the aerial survey represented a maximum number of cormorants potentially feeding on the lake and was represented in the equation as an instantaneous bird count. The number of grams of fish consumed per cormorant per day was estimated from the literature (Glahn and Brugger 1995). Glahn and Brugger (1995) used a bioenergetics model to estimate double-crested cormorant energy expenditures, food demand and impact on catfish in Mississippi. Estimates of cormorant consumption of largemouth bass were based on cormorant data collected on Lake Chicot. The grams of largemouth bass per gram of fish consumed by a cormorant were derived from a cormorant diet study conducted on Lake Chicot in 2001 (Fenech et al. 2004). Fenech et al. (2004) collected cormorants ( $N = 455$ ) from January to April 2001 and from October to December 2001. Cormorants were collected from early- to mid-morning to maximize the probability that fish found in the stomach had been consumed from Lake Chicot. It was not always possible to observe cormorants feeding and immediately collect those individuals. Therefore, it was assumed that stomach contents of cormorants originated from Lake Chicot. The estimate of grams of fish consumed per cormorant per day was not taken from Fenech et al. (2004) because that study represented only morning cormorant feeding, not the entire day. The average weight of a largemouth bass in the Lake Chicot fishery was 250 g (W. J. Smith, Arkansas Game and Fish Commission, unpublished data). The number of bass per gram of bass was the reciprocal of the average largemouth bass weight.

The percent of the largemouth bass population consumed each year by cormo-

rants was estimated by dividing the number of largemouth bass consumed by cormorants per year by Lake Chicot largemouth bass population abundance. Cormorant predation was estimated with a mean, upper, and lower 95% confidence interval value using the appropriate input parameters. The Lake Chicot largemouth bass population abundance ( $V$ ) was determined by

$$V = (W / \mu)$$

where  $W$  was the number of largemouth bass harvested per year, and  $\mu$  was the annual exploitation rate of largemouth bass. The number of largemouth bass harvested came from an Arkansas Game and Fish Commission (AGFC) creel survey conducted on Lake Chicot between 1993 and 1996 (W. J. Smith, AGFC, unpublished data). This creel survey provided the most recent estimate of largemouth bass angler harvest, and the four years of creel data were averaged to estimate  $W$ . The annual exploitation rate was estimated by subtracting annual natural mortality from total annual mortality. Total annual mortality was estimated from a catch curve using 1991 Lake Chicot largemouth bass data (W. J. Smith, AGFC, unpublished data). Five natural mortality estimates were calculated using Fishery Analyses and Simulation Tools (FAST) version 2.0 (Slipke and Maceina 2001). Up to six different estimates of natural mortality can be calculated using FAST. However, the Peterson and Wroblewski (1984) estimate was not included in this study because of insufficient fish weight data.

A sensitivity analysis using the model was conducted to determine the most important factor affecting percent of the largemouth bass population consumed each year by cormorants. The upper and lower 95% CL for a given parameter were input, while the other parameters were held constant. Parameters varied during the sensitivity analysis were number of days per year cormorants were on the lake, number of cormorants, grams of fish consumed per cormorant per day, and largemouth bass population abundance. The proportion of the difference between the two estimates of percent of the largemouth bass population consumed each year by cormorants (corresponding to the upper and lower 95% CL for a given parameter) was used to indicate the model's sensitivity to that parameter.

### Diet Overlap

Diets of cormorants were characterized by Fenech et al. (2004). Diets of largemouth bass from Lake Chicot were characterized in this study. Largemouth bass were collected during the same time period that cormorants were collected, using a Coffelt pulsed DC boat electroshocker model WP-15 (5000-watt generator; 25% duty cycle; 60 Hz; 3–6 amps; 400–500 volts). Bass were collected once during the fall, twice during the winter, and once during the spring. Gastric lavage was used to remove stomach contents (Van Den Avyle and Roussel 1980). Stomach samples were stored on ice in the field, and then frozen for later analysis. After samples were thawed, stomach contents were washed on a sieve. Specific prey items were identified to the lowest possible taxa and weighed to the nearest g. The percent frequency occurrence, percent by number, and percent by weight of prey items from cormo-

rants and bass were used to calculate relative importance (George and Hadley 1979) of the prey items in the respective diets. Relative importance is calculated by first adding the percent frequency of occurrence, percent of total number, and percent of total weight of prey items to obtain the absolute importance index. The absolute importance index is then multiplied by 100 and divided by the summation of the absolute importance indices to estimate relative importance (George and Hadley 1979).

The competitive relationships in foraging behavior between cormorants and largemouth bass were examined using the Schoener (1970) diet overlap index, which is based on relative importance. The percent of diet overlap between cormorants and largemouth bass ( $\alpha$ ) was estimated by

$$\alpha = 100 * (1 - 0.5 \sum_{i=1}^n |P_{xi} - P_{yi}|)$$

where  $P_{xi}$  is the relative importance of prey species  $i$  in the cormorant diet and  $P_{yi}$  is the relative importance of prey species  $i$  in the largemouth bass diet. Diet overlap was determined seasonally (fall, winter, and spring) and for the entire over-wintering period (late September through mid-April).

Diet overlap was also examined during the same seasons using a Spearman rank correlation ( $\alpha = 0.05$ ). Diet overlap was not examined during the summer for either the Shoener index or Spearman rank correlation, because cormorants were not found on Lake Chicot during that season.

**Results**

The number of largemouth bass consumed per year by cormorants ranged from 118 to 6250, with an average consumption of 2004 largemouth bass (Table 2). The number of largemouth bass harvested by anglers, based on the creel survey, ranged from 7263 to 22,388. The average (SD) number of largemouth bass harvested was 14,183 (6250). Total annual mortality for Lake Chicot largemouth bass was 57% and the average natural mortality was 49% (4%). Therefore, exploitation was estimated to be 8%. Population abundance estimates ranged from 90,787 to 279,851 largemouth bass. The average population abundance (SD) was 177,290 (78,119). The average percent of the largemouth bass population consumed each year by cor-

**Table 2.** Effects of cormorant predation on the Lake Chicot, Arkansas, largemouth bass (LMB) population. Population abundances were estimated using creel data from Lake Chicot.

	Highest effect	Lowest effect	Average effect
LMB consumed	6250	118	2004
LMB population abundance	100,734	253,848	177,290
Population loss (%)	6.20	0.05	1.13

**Table 3.** Sensitivity analysis of parameters used to model the percent of largemouth bass population of Lake Chicot consumed each year by cormorants. The proportion of the difference between the two estimates of percent of the bass population consumed each year by cormorants (corresponding to the upper and lower 95% CL for a given parameter) was used to indicate the model's sensitivity to that parameter.

Model parameter	Proportional difference
<i>N</i> days per year cormorants were on the lake	4.77
<i>N</i> cormorants feeding	10.37
Grams of fish consumed per cormorant per day	1.07
Largemouth bass population abundance	3.08

**Table 4.** Relative importance indices of prey items occurring in cormorant (C) and largemouth bass (B) diets collected in fall, winter, spring, and all seasons combined at Lake Chicot, Arkansas.

Taxa	Spring		Winter		Fall		Combined	
	C	B	C	B	C	B	C	B
<i>Dorosoma</i> spp.	44	0	61	20	49	58	51	29
Cyprinidae	0	10	0	5	16	3	5	5
<i>Menidia beryllina</i>	0	5	0	3	2	5	1	15
<i>Morone</i> spp.	31	8	34	0	8	0	24	2
<i>Ictalurus</i> spp.	10	0	3	1	18	0	10	0
<i>Aplodinotus grunniens</i>	4	0	0	0	1	0	2	0
Centrarchidae	0	12	0	25	0	2	0	11
<i>Pomoxis</i> spp.	0	0	0	10	0	0	0	5
<i>Micropterus salmoides</i>	4	0	0	1	0	0	1	0
<i>Lepomis</i> spp.	10	45	3	19	7	14	6	17
Other prey items	0	20	0	15	0	17	0	15

morants was 1.13% (Table 2). However, the percent of the largemouth bass population consumed by cormorants ranged between 0.05% and 6.20%, depending upon the input values for each equation parameter.

The model was most sensitive to estimates of the number of cormorants feeding on Lake Chicot (Table 3). The model was approximately equally sensitive to estimates of the number of days per year cormorants were on the lake and the largemouth bass population abundance. Estimates of the grams of fish consumed per cormorant per day had the least effect on the estimated percent of the largemouth bass population consumed by cormorants each year.

Shad were important in the diets of cormorants and largemouth bass in winter and fall, but shad were not important in the diet of largemouth bass in the spring (Table 4). *Lepomis* spp. were a component of the diets of cormorants and largemouth bass in all seasons, but were consistently more important to largemouth bass than

cormorants. Conversely, *Morone* spp. were relatively important in the diet of cormorants during all seasons, but were generally unimportant in the diet of largemouth bass. Likewise, during spring and fall, *Ictalurus* spp. were relatively important in the diet of cormorants, but were absent from the diet of largemouth bass. Schoener diet overlap indices were 23%, 19%, and 66 % in the spring, winter, and fall, respectively. The diet overlap index for all three seasons combined was 43%. Cormorant and largemouth bass diets never showed a significant relation during any season.

## Discussion

In this study, cormorants only accounted for 10% of the total annual mortality of the largemouth bass population based on the highest estimate of population loss due to cormorants. Conversely, bass anglers harvested approximately seven times as many bass as cormorants consumed. Several other studies have compared sport fish losses from predation by cormorants and harvest by anglers. Simmonds et al. (2000) calculated that in some Oklahoma reservoirs with low cormorant densities (2.5 cormorant use-days/ha), anglers harvested approximately eight times more largemouth bass than cormorants. At higher cormorant densities (23.4 cormorant use-days/ha), anglers were only taking 0.6 times the number of largemouth bass consumed by cormorants (Simmonds et al. 2000). Belyea et al. (1999) estimated that anglers harvested three times the number of legal size (175 mm) yellow perch *Perca flavescens* as cormorants in the Les Cheneaux Islands area of northern Lake Huron. VanDeValk et al. (2002) determined that anglers took about 1.3 times the number of walleye *Sander vitreus*, and about 0.1 times the number of yellow perch as cormorants in Oneida Lake, New York. They also stated that anglers and cormorants did not always pursue the same age classes of these two species.

The most sensitive parameter in our model was the number of cormorants feeding on Lake Chicot. Therefore, natural resource managers that estimate cormorant effects on sport fish should rely less on extensive cormorant diet studies, but expend more resources to obtain accurate bird counts. Aerial counts of cormorants are effective, but should be used in conjunction with ground-truthing counts to verify actual cormorant abundances (David 1987). Weekly or even semi-weekly counts may be needed to capture the temporal and seasonal variability of cormorant abundance estimates.

Cormorants could affect growth rates of largemouth bass indirectly through competition for food resources. This would only be true if there were a high degree of diet overlap, and if the food resource is limiting. Mathur (1977) assumed any diet overlap value greater than 50% was biologically significant, and many studies use 60% as a threshold value (Zaret and Rand 1971, Mathur 1977). Diet overlap in this study was only greater than 60% during the fall. Higher diet overlap in the fall may be attributed to the increased consumption of small forage fish (e.g., cyprinids and atherinopsids) by cormorants during that season. Diet overlap indices could be misleading if the resource is not limiting (Hurlbert 1978). Although diet overlap values in the fall were greater than 60%, actual competition between cormorants and large-



mouth bass may not occur at Lake Chicot. Determining the degree of resource limitation was beyond the scope of this study, but the possibility of competition exists during the fall.

Cormorants consumed a small proportion of the largemouth bass population in Lake Chicot during this study. These results may be system-specific or relevant only for 2001. Few studies have examined the long-term variability of cormorant diets within a single system. The expense of diet studies and sensitivity of the public to lethal cormorant collections make such studies difficult. As the number of wintering cormorants increases, the importance of accurately assessing cormorant influences on sport fish populations will also increase. This study indicates the degree of variability in parameters necessary to model the influence of cormorants on sport fish, and highlights the need for more comprehensive, multi-year studies of cormorant diets.

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