Food Habits of Double-crested Cormorants Wintering in the Delta Region of Mississippi

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Abstract.—The diet of Double-crested Cormorants (*Phalacrocorax auritus*) wintering in the Delta region of Mississippi was studied from collections of 202 birds taken at catfish farms during the winters of 1987-88 through 1989-90, and from collections of 461 birds at night roost sites during the winters of 1989-90 and 1990-91. Channel Catfish (*Ictalurus punctatus*) and Gizzard Shad (*Dorosoma cepedianum*) were the only two important prey species, comprising >90% of the diet from all samples. However, the proportion of these two prey species in the diet varied dramatically ($P<0.05$) among months and geographic locations of collections, as well as between sexes of birds collected. Overall, the diet was approximately equal between catfish and shad, but catfish was most often consumed by males during the spring months in the areas of highest catfish concentration. The size range of catfish preyed upon appeared to parallel the size class of fish used for stocking commercial ponds in the spring. Based on these analyses, we recommend strategies for reducing cormorant predation on commercial catfish.

Key words.—Catfish predation, Channel Catfish, diet, *Dorosoma cepedianum*, Double-crested Cormorant, Gizzard Shad, *Ictalurus punctatus*, Mississippi, *Phalacrocorax auritus*.

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Aquaculture has grown tremendously in the last 20 years in the southern states, especially the production of catfish (*Ictalurus punctatus*) in the Delta region of Mississippi. The Mississippi catfish industry has rapidly expanded during the past decade with over 40,000 ha of ponds currently in production, approximately 90% located in the Delta region of Mississippi (Brunson 1991). The growth of this industry has been paralleled by burgeoning populations of Double-crested Cormorants (*Phalacrocorax auritus*) in eastern and central North America (Vermeer and Rankin 1984, Hobson *et al.* 1989, Dolbeer 1990). Increasing numbers of cormorants, currently estimated at approximately 30,000 birds (Aderman and Hill 1995), winter in the region. The presence of these populations foraging at catfish facilities is reported to result in serious economic losses, estimated at $3.3 million (US$) annually (Stickley and Andrews 1989). However, objective data on the impact of the Double-crested Cormorant on the Mississippi Catfish industry are lacking.

As part of a study to determine the impact of Double-crested Cormorants on the Mississippi catfish industry, the diet of this species was investigated through the wintering period from November through April at both catfish farms and roost sites.

The diet of the Double-crested Cormorant has been studied in freshwater ecosystems from various locations in the United States and Canada (Knopf and Kennedy 1981, O'Meara *et al.* 1982, Craven and Lev 1987, Campo *et al.* 1988, Hobson *et al.* 1989, Ludwig *et al.* 1989). Only one study in Arkansas (Bivings *et al.* 1989) has reported the diet of cormorants associated with aquaculture facilities, but this was limited to birds collected only during the fall months. By examining both temporal and spatial differences in the diet and the size classes of prey species consumed, we attempted to determine the temporal and spatial magnitude of cormorant predation on catfish and to evaluate possible damage-prevention strategies.

METHODS

Study Area

The study area was a 16,000 km^2 portion of the alluvial plain of the Mississippi River, commonly referred to as the Delta region of Mississippi (Fig. 1). Catfish production is interspersed with cotton and soybean production throughout this intensively farmed region. The largest concentration of catfish acreage in the eastern portion of the study area is in Humphreys and Sunflower counties (Fig. 1). Also interspersed within this region are isolated areas of cypress swamp habitat that wintering cormorants use for night roost sites. Cormorants examined for food habits were collected within this study area either at catfish farms or at night roost-sites.

Catfish Farm Collections

Preliminary collections under depredation permits were initiated during the winters of 1987-88 and 1988-89 at catfish farms requesting assistance from U.S. Department of Agriculture/Animal and Plant Health and Inspection Service (USDA/APHIS) Animal Damage Control biologists. Cormorants were collected at these farms throughout the daylight hours using a 12-gauge shotgun. Upon retrieval, the stomach and esophageal contents were examined on site and the length of each undigested and partially digested fish measured or estimated to the nearest centimeter.

From November 1989 through April 1990, a more detailed study of the diet of cormorants at catfish farms was conducted. No cormorants were collected in December because of an unusually severe freeze that froze catfish ponds and forced cormorants out of the study area. Collections at three or four catfish farms each month were based on a random sample of producers responding to a questionnaire survey (Stickley and Andrews 1989) and reporting 50 or more cormorants occurring at their farm in previous years.

Before collection, telephone inquiries of randomly selected producers were made to determine the approximate number, if any, of cormorants occurring at the farm. If the producer reported no cormorant use or only rare use, another farm was selected and the previous farm remained on the list for sampling in later months. If no cormorants were observed after several hours, the collection party, consisting of two or three people, moved to the next nearest farm or pond complex until cormorants were located. When cormorants were located at a farm, information was obtained from the owner or manager as to which ponds were most frequented by cormorants. At these ponds, blinds were fabricated or shooters lay prone in camouflage clothing on the pond levee. Cormorant decoys, modified from duck decoys, were deployed in the pond approximately 30 m from the blind or shooters. Between five and 15 cormorants were collected at each farm with 12-gauge 3" magnum shotguns, using BB size steel shot.

Upon retrieval of each carcass, 20 cc of a 10% formalin solution was injected down the esophagus to stop post-mortem digestion. Each carcass was then weighed to the nearest 0.1 kg, aged according to plumage characteristics, and sexed internally, before dissecting out the stomach-esophageal specimen. These were placed in 0.5 liter freezer bags labeled with specimen number, date, and location of collection and frozen until contents were examined.

The total length of each intact fish in stomach-esophageal specimens was measured to the nearest mm between the mouth and the posterior end of the caudal fin, using an engineering compass and a 350 mm ruler. On partially digested (i.e., typically with the head missing) catfish and Gizzard Shad (*Dorosoma cepedianum*) other measurements were taken as an index to total length (see below). On catfish, these measurements included the distance between the anterior point of attachment of the adipose fin to the posterior tip of the caudal fin and the distance between the posterior point of attachment of the anal fin to the posterior tip of the caudal fin. For Gizzard Shad the length of the caudal fin from the base to the most posterior point was measured. These measurements and total lengths were taken from catfish and Gizzard Shad seined at catfish facilities to develop regression equations for estimating the total lengths of partially digested fish.

The linear regression equation for total catfish length in mm (Y), based on adipose to caudal fin length in mm (X), was: $Y = -18.7165 + 2.843X$ for 122 fish measured. The slope of this model was significant ($P=0.0001$, $df=1,121$, $R^2 = 0.9583$). A similar equation based on anal to caudal fin length from the same sample of catfish was $Y = 8.269 + 2.858X$. The slope of this model was also significant ($P=0.0001$, $df=1,121$, $R^2 = 0.9599$). The linear regression equation for estimating total shad length in mm (Y) from caudal fin length in mm (X) was $Y = 12.642 + 3.737X$ ($P=0.0001$, $df=1,162$, $R^2 = 0.9222$).

Total length of other partially digested fish species was estimated based on comparison with reference fish of various sizes. Based on total lengths measured, derived or estimated, weights were derived from the following species-specific length in mm (L) to weight in g (W) equations derived from the literature: catfish, $W = 0.0000184\ (10L^3) - 0.003298348\ (10L^2) + 0.25646117\ (10L) + 0.27357209$ (Steeby *et al.* 1991); Gizzard Shad, $W = 0.000004207\ L^{3.147}$ (Anderson 1980); Bluegill and other sunfish (*Lepomis* spp.), $W = 0.000004226\ L^{3.316}$ (Anderson 1980); Black and White Crappie (*Pomoxis* spp.), $W = 0.000012189\ L^{3.052}$ (Anderson 1980). For other incidental fish species the actual weight rather than length of fish from the stomach contents was used.

Roost Site Collections

Cormorants were collected from their night roost sites during the months of November to April during the winters of 1989-90 and 1990-91. Each month, between five and 20 cormorants (the number proportional to roost size) were collected from two to four randomly selected roost sites where more than 1,000 birds had been censused previously. Cormorants were collected between 1400 and 1700 h as they returned to

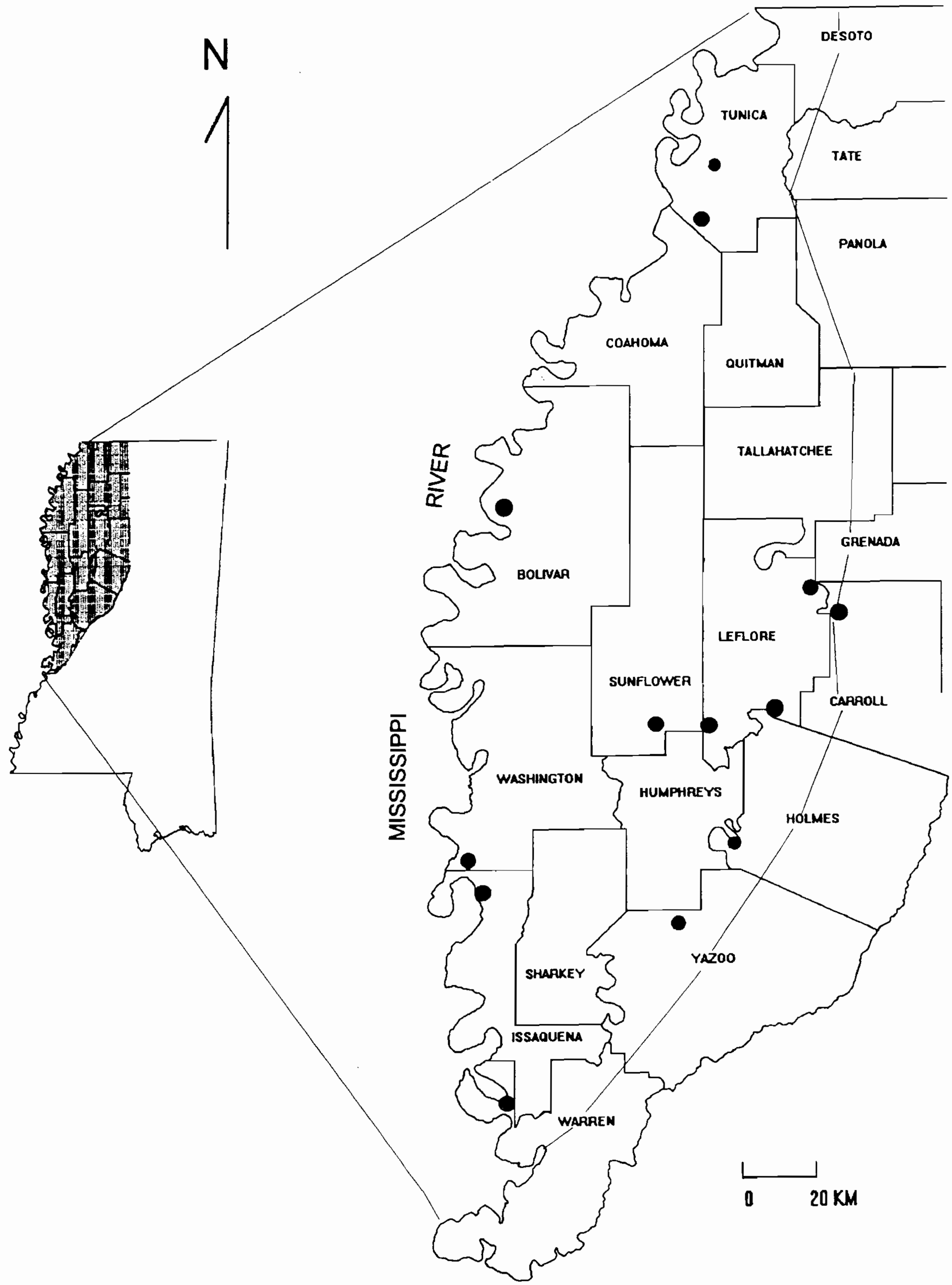

Figure 1. The distribution of counties and Double-crested Cormorant winter roost-sites in the Delta region of Mississippi.

the roost. Two or three shooters in a boat, draped with camouflaged burlap, positioned themselves outside the actual roosting area, but on the flight path of the cormorants. Fabricated cormorant decoys were deployed near the boat to attract cormorants. Other procedures were identical to those used for catfish farm collections.

Table 1. Percent occurrence (% N) and percent biomass (% Wt) of fish groups in the stomach-esophageal contents of 66 Double-crested Cormorants collected at six catfish farms in the Delta region of Mississippi during selected months of the winters of 1987-88 and 1988-89.

	October (N=5)		January (N=12)		March (N=49)		Overall (N=66)	
Fish Groups	% N	% Wt	% N	% Wt	% N	% Wt	% N	% Wt
Catfish	0	0	50.0	48.6	91.0	95.9	77.3	85.3
Shad	100	100	0	0	2.0	0.6	9.1	5.3
Bream[1]	0	0	50.0	51.4	8.0	3.5	15.2	9.4
Other	0	0	0	0	0	0	0	0

[1]Includes sunfish and crappie species.

Data Analysis

Only cormorants with measurable fish in their esophageal-stomach contents were used in the analysis. For analysis, fish species identified from these contents were categorized into four fish groups; catfish, shad, bream (including sunfish and crappie) and miscellaneous species. Primary analysis considered percent biomass (grams live weight) of each fish group collected at farm and roost sites, separately. For statistical comparisons of these data, a SAS General Linear Models ANOVA (SAS Institute 1987) was used considering the square root-arcsine transformation of catfish percentages as the dependent variable. Tukey's Studentized Range Test was used to separate differences among means. Factors considered in these analyses were time of collection, months of collection, sites of collection, and sexes of birds. Age of birds was not used because it could not be determined adequately from plumage characteristics. Percent frequency of occurrence of each fish group in the diet for farm and roost collections was summarized for comparison to biomass data. Data on fish lengths were summarized to examine size classes preferred by cormorants.

RESULTS

Catfish Farm Collections

Esophageal-stomach contents were analyzed from 66 cormorants collected in October, January and March at six catfish farms over the winters of 1987-88 and 1988-89. Analysis, based on percent biomass revealed a diet consisting of 85.3% Channel Catfish, 5.3% Gizzard Shad and 9.4% bream. Percent occurrence analysis showed similar results of 77.3% catfish, 9.1% shad and 15.2% bream. However, the diet varied from zero to 100% catfish among farms and varied similarly among months of collection (Table 1). Considering that the diet from March collections was almost all catfish (Table 1) and 74% of the samples was obtained in March, this disproportional monthly sampling appeared to skew the overall diet towards catfish.

Of cormorants collected at 19 catfish farms in 1989-90, 136 stomach-esophageal samples were used in the analysis and monthly sample sizes varied from 12 to 41. Analysis revealed a percent biomass diet consisting of 63.9% catfish, 30.5% Gizzard Shad and 5.6% bream. The bream that could be identified were Green Sunfish (*Lepomis cyanellus*). Percent occurrence paralleled biomass data with 60.3% catfish, 35.3% shad and 10.3% bream. Similar to previous data from farm collections, there was a significant difference in diet among farms ($P<0.05$) and months of collection ($P<0.05$) (Fig. 2). As with previous data, percent catfish among farms varied from zero to 100% and among months varied most between fall and spring collections.

There was also a significant difference ($P<0.05$) in diet between sexes. Males had 70.4% catfish biomass versus 43.7% for females (Table 2). No differences were found in cormorant diet ($P>0.05$) with respect to time of collection (morning versus afternoon). Size classes of catfish from 252 catfish measured from the 1989-90 farm samples varied from 5 cm to 28 cm with a mean of 15.9 cm ± 0.35 (SE). A frequency distribution of these data indicated that most of the catfish fell within common commercial stocking sizes of between 10 to 20 cm (Fig. 3).

Roost Collections

Analysis of 204 stomach-esophageal samples from roost collections in 1989-90 and 257 samples in 1990-91 provided more extensive information on the diet of cormo-

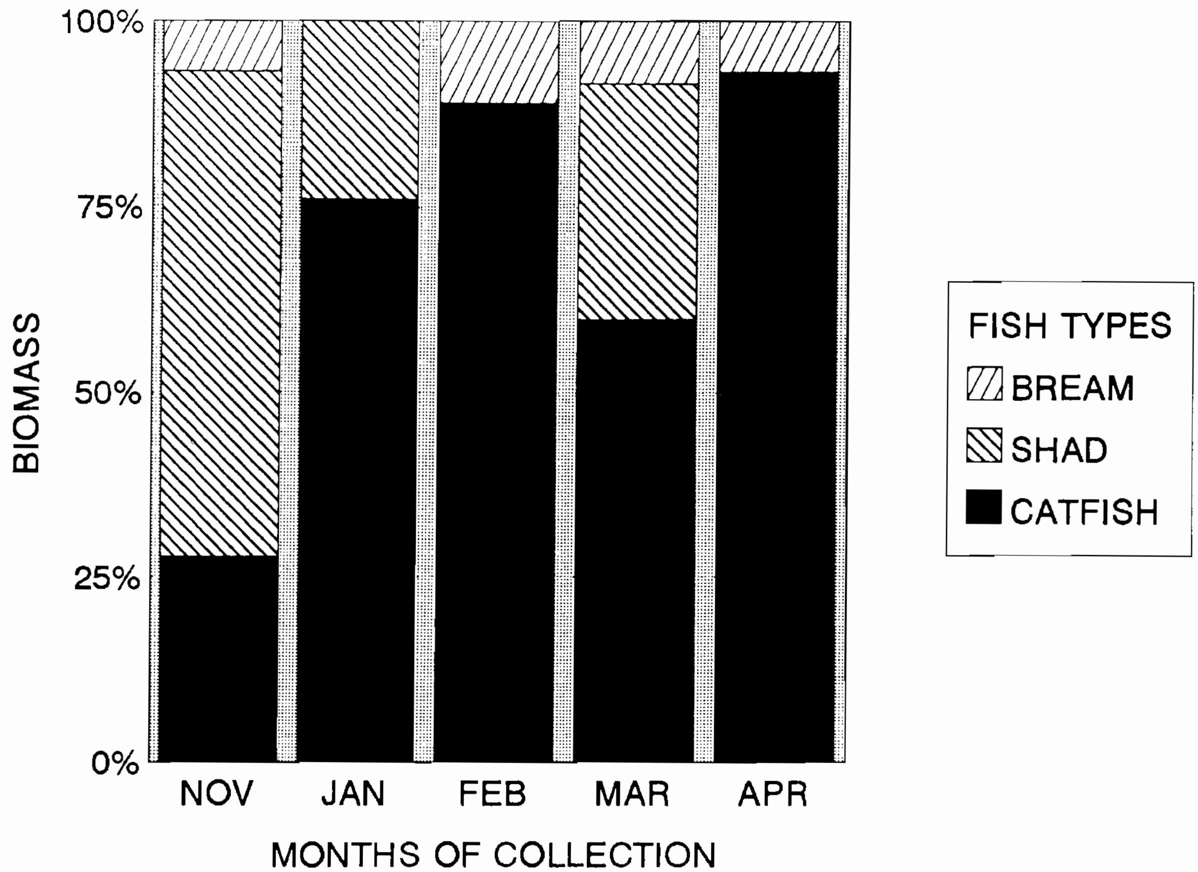

Figure 2. Monthly changes in the percent biomass of fish types in the diet of 136 Double-crested Cormorants collected at 19 catfish farms in the Delta region of Mississippi during the winter of 1989-90.

rants wintering in the Mississippi Delta region (Table 3). Data from both years included cormorants from 13 different roost sites and at least 43 samples from each month during the wintering period (November through April).

Between years the diets, based on percent biomass and percent occurrence appeared remarkably similar (Table 3). Roost samples contained slightly lower percentages of catfish in the diet and a slightly greater diversity of prey species than did samples from farm collections. The greater diversity was reflected in the small percentage of "other fish", a category not found in farm collections. Included in this group were Largemouth Bass (*Micropterus salmoides*), White Bass (*Morone chrysops*) and Common

Table 2. Percent biomass (% Wt) of fish groups in the stomach-esophageal contents of male and female Double-crested Cormorants collected at catfish farms (1989-90) and at their night roost-sites (1989-90 and 1990-91) in the Delta region of Mississippi.

	Catfish Farm Collections[1]		Roost Site Collections[2]	
Fish Groups	Males (N=85) (% Wt)	Females (N=39) (% Wt)	Males (N=335) (% Wt)	Females (N=121) (% Wt)
Catfish	70.4	43.7	60.7	22.0
Shad	24.8	51.8	33.0	69.7
Bream[3]	4.8	4.5	4.9	4.7
Other	0	0	1.4	3.6

[1]Does not include 12 birds where the sex could not be determined.
[2]Does not include 5 birds where the sex could not be determined.
[3]Includes sunfish and crappie species.

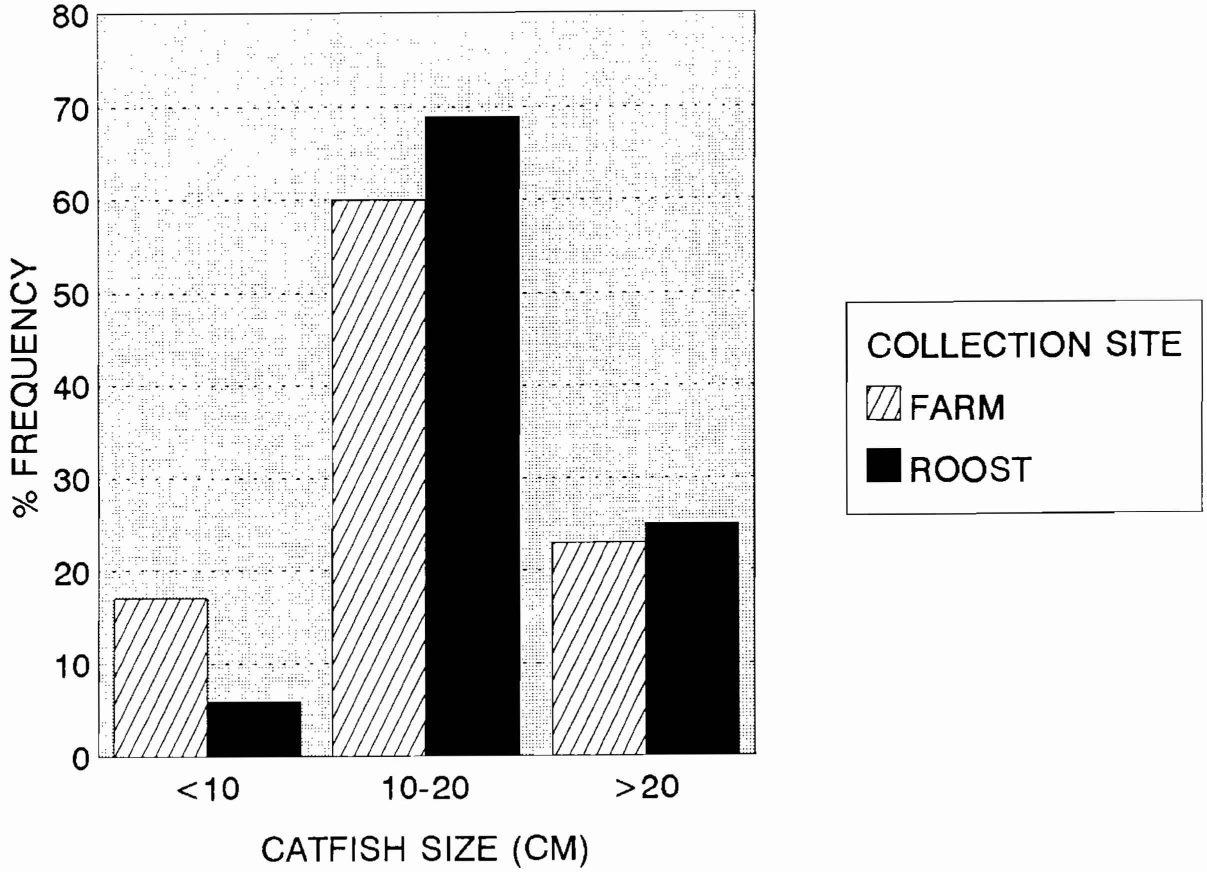

Figure 3. Percent frequency of catfish size classes measured from the stomach-esophageal contents of 136 and 461 Double-crested Cormorants collected at catfish farms and night roost sites in the Delta region of Mississippi, respectively, during the winters of 1989-90 and 1990-91.

Carp (*Cyprinus carpio*), as well as unidentified minnows (Cyprinodontidae) and suckers (Catostomidae).

As in the farm collections, there were significant differences among months ($P<0.05$) with fall months having the lowest percentages of catfish (Fig. 4). The month of March with 86.5% catfish biomass was consistently different ($P<0.05$) from all other months. Because of the severe freeze of catfish ponds in that month, December 1989 was the only month among years where catfish consumption was zero and this caused a significant difference between December and all months except February and November. November, having the second lowest percentage of catfish, was also different ($P<0.05$) from all other months except December.

The size-class distribution of catfish was also similar to farm collections. Catfish size ranged from 4.3 cm to 33.0 cm with a mean of 16.9 cm $\pm$ 0.19SE from a sample of 692 fish

Table 3. Percent occurrence (% N) and percent biomass (% Wt) of fish groups in the stomach-esophageal contents of 204 and 257 Double-crested Cormorants collected at their night roost-sites in the Delta region of Mississippi during the winters of 1989-90 and 1990-91, respectively.

Fish Groups	1989-90 (N=204)		1990-91 (N=257)	
	(% N)	(% Wt)	(% N)	(% Wt)
Catfish	55.4	50.7	54.8	50.1
Shad	40.2	40.8	47.5	44.0
Bream[1]	12.3	5.2	11.7	4.5
Other	2.9	3.4	1.6	1.3

[1]Includes sunfish and crappie species.

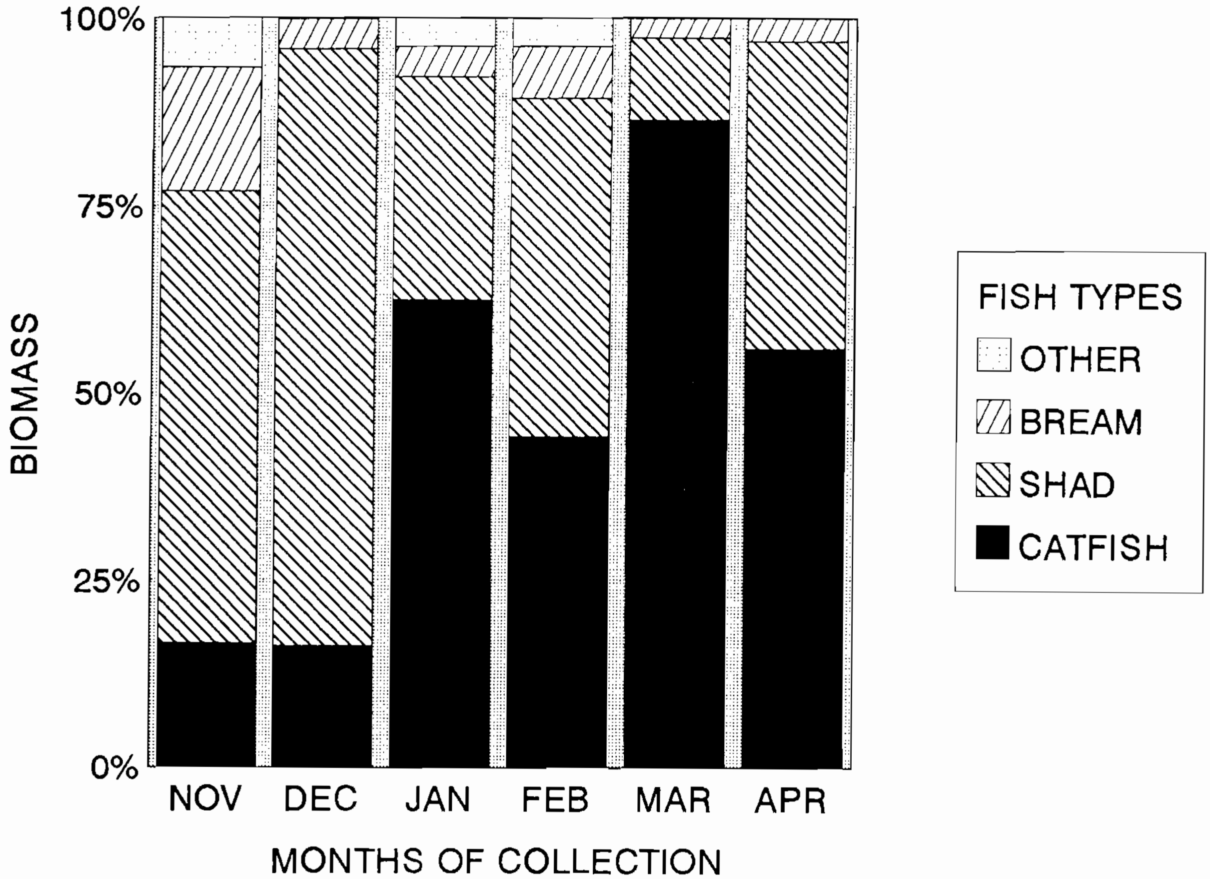

Figure 4. Monthly changes in the percent biomass of fish types in the diet of 461 Double-crested Cormorants collected at 13 night roost-sites in the Delta region of Mississippi during the winters of 1989-90 and 1990-91.

measured. A frequency distribution showed a similar proportion of commercially-stocked size classes to that found in farm collections (Fig. 3). Fish sizes of 1,335 fish other than catfish measured had a wider range (1.6 cm to 37.1 cm) but averaged significantly smaller ($P<0.05$) than did catfish (mean = 11.7 cm ± 0.12SE). There was a significant difference ($P<0.05$) between cormorant sexes in the size of fish, other than catfish, consumed with males consuming slightly larger fish. However, there was no difference ($P>0.05$) between sexes in the sizes of catfish consumed.

In addition to temporal differences in cormorant diet, analysis revealed geographic differences in diet with respect to location of roost sites in the study area. Percent catfish biomass in cormorant diets from seven roost locations in the eastern part of the study ranged from 55.3% to 100% and were significantly different ($P<0.05$) from diets from six western roost locations along the Mississippi River (Fig. 1), which had between 5.1% and 30.1% catfish. Overall, 284 cormorants collected from eastern roosts had diets composed of 74.5% catfish and 20.1% Gizzard Shad and 177 cormorants collected from western roosts had diets composed of only 14.3% catfish and 76.9% Gizzard Shad (Table 4).

Further analysis of roost collections indicated a significant difference ($P<0.05$) in diet among male and female cormorants and a significant ($P<0.05$) interaction between sex and roost location. Males had 60.7% catfish biomass in the diet versus 22.0% for females (Table 2). Sex ratios of cormorants sampled in eastern roosts were 3.6:1 males compared to 1.9:1 in western roosts.

DISCUSSION

This study suggests that cormorants could have a negative impact on the commercial catfish industry in Mississippi, but

Table 4. Percent occurrence (% N) and percent biomass (% Wt) of fish groups in the stomach-esophageal contents of 284 and 177 Double-crested Cormorants collected from seven eastern night roost-sites and six western night roost-sites in the Delta region of Mississippi, respectively.

	Eastern Roost Sites (N=284)		Western Roost Sites (N=177)	
Fish Groups	% N	% Wt	% N	% Wt
Catfish	77.5	74.5	19.2	14.3
Shad	21.5	20.1	80.8	76.9
Bream[1]	9.9	3.6	15.2	6.6
Other	1.4	1.8	3.4	2.3

[1]Includes sunfish and crappie species.

that the proportion of catfish in the diet seems to vary significantly with location and time of year. Whether most of the catfish in the diet were from commercial ponds can not be confirmed, but the size class distribution of fish and the striking lack of catfish in the diet when commercial ponds were frozen over in December 1989 would strongly suggest this to be the case. Previous studies of the diet of cormorants (Craven and Lev 1987, Ludwig *et al.* 1989) would suggest that the diet is largely determined by availability of prey species within certain size limits. The 1991 mid-winter inventory of small "stocker"-size (15 to 23 cm long) catfish in the Delta region of Mississippi was estimated at 200 million fish (USDA 1992). Catfish, concentrated in shallow ponds (1-2 m deep) at densities up to 150,000 fish/ha (Hodges 1989), are likely to be the most readily available prey for cormorants in this area. The average size of catfish consumed, approximately 16 cm, corresponds with the average size of fish (15 to 23 cm) used to stock the catfish ponds for food production (M. W. Brunson, pers. comm.). However, this average size is significantly larger than the average size of other fish consumed in this study or reported from other studies (Bivings *et al.* 1989, Campo *et al.* 1988). Thus, we speculate that because of the concentrated availability of catfish, cormorants, particularly males, may have adapted their foraging behavior to consume slightly larger fish.

The variability of the diets of cormorants foraging at catfish farms would appear surprising, considering the seemingly enormous availability of catfish as prey. However, observations of collection teams noted that ponds where cormorants concentrated often contained shad. Recent observational studies of cormorants foraging at catfish farms (Stickley *et al.* 1992) have suggested that, perhaps because of ease in handling, cormorants might prefer Gizzard Shad that proliferate in catfish ponds. In contrast, catfish are difficult to manipulate for swallowing because of their pectoral fin spines. Because of this, and because larger males are more likely to successfully resist harassment by other birds attempting to steal fish, males may be more likely to prey on catfish than are the smaller females. Campo *et al.* (1988) also found that males consumed more catfish and generally larger fish than did females.

Shad has been previously reported to be an important prey species for wintering cormorants at reservoirs in Texas (Campo *et al.* 1988) and aquaculture facilities in Arkansas (Bivings *et al.* 1989). The visibility and schooling behavior of shad compared with catfish may also be a factor in cormorant prey selection. Green Sunfish, the only other species of significance in farm collections, is also a likely resident of catfish farms (L. E. Miranda, pers. comm.).

The temporal change in diet from fall to spring indicated from both the farm collections and roost collections suggests a decreased availability of shad, an increase in availability of catfish, or both. Based on information USDA Aquaculture Reports (USDA 1992) the latter appears to be the case, as March is the time that the most catfish is stocked into food fish ponds, thereby increasing the availability of suitable catfish prey by as much as 50%. However, Campo *et al.* (1988) reported that consumption of shad by cormorants also decreased in Texas from fall to spring, which suggests a decreased availability of this species.

Although the total standing crop of Gizzard Shad in our study area is unknown, shad are reported to comprise 43% of the standing crop of all fish in Mississippi reservoirs with densities as high as 14,555/ha (Miranda *et al.* 1991). Gizzard Shad, particularly small fish, are susceptible to winter kill at water temperatures below 3.3°C (Jester and Jensen 1972) and winter kills of shad in catfish ponds have been observed (Hodges 1989). These kills may reduce the availability of this species in the spring months.

Considering that the diet from farm collections did not vary between morning and afternoon collections, afternoon and evening roost collections would likely be unbiased and probably form the best basis for assessing the diet of wintering cormorant populations. As anticipated, these samples were slightly lower in catfish biomass and more diverse in prey species recorded.

The spatial availability of catfish appeared to be an important factor in the food habits of cormorants among roosting areas. Although numbers of catfish in these areas are unknown, Cooperative Extension Service records on commercial catfish acreage by county (Brunson 1991) provide an index to catfish availability. Six western roosts, having low catfish biomass, were located in five counties bordered by the Mississippi River (Fig. 1) and, excluding brood fish ponds, contained 6,835 ha of catfish ponds. The seven eastern roosts were located in five counties (Fig. 1) having a similar 7,374 ha of catfish ponds. However, four of these roosts were situated within 5 km of Humphreys county, the county with the highest catfish acreage in the United States, containing 12,470 ha of catfish ponds.

Assuming that cormorants in the eastern roosts were exploiting catfish in Humphreys county, as well as in the five other counties, the total hectares of catfish availability for eastern roosts was 19,844 compared to only 6,835 for western roosts, an abundance ratio of 2.9 to 1. Although this is only a gross approximation of catfish availability, it may help explain the large differences in cormorant consumption of catfish among these roosting areas. Differences in diet between males and females also may have influenced the difference in diet between regions, since males appeared to be more abundant in eastern roosts.

Although a number of the lakes in this area are used for sport fishing, we have no data to suggest that cormorants negatively impact the sport fishery. Even the small percentage of bream in the diet were primarily Green Sunfish which is of little importance to this fishery. Although the large consumption of shad might suggest cormorant competition with game fish such as bass for prey, considering the large standing crop of Gizzard Shad, there is probably no substantial negative impact.

MANAGEMENT IMPLICATIONS

Although cormorants wintering in the Delta region of Mississippi certainly have a varying degree of negative impact on the catfish industry, the ubiquitous Gizzard Shad is an important prey species that appears to lessen this impact. Considering the importance of shad as prey for cormorants in Arkansas and Texas (Campo *et al.* 1988, Bivings *et al.* 1989), this may be true of other catfish production areas in the south as well. Although research is needed to investigate both the benefits and risks of such a strategy, increasing the availability of shad by stocking these fish in areas of heavy catfish predation in the spring may help reduce catfish losses.

The large variation of catfish biomass in the cormorant diet between roosting areas with high catfish density versus lower catfish density suggests that catfish losses in the region might also be reduced by dispersing roosting cormorants away from areas of high catfish density.

Size classes of catfish taken and seasonal patterns of catfish predation suggest that catfish growers need to be primarily concerned about predation on fish ranging from 10 to 20 cm, particularly in the spring. Clearly, management practices that limit the availability of these size classes during the spring months could help reduce losses. This might include increasing the size of "stocker" fish or delaying stocking until after cormorant migration in mid April.

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