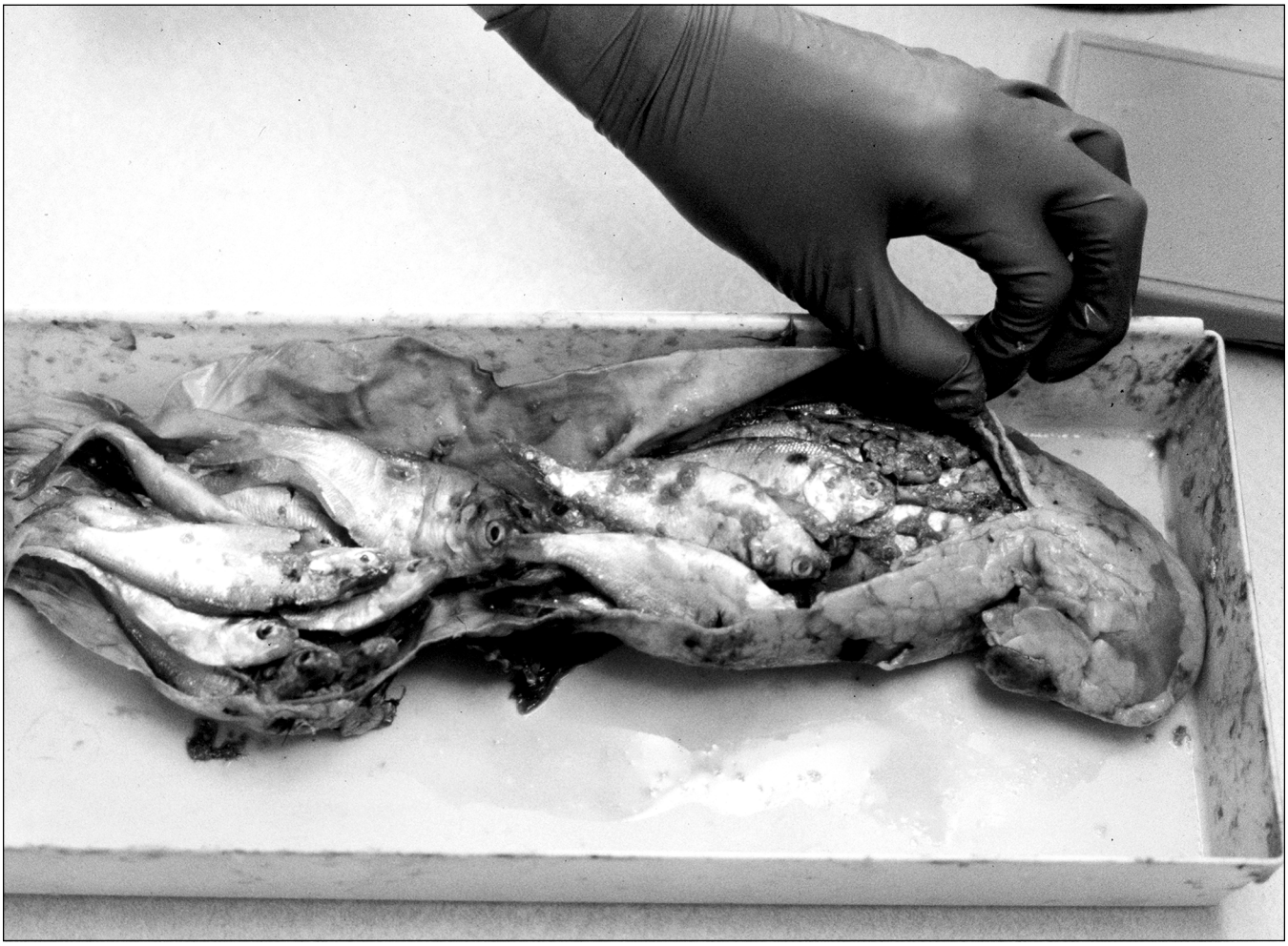

Diet of the Double-Crested Cormorant in Western Lake Erie

By Michael T. Bur, Sandra L. Tinnirello, Charles D. Lovell, and Jeff T. Tyson

Abstract: Sport and commercial fishing interest groups are concerned about potential impacts double-crested cormorants *(Phalacrocorax auritus)* may have on fish species. Our objectives for this study were to determine the diet of the cormorant in western Lake Erie and the diet overlap and competition for resources with piscivorous fish, such as walleye *(Stizostedion vitreum.)* The stomach contents of 302 double-crested cormorants collected in western Lake Erie consisted primarily of young-of-the-year gizzard shad *(Dorosoma cepedianum)*, emerald shiner *(Notropis atherinoides,)* and freshwater drum *(Aplodinotus grunniens).* In the spring, freshwater drum were the most frequently occurring food in the stomachs and constituted the greatest portion of the diet by weight. Young gizzard shad became the most abundant prey and made up the largest percentage of the diet by weight in the stomachs from the end of July through October. Emerald shiners were abundant in the diet during June, September, and October. The fish species that cormorants ate resembled, by proportion, the species mix found in trawl catches. The diets of cormorants and walleyes were similar from July to October with significant overlap. Results from this study suggest impacts of cormorants at current population levels in Lake Erie are not detrimental to sport and commercial fishing. Therefore, control for the purpose of reducing competition for prey fish with walleye is not warranted at this time.

Keywords: diet, double-crested cormorant, emerald shiner, freshwater drum, gizzard shad, Lake Erie, *Phalacrocorax auritus,* selectivity, walleye

Double-crested cormorant (DCCO) numbers have increased dramatically in many parts of North America over the last 20 years (Hatch 1984, Vermeer and Rankin 1984, Chapdelaine and Bedard 1995). Reduced levels of environmental contaminants, increased food availability, and reduced human persecution are factors most likely responsible for population increases (Ludwig 1984, Fox and Weseloh 1987).

The DCCO is thought to have first nested in the Great Lakes (Lake Superior) between 1913 and 1920 (Fargo and Van Tyne 1927). In the Great Lakes, the population has increased at an average annual rate of 29 percent from 1970 to 1991 (Weseloh et al. 1995) and 23 percent from 1990 to 1994 (Tyson et al., this volume).

The first documented colony in Lake Erie was established in 1939 (Langlois 1950). In 1991, the two major Lake Erie colonies were on East Sister and Middle Islands (Weseloh et al. 1995). The species, first nested on West Sister Island in 1992, and by 1997 there were approximately 1,500 nesting pairs on the island (M. Shieldcastle, pers. commun.). In 1997, East Sister and Middle Islands had nesting colonies with 4,500 and 3,000 nesting pairs, respectively (D. Weseloh, pers. commun.).

DCCO's feed almost exclusively on small prey fish (Hobson et al. 1989, Ludwig et al. 1989, Orta 1992, Campo et al. 1993). Results of studies on cormorant diets generally indicate that cormorants are opportunistic feeders and do not select a particular species (Hobson et al. 1989, Ludwig et al. 1989, Campo et al. 1993). In the Great Lakes, alewives *(Alosa pseudoharengus)* and minnows (Cyprinidae) predominate year 'round while yellow perch *(Perca flavescens)* and smallmouth bass *(Micropterus dolomieui)* are abundant only at times in the cormorant's diet (Craven and Lev 1987, Ludwig et al. 1989, Johnson and Ross 1995, Neuman et al. 1997). Compared with other Great Lakes, Lake Erie has a large percid population consisting mostly of walleye and yellow perch. Therefore, food habits of cormorants in Lake Erie may not resemble those found in dietary studies done on populations from the other Great Lakes. Neuman et al. (1997) found significant spatial and temporal heterogeneity in the diet of DCCO's among breeding colonies within a lake for the lower Great Lakes (Erie, Huron, and Ontario). Other authors have also reported annual, seasonal, or location differences in Great Lakes cormorant diets (Craven and Lev 1987, Ludwig et al. 1989, Ross and Johnson 1995).

There are mounting concerns by sport and commercial fishing interests that the DCCO will deplete preferred fish species (e.g., walleye, yellow perch, and smallmouth bass). As in other Great Lakes, such as Lake Ontario (Ross and Johnson 1995), fishermen on Lake Erie are concerned that cormorants may affect the Lake Erie fishery.

The magnitude of DCCO piscivory in western Lake Erie has been estimated from a bioenergetics model (Madenjian and Gabrey 1995). Information on the specifics of the diet such as prey species, life stage, and size, have not been identified. This information will lead to a greater understanding of the predator–prey dynamics associated with cormorants and their prey and aid fishery managers in determining possible impacts on the sport and commercial fishery.

Our objectives were to (1) determine the diet of the DCCO in western Lake Erie and (2) compare diet overlap between cormorants and piscivorous fish, such as walleye.

Study Area

The study area was located in the western basin of Lake Erie (fig. 1). Cormorants were primarily collected near Middle Island, located in waters just north of the international boundary in Ontario, Canada. Middle Island is located at the eastern perimeter of the western basin islands. Secondary sites included waters adjacent to West Sister Island and a diked marsh in Sandusky Bay, both in Ohio waters.

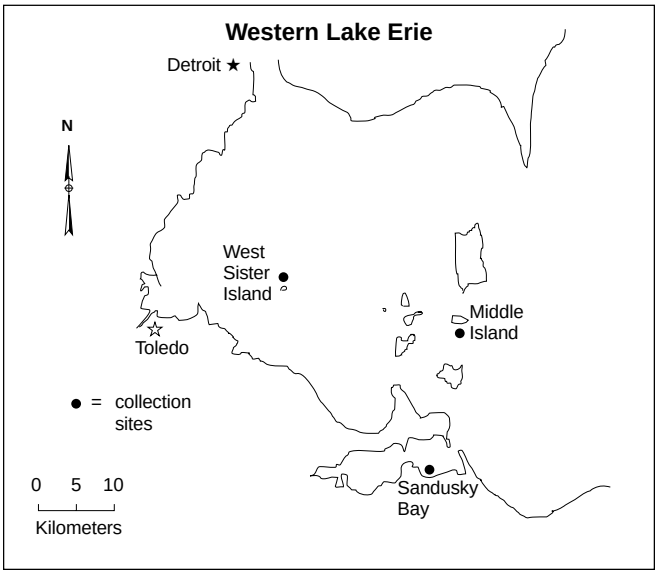

Figure 1—Locations of collection sites for double-crested cormorants in western Lake Erie, April–October 1997.

Methods

Cormorant diet composition was determined from stomach contents of adults and juveniles collected in waters adjacent to Middle Island, West Sister Island, and in Sandusky Bay. We attempted to collect 20 adult or juvenile cormorants every 2 weeks from April 15 to October 15, 1997.

Cormorants were shot with a 12-gauge shotgun (with nontoxic steel shot) as they returned to their nest or roost sites from foraging in the lake. Shooters occupied camouflaged blinds (water and land) and used confidence decoys to attract birds. Whenever possible, individual birds were selected randomly from flocks. Most birds were collected over water from a boat 150–200 m offshore. Secondarily, shooters approached an individual or a group of feeding cormorants on the water by boat, and cormorants were shot as they attempted to flee. An immediate attempt was made to euthanize any wounded bird. Regurgitation was noted and, if possible, recovered when the cormorant was retrieved.

Immediately after collection, our field crews recorded the location and tagged each bird with a unique identification number. They injected, 60 mL of 10-percent formalin into the birds' stomach with a 60-mL syringe and rigid catheter tube to fix stomach contents. We stored birds on ice in a cooler and returned them to the laboratory, where we identified each to sex, weighed it, and measured it for overall length, wing cord, tarsal length, culmen length, and culmen depth. After making an incision from the base of the bill to the vent and separating the surrounding tissue from the esophageal and stomach area, we removed the esophagus and stomach of each bird, placed them in a labeled plastic bag, and chilled them on ice for later processing.

We identified the species of all food items. Fish in cormorant stomachs were identified from whole specimens, partial fish (e.g., backbone with flesh), and fragments (e.g., scales, otoliths, and other diagnostic bones). We measured total length of whole fish to the nearest millimeter. When possible, we measured standard and backbone lengths from partially digested

fish. We used equations from Knight et al. (1984) and K. Kayle (pers. commun.) to convert standard and backbone lengths to total lengths. We estimated wet weights of fish, at time of ingestion, using total length/wet weight regressions (Hartman 1989; M. Kershner, pers. commun.). For fish too digested to measure, we estimated their weight based on the mean weight of that species from the same stomach or another stomach collected on the same date.

The Ohio Division of Wildlife made monthly (May–September) fish assessments at 41 sites in western Lake Erie to assess young-of-the-year (age-0) fish abundance. Crews collected fish collected with a 10-m bottom trawl that was towed for 10 minutes and enumerated fish by species and age groups (age-0 or ≥age-1). During the July–October assessments, crews removed the walleye stomachs immediately after capture and examined them for food contents. Researchers identified each food item to taxon and measured it (total, standard, or backbone lengths). Later, investigators compared the diets of walleye with those of DCCO's collected during the same months to determine extent of diet overlap.

To determine whether cormorants selectively fed on certain prey when compared with trawl catches, we used a measure of prey selection incorporating Chesson's alpha (α) (Chesson 1978, 1983). The formula for this index is

$$\text{alpha } (\alpha) = \frac{r_i / p_i}{\sum (r_i / p_i)}$$

where

r_i = the proportion of prey item *i* in the cormorant's diet; and

p_i = the proportion of prey item *i* in the trawl catch.

For each prey fish species, the calculated values were corrected to range from –1 to 1 (Chesson 1983), where values between 0 and 1 indicated positive selection, values approaching –1 indicated negative selection, and values near 0 indicated no selection. A value of 1 indicated that a prey species was not sampled in trawl catches.

Determination of cormorant and walleye diet overlap was calculated using the index described by Schoener (1970):

$$\text{alpha } (\alpha) = 1 - 0.5(\sum |p_{xi} - p_{vi}|)$$

where

p_{xi} = proportion of food category *i* in the diet of species *x;*

p_{yi} = proportion of food category *i* in the diet of species *y;* and

n = number of food categories.

Values ranged from 0 (no overlap) to 1 (complete overlap). Overlap is generally considered to be biologically significant when the value exceeds 0.60 (Zaret and Rand 1971). Food items were reported as weighted average of wet weight percentages for each month (Schoener 1970, Wallace 1981).

Differences in total number and weight of food items found in stomachs of DCCO's by sex during each month (April–October) were tested using analysis of variance (ANOVA) (PROC ANOVA, SAS Institute, Inc. 1995). Also, ANOVA was used to test for differences between (1) total length of prey eaten by cormorants with available prey in trawl catches and (2) prey consumed by cormorants and walleye.

Results

Overall Diet

We collected 302 cormorants (167 males, 130 females, and 5 unidentified) from April 15 to October 15, 1997, of which 248 (82 percent) contained food items in the stomach. There were 7,794 prey items representing 15 species of fish and 2 invertebrates (table 1). The mean number of prey items per stomach was 31.4 (SE = 3.1). The largest number of food items found was 323 in the month of July, of which 321 where gizzard shad. Gizzard shad was the most abundant and frequently occurring food item and represented the largest percentage by weight. Emerald shiners were next most numerous and the third most frequently occurring prey consumed. Although freshwater drum were not extremely abundant in the diet, they were the second most frequently occurring by stomach and constituted the second largest percentage by weight. Yellow perch and walleye, important sport and commercial fish in Lake Erie, made up less than 1 percent of the cormorant diet by number and only 3 percent by weight. White bass *(Morone chrysops)* were consumed by almost 9 percent of cormorants and made up nearly 5 percent of prey identified. Females *(n* = 107; $\bar{x}$ = 35.8; SE = 5.1) consumed a slightly larger number of prey than males *(n* = 136; $\bar{x}$ = 28.0; SE = 4.0 , *P* = 0.225).

Lengths and weights of fish found in cormorant stomachs were highly variable. Prey fish ranged in length from 32 to 413 mm. Gizzard shad and emerald shiners were among the smallest prey eaten and had

Table 1. Prey species found in stomachs of double-crested cormorants collected from western Lake Erie from April to October, 1997

Species	*N*	% Number	Total length (mm) Mean	Total length (mm) SE	% Frequency	% Weight
Alewife	1	0.0	40.0	—	0.4	0.0
Gizzard shad	5,442	69.8	74.7	0.6	50.0	48.3
Smelt	3	0.0	88.0	—	1.2	0.0
White perch	5	0.1	96.3	44.8	1.6	0.2
White bass	37	0.5	144.3	14.7	8.9	4.6
Freshwater drum	105	1.3	265.2	5.6	33.9	33.4
Bullhead	2	0.0	—	—	0.4	—
Carp	8	0.1	126.0	4.5	0.4	0.3
Emerald shiner	2,129	27.3	66.9	0.4	33.5	8.5
Unidentified minnows	1	0.0	—	—	0.4	—
Centrarchid	3	0.0	—	—	0.8	0.0
Pumpkinseed	2	0.0	—	—	0.8	0.0
Smallmouth bass	3	0.0	136.2	13.6	0.8	0.3
Yellow perch	19	0.2	148.2	19.5	5.2	1.0
Walleye	6	0.1	269.2	44.6	2.4	0.9
Catfish	4	0.1	335.8	6.3	1.6	2.5
Stonecat	1	0.0	—	—	0.4	0.9
Crayfish	1	0.0	—	—	0.8	—
Snails	1	0.0	—	—	0.4	—
Unknown	2	0.3	—	—	6.9	—

lengths as short as 32 mm and mean weights as low as 6.9 g (SE = 0.2) and 2.5 g (SE = 0.1), respectively. Freshwater drum was one of the largest prey species, ranging in length from 110 to 334 mm with a mean weight of 195.3 g (SE = 9.9). The mean total length of prey consumed by male cormorants ($\bar{x}$ = 179.2, SE = 9.4) was significantly greater than that for females ($\bar{x}$ = 130.7, SE = 9.0) ($P < 0.001$). The weight of stomach contents ranged from 3 to 740 g. The average weight of stomach contents in each cormorant was 252.5 g (SE = 8.7). The mean weight of all prey in each stomach for male cormorants ($\bar{x}$ = 278.8 g, SE = 12.0) was greater than for females ($\bar{x}$ = 224.7 g, SE = 11.8) in western Lake Erie ($P < 0.001$).

Temporal Diet

Mean number of prey per stomach varied extensively during the study period (fig. 2). During April and May, the number of prey items per stomach was relatively low: 4.4 and 2.5, respectively. Emerald shiners were the most abundant prey in the diets during April and June. From July to October young-of-the-year (age-0) gizzard shad were the most numerous prey eaten. Age-0 gizzard shad first appeared in the diet during the latter half of July. The largest number of food items found in a single cormorant stomach was 323 during July, of which 321 were age-0 gizzard shad. On average, 54 (SE = 10.8) gizzard shad were identified in each cormorant stomach in July. Mean number of shad was 23.9 in August, 21.1 in September, and 18.5 in October. Emerald shiners made up nearly 50 percent of the diet (by number) during September ($\bar{x}$ = 11.8, SE = 3.8) and October ($\bar{x}$ = 16.6, SE = 3.5).

The importance of each of the four major prey taxa varied each month during the study. Freshwater drum was the most frequently occurring food item in cormorant stomachs from April to July and remained present in the diet through October (fig. 3). Gizzard shad equaled freshwater drum in importance as a food item in July and was the most frequently occurring food item from August to October. Emerald shiners occurred in the diet frequently in June and again in September and October. White bass occurred in the

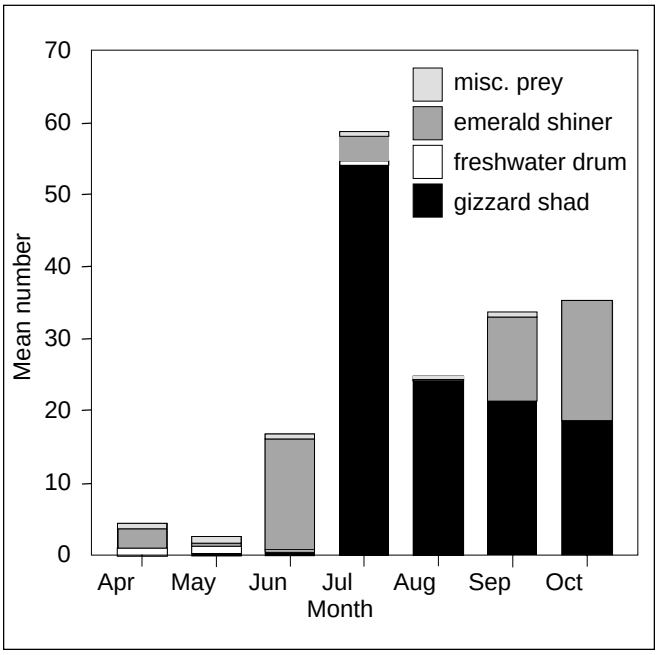

Figure 2—Mean number of individual prey identified per double-crested cormorant stomach, by month, in western Lake Erie, April–October 1997.

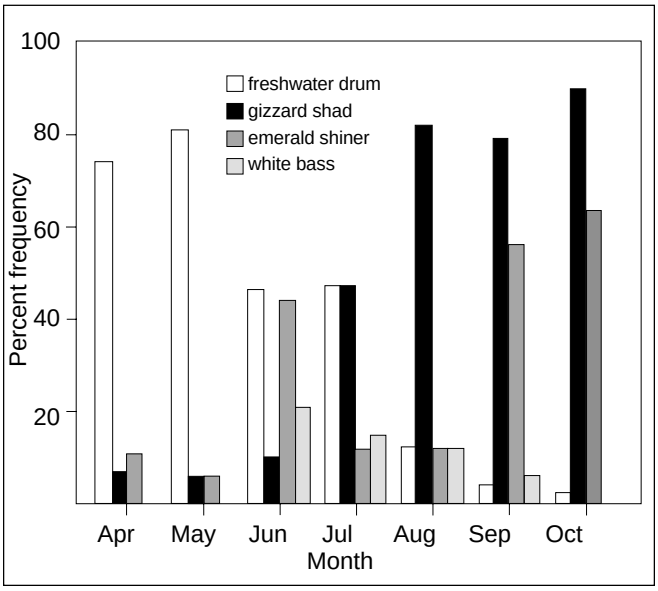

Figure 3—Percent frequency of prey items in double-crested cormorant stomachs, by month, in western Lake Erie, April–October 1997.

diet from June to September. Several other fish species occurred in the diet more frequently in the spring, including: yellow perch in April (11.1 percent) and May (12.5 percent), rainbow smelt *(Osmerus mordax)* in May (12.5 percent), channel catfish *(Ictalurus punctatus)* in April (7.4 percent), and stonecat *(Noturus flavus)* in May (6.3 percent).

During most months, major food items occurred with similar frequency in stomachs of male and female cormorants, with some exceptions. In June and July, freshwater drum occurred with more frequency in male stomachs(June, 33.3 percent; July, 28.3 percent) than in female stomachs(June, 12.8 percent; July, 18.3 percent). During June, which coincided with feeding of nestlings, emerald shiners occurred more frequently in the stomachs of female (25.6 percent) than male (17.9 percent) cormorants. During October, gizzard shad and emerald shiners occurred more frequently as diet components for male (gizzard shad, 60.9 percent; emerald shiner, 41.5 percent) cormorants than for female (gizzard shad, 29.3 percent; emerald shiner, 22.0 percent) cormorants.

Changes in prey fish species consumed were reflected by monthly changes in percent prey size. Mean weights of stomach contents varied significantly among months *(P* = 0.033). During April to July, large prey species, including freshwater drum, white bass, and channel catfish made up the largest percentage of the biomass. Freshwater drum accounted for the greatest percentage from April to July. Small prey, including age-0 gizzard shad and emerald shiners, dominated the biomass from July to October (fig. 4). From August to October, age-0 gizzard shad represented the greatest percentage of monthly diet by weight. Emerald shiners accounted for almost 25 percent of weight of prey consumed in June. White bass ranged from nearly 15 percent of weight of prey consumed in June to less than 1 percent in September.

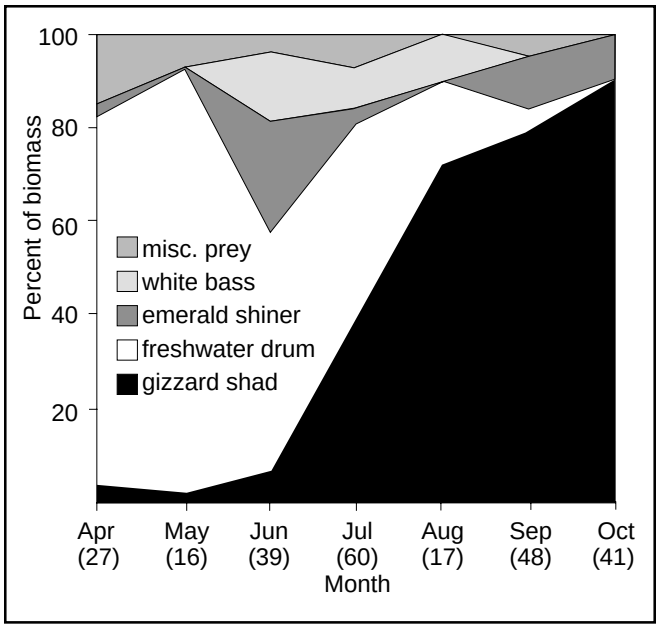

Figure 4—Percent biomass of prey items identified in cormorant stomachs by month, April–October 1997. Sample sizes are in parentheses.

Table 2. Mean total length of prey fish (in mm) consumed by double-crested cormorants during April to October, 1997, in western Lake Erie

	Sexes combined			Males			Females			Unknown		
	N	Mean	SE	*N*	Mean	SE	*N*	Mean	SE	*N*	Mean	SE
April	73	122.4	11.1	22	187.1	24.8	51	94.5	9.7	—	—	—
May	22	201.5	20.8	6	277.2	26.3	16	173.1	23.4	—	—	—
June	374	83.0	2.5	205	85.7	4.0	169	79.7	2.6	—	—	—
July	1,294	54.5	1.0	309	70.3	3.5	985	49.5	0.7	—	—	—
August	233	75.1	1.9	34	98.6	11.0	158	73.6	0.9	41	61.4	1.1
September	929	89.8	0.8	517	87.0	1.2	384	94.7	1.0	28	75.3	3.8
October	809	90.3	1.0	526	94.2	1.2	283	83.0	1.7	—	—	—

The lengths of prey fish consumed changed significantly throughout the sampling period *(P* < 0.001). Larger prey were consumed in April and May (mean total lengths of 122.3 mm and 201.6, respectively) (table 2). Mean total lengths of prey consumed from June to October were less than 100 mm. Total length of gizzard shad in June averaged 178.1 mm, which corresponded to yearling and older fish. By July, mean lengths of age-0 gizzard shad were just over 45 mm and gradually increased to 103 mm by October. Lengths of yellow perch in diets averaged 127 mm in spring, 86 mm in July, and more than 190 mm by September. Male cormorants consistently ate larger prey fish than females during most months *(P* < 0.001).

Cormorant and Trawl Comparisons

Cormorants appeared opportunistic in their foraging habits; however, some selection for older and larger fish may have existed, as determined by Chesson's alpha (Chesson 1978, 1983). Age-0 (young-of-the-year) gizzard shad were selectively eaten in September (α = 0.622) as were yearling and older (age $\geq$1) gizzard shad in June (α = 0.988), July (α = 0.985), and September (α = 1.000). Yearling and older (age $\geq$1) freshwater drum were selected in May (α = 0.984) and from July to September (α values ranged from 0.291 to 0.695). The only instance when emerald shiners were preferred was in July, when cormorants selected age-0 fish (α = 0.236). No apparent differences existed in prey selection between sexes.

In general, cormorants fed on age-0 prey fish that were of similar sizes to those in trawl catches. Length ranges of age-0 gizzard shad collected from cormorant stomachs and trawls overlapped (fig. 5). Gizzard shad from trawls were larger than those in cormorant stomachs collected in July *(P* = 0.004) or September *(P* = 0.001). During August, the mean length of gizzard shad was greater from the trawls *(P* < 0.001). Emerald shiners were larger in trawls than in stomachs in June *(P* < 0.001), July *(P* = 0.012), and September *(P* < 0.001). Freshwater drum *(P* < 0.001) and white bass *(P* < 0.001) were larger in cormorant stomachs than in trawl catches (fig. 5). Freshwater drum and white bass in cormorant stomachs were typically age-1 and older fish, whereas the trawl usually collected only young-of-the-year of these species.

Cormorant and Walleye Comparisons

Gizzard shad made up the largest proportion by mean percentage wet weight in diets of cormorants and walleye (fig. 6). The proportion of emerald shiners in walleye diets was greater than for cormorants. Mean percentage wet weights of white bass were similar for both predators. Freshwater drum, which was evident in the diet of cormorants, was absent in walleye diets.

Diets of cormorants (sexes combined) and walleyes overlapped in August, September, and October (table 3). Diet overlap was higher between female cormorants and walleyes than between male cormorants and walleyes for all months except September. Range of prey fish lengths consumed by cormorants and walleyes was similar. Mean lengths of gizzard shad consumed by cormorants was less than those consumed by walleyes (fig. 7). Conversely, walleyes tended to consume smaller emerald shiners than cormorants. The lengths of white bass, the only other prey fish common to cormorants and walleyes, were similar (July, *P* = 0.150; September, *P* = 0.328), except in July, when lengths were greater from DCCO stomachs *(P* = 0.029).

Discussion

DCCO's have been reported to be opportunistic foragers, feeding on the most abundant and easily accessible prey (Craven and Lev 1987, Ludwig et al. 1989, Campo et al. 1993, Derby and Lovvorn 1997). Studies have shown that DCCO's consume a diversity of prey (Blackwell 1995). Our results revealed similar conclusions: cormorants fed on the most available and abundant prey fish. The abundance of fish in cormorant stomachs corresponded to abundances in trawl catches by Ohio Division of Wildlife (Ohio Division Wildlife 1997). Cormorants on Lake Erie consumed larger, older fishes early in the year when smaller prey fishes were not available. Once age-0 fish reached a size that made them available as prey, cormorants

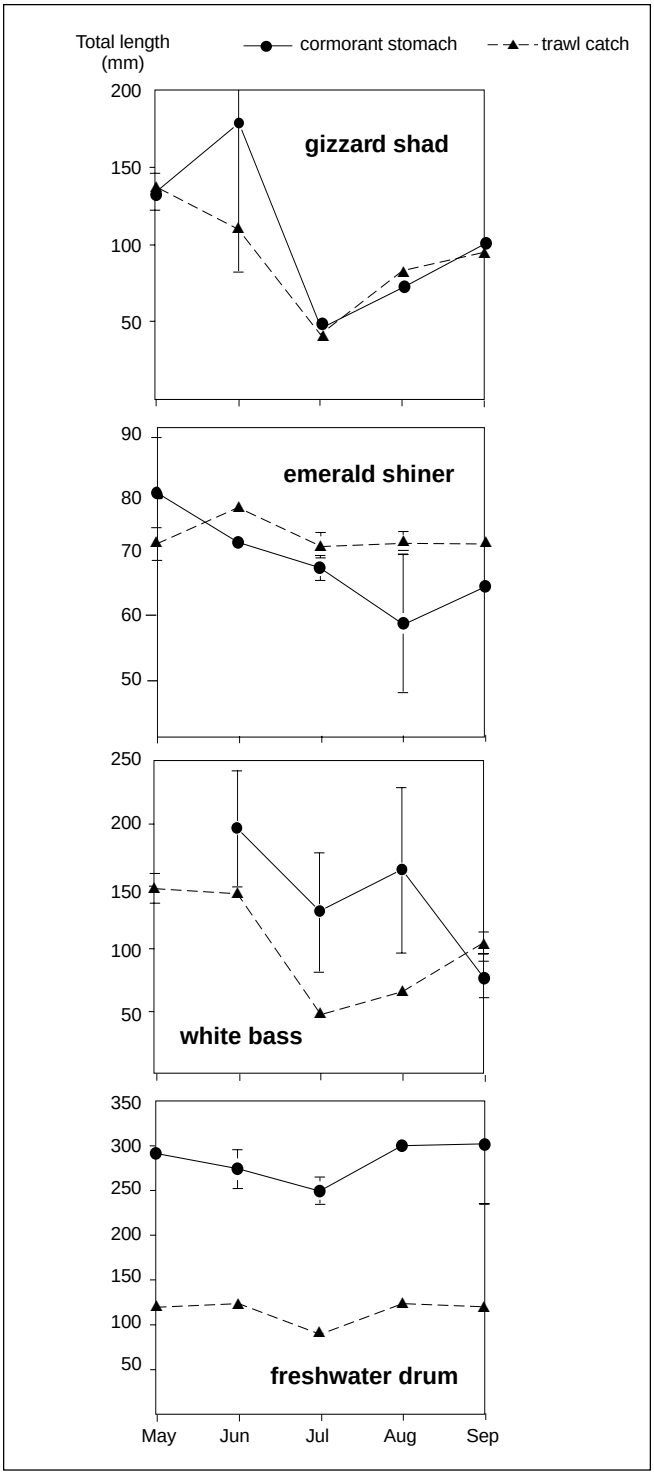

Figure 5—Mean total length (± 2 standard errors) of prey fish consumed by cormorants and caught in bottom trawls in western Lake Erie, May–September 1997.

Table 3. Diet overlap values for double-crested cormorants and walleye in western Lake Erie, July–October 1997, from Schoener (1970)

	Double-crested cormorants		
Month	**Males/walleye**	**Females/walleye**	**Sexes combined/walleye**
July	[1]0.458	0.619	0.532
August	0.400	0.637	0.614
September	0.612	0.591	0.602
October	0.814	0.851	0.827

[1]Values were calculated by sex and sexes were combined for cormorants.

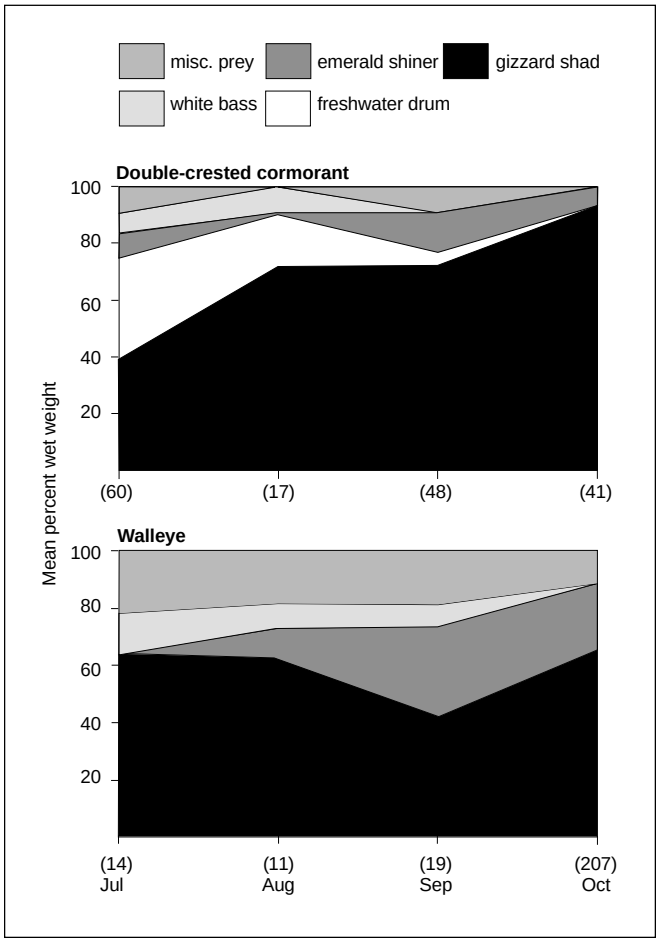

Figure 6—Mean percent wet weight of prey consumed by cormorants and walleye from western Lake Erie, July–October 1997. Sample sizes are in parentheses.

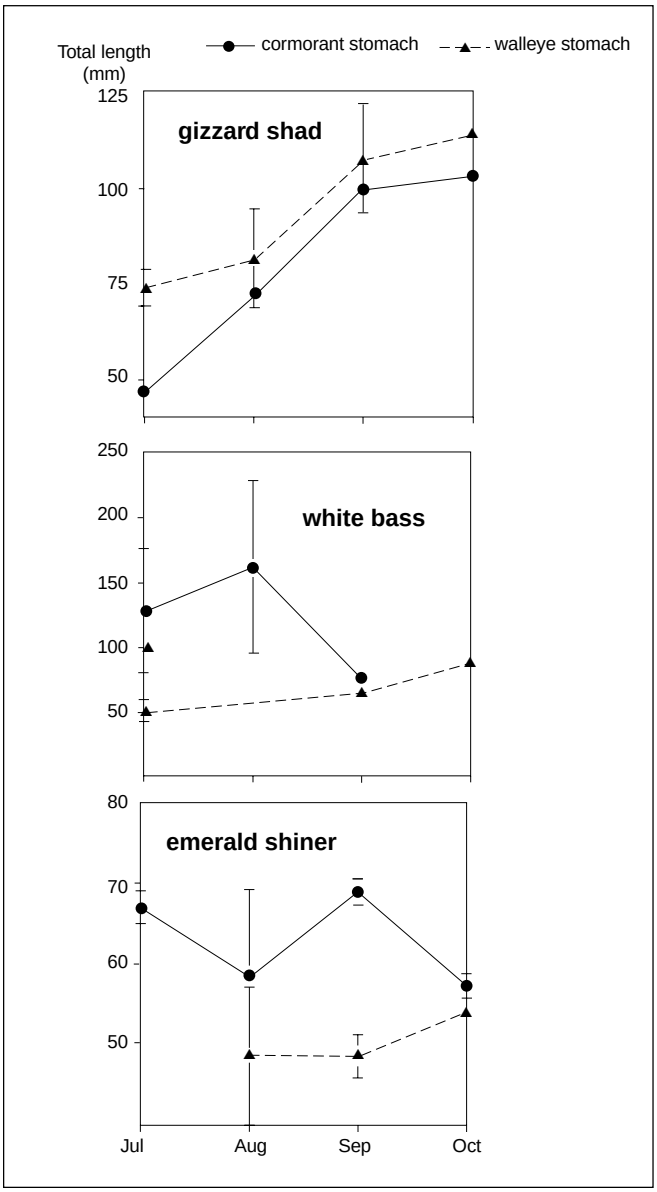

Figure 7—Mean total length (± 2 standard errors) of prey fish consumed by cormorants and walleyes in western Lake Erie, July–October 1997.

switched to age-0 fish as the major component of their diet. Cormorants on Lake Erie preyed on various fish species (*n* = 15) (table 1). Some of these prey fish are bottom dwellers; others are pelagic.

Diet studies in the Great Lakes indicate that small fish, such as alewife and sticklebacks (Gasterosteidae), are often the most frequently occurring food (Craven and Lev 1987, Ross and Johnson 1995, Neuman et al. 1997). Two of the most frequently occurring species from our Lake Erie study were young gizzard shad and emerald shiners, both of which are small and have little sport or commercial value. Lake Erie is shallower and warmer than the other four Great Lakes and supports a slightly different composition of fish species. Sport fish were present in cormorant diets from other Great Lakes studies (Ross and Johnson 1995, Maruca 1997, Neuman et al. 1997) much more frequently than in cormorant diets from this study. Yellow perch and walleye, valuable sport and commercial fish, each occurred in less than 6 percent of the stomachs. The only other species of importance to the sport fishery was smallmouth bass, which was found in less than 1 percent of stomachs.

Importance of major prey items during different life-history periods of cormorants (egg incubation, nestling, and fledgling) varied over the course of this study. In western Lake Erie, egg incubation is typically initiated by mid-April, nestling period occurs from late May to late July, and first birds fledge during the last week in July (D. Weseloh, pers. commun.). During the incubation and nestling periods, cormorants consumed freshwater drum more frequently than any other food item (fig. 3). The high incidence of freshwater drum in diets suggested that fish were schooling and were readily available because they were either in prespawning or spawning condition or were feeding (Daiber 1950, Trautman 1981). Additionally, during this period most age-0 fish were not large enough to be consumed as forage. Cormorants fed heavily on emerald shiners during the nesting period. The appearance of age-0 gizzard shad coincided with the fledging period for young cormorants. Emerald shiners and gizzard shad, the two most prevalent fish in cormorant diets, are small, soft-bodied, schooling fish of significant abundance in Lake Erie. These charac-

teristics make both species suitable for consumption by cormorants during nestling and fledging periods.

Cormorants fed on fish in western Lake Erie in proportions similar to those found in trawl catches. Most values for Chesson's selectivity index suggested cormorants did not preferentially feed on a particular species. Some values that suggested prey selection for larger fish may be biased because bottom trawls do not effectively capture larger, older fish, which can evade the trawl.

Cormorants did not selectively feed on any particular size range of age-0 fishes in Lake Erie. Although the ANOVA values suggested significant differences in lengths of gizzard shad and emerald shiners between cormorant stomachs and trawls, these differences were small. The range of fish lengths in cormorant stomachs was similar to that found in bottom trawls. The larger size of freshwater drum and white bass consumed by cormorants compared with those caught in trawls was due primarily to avoidance of the trawl by the larger, faster-swimming fishes.

DCCO's and walleyes shared the same food resource base. There was greater dietary overlap between walleye and female cormorants than male cormorants or between walleye and cormorants of combined sexes. Diet comparisons were made from July to October, when age-0 gizzard shad attained a size that made them available to both cormorants and walleyes. Cormorants consumed smaller gizzard shad than walleye. This is puzzling because gizzard shad can grow large enough to become unavailable to walleye. Cormorants did not appear to be limited by size of prey consumed, as evidenced by consumption of prey up to 350 mm. Walleye tended to consume slightly smaller emerald shiners than did cormorants, but this may have been an artifact of the sampling regime. A large percentage of walleye growth occurs in fall, and that growth is related to consumption of age-0 clupeids, of which gizzard shad is a major component (Hartman 1989). Thus, fall appears to be the period with highest potential for competitive interactions between these predators.

Management Recommendations

Results from this study suggest that impacts of DCCO's at current population levels to sport and commercial fisheries in Lake Erie are minimal. Similar conclusions were drawn from other diet studies in which sport or commercial fish were obvious components but were not heavily affected by cormorant predation (Craven and Lev 1987, Hobson et al. 1989, Maruca 1995). There have been various attempts by different organizations and individuals to control DCCO populations (J. Trapp, pers. commun.). In the United States, cormorants are protected under migratory bird laws and treaties; hence, any control measures would have to be under special permits showing evidence of damage or negative impacts. Most control measures have proven ineffective. For Lake Erie, no permits have been requested issued, and evidence suggests that, at this time, there is no cause for controlling cormorant populations to reduce impacts on the sport and commercial harvests.

Concern over DCCO impacts on the forage fish base in Lake Erie is greatest in fall, when cormorant and walleye diets overlap the most. However, selective predation by cormorants and walleyes may reduce competitive interactions. Fall is also the time in which migratory waterbirds, such as DCCO's and red-breasted mergansers, use western Lake Erie as a feeding and resting area. Madenjian and Gabrey (1995) employed a bioenergetics model that indicated that all species of waterbirds combined consumed an equivalent of 15.2 percent of the prey biomass that supports walleye populations in western Lake Erie for a single growing season. Predation by cormorants on fish accounted for only 1.7 percent of the biomass that supports walleyes for 1 year. Even if the nesting DCCO population doubled, the model calculated that predation on forage fish would increase only modestly (Madenjian and Gabrey 1995). Predation by migrant cormorants accounts for only 3 percent of the consumption by all migrant waterbirds. Presently, DCCO impacts on the forage base do not warrant control measures for this species on Lake Erie.

The bottom trawl used to assess the Lake Erie fish community has its own set of biases associated with it. The trawl samples only the bottom 2 m of the lake. Gizzard shad and emerald shiners (the two most important prey species of walleye and cormorants in the western basin) typically are distributed throughout the water column. Therefore, the trawl may underestimate relative abundance of these pelagically distributed forage species. Because of biases associated with this gear, researchers have developed other indicators of prey availability. An index of prey availability derived from walleye prey-size selectivity has proved useful for forage assessment in western Lake Erie (J. Tyson, Ohio Division of Wildlife, unpubl. data). Because cormorant diets proved similar to walleye diets, the possibility exists to construct an index from cormorant diets, as well. Constructing a prey availability index from cormorant diets could provide an additional tool for assessing annual composition and abundance of forage fish.

Acknowledgments

We thank J. Bales, R. Barna, G. Barrett, B. Blackwell, R. Dolbeer, T. Girard, S. Goclan, B. Ickes, N. Meade, A. Montoney, T. Seamans, R. Slemons, M. Tobin, and D. Weseloh for assistance in field collections and processing DCCO's. Comments from Jerome Jackson, Mark Tobin, and an anonymous reviewer improved an earlier draft of the manuscript. This study was funded in part by Lake Erie Protection Fund small grant LEPF–57–97.

References Cited

Blackwell, B. F.; Krohn, W. B.; Allen, R. B. 1995. Foods of nestling double-crested cormorants in Penobscot Bay, Maine, USA: temporal and spatial comparisons. Colonial Waterbirds 18 (Spec. Publ. 1): 199–208.

Campo, J. J.; Thompson, B. C.; Barron, J. C.; Telfair, R. C., II; Durocher, P.; Gutreuter, S. 1993. Diet of double-crested cormorants wintering in Texas. Journal Field Ornithology 64(2): 135–144.

Chapdelaine, G.; Bedard, J. 1995. Recent changes in the abundance and distribution of the double-crested cormorant *(Phalacrocorax auritus)* in the St. Lawrence River, estuary and gulf, Quebec, 1978–1990. In: Nettleship, D. N.; Duffy, D. C., eds. The double-crested cormorant: biology, conservation, and management. Colonial Waterbirds 18 (Spec. Publ. 1): 70–77.

Chesson, J. 1978. Measuring preference in selective predation. Ecology 59: 211–215.

Chesson, J. 1983. The estimation and analysis of preference and its relationship to foraging models. Ecology 64: 1297–1304.

Craven, S. R.; Lev, E. 1987. Double-crested cormorant in the Apostle Islands, Wisconsin, USA: population trends, food habits, and fishery depredation. Colonial Waterbirds 10: 64–71.

Daiber, F. C. 1950. The life history and ecology of the sheepshead, *Aplodinotus grunniens* rfinesque, in western Lake Erie. Ph.D. dissertation. Columbus, OH: The Ohio State University. 88 p.

Derby, C. E.; Lovvorn, J. R. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. Canadian Journal of Fisheries and Aquatic Science 54: 1480–1493.

Fargo, W. G.; Van Tyne, J. 1927. Fall bird notes from the eastern shore of Lake Superior. Canadian Field-Naturalist 41: 7–9.

Fox, G. A.; Weseloh, D. V. 1987. Colonial waterbirds as bio- indicators of environmental contamination in the Great Lakes. In: Diamond, A. W.; Filion, F. L., eds. The value of birds. Tech. Publ. 6. Cambridge, UK: International Council for Bird Conservation: 209–216.

Hartman, K. J. 1989. Western Lake Erie walleye: predation, prey utilization and the relationship with somatic growth. Ph.D. dissertation. Columbus, OH: The Ohio State University.

Hatch, J. J. 1984. Rapid increase of double-crested cormorants nesting in southern New England. American Birds 38: 984–988.

Hobson, K. A.; Knapton, R. W.; Lysack, W. 1989. Population, diet, and reproductive success of double-crested cormorants breeding on Lake Winnipegosis, Manitoba, in 1987. Colonial Waterbirds 12: 191–197.

Johnson, J. H.; Ross, R. M. 1996. Pellets versus feces: their relative importance in describing the food habits of double- crested cormorants. Journal of Great Lakes Research 22: 795–798.

Knight, R. L.; Margraf, F. J.; Carline, R. F. 1984. Piscivory by walleyes and yellow perch in western Lake Erie. Transactions of the American Fisheries Society 113: 677–693.

Langlois, T. H. 1950. Crow ducks on Little Chicken Island. Ohio Conservation Bulletin 13: 6–7.

Ludwig, J. P. 1984. Decline, resurgence and population dynamics of Michigan and Great Lakes double-crested cormorants. Jack-Pine Warbler 62(4): 91–102.

Ludwig, J. P.; Hull, C. N.; Ludwig, M. E.; Auman, H. J. 1989. Food habits and feeding ecology of nesting double-crested cormorants in the upper Great Lakes, 1986–1989. Jack-Pine Warbler 67: 117–129.

Madenjian, C. P.; Gabrey, S. W. 1995. Waterbird predation on fish in western Lake Erie: a bioenergetics model application. Condor 97: 141–153.

Maruca, S. L. 1997. The impact of cormorant predation on yellow perch in Les Cheneaux Islands, Lake Huron. In: Diana, J. S.; Belyea, G. Y.; Clark, R. D., eds. History, status, and trends in populations of yellow perch and double-crested cormorants in Les Cheneaux Islands, Michigan. Spec. Rep. 17. Ann Arbor: Michigan Department of Natural Resources, Fisheries Division: 47–82.

Mastrangelo, P.; Sloan, C.; Bruce, K. 1997. Incorporating depredation permits into integrated damage management plans for aquaculture facilities. Eastern Wildlife Damage Management Conference 7: 36–43.

Neuman, J.; Pearl, D. L.; Ewins, P. J.; Black, R.; Weseloh, D. V.; Pike, M. 1997. Spatial and temporal variation in the diet of double-crested cormorants *(Phalacrocorax auritus)* breeding on the lower Great Lakes in the early 1990s. Canadian Journal of Fisheries and Aquatic Sciences 54: 1569–1584.

Ohio Division of Wildlife. 1997. Ohio's Lake Erie fisheries, 1996. Report to the Lake Erie Committee, March 1997. [Place of publication unknown]: Ohio Division of Wildlife. 84 p.

Orta, J. 1992. Family Phalacroncoracidae (cormorants). In: Handbook of birds of the world. [Place of publication, publisher, and total pages unknown.]

Ross, R. M.; Johnson, J. H. 1995. Seasonal and annual changes in the diet of double-crested cormorants: implications for Lake Ontario's fishery. Great Lakes Research Review 2: 1–9.

SAS. 1995. SAS user's guide. Statistics. Version 5. Cary, NC: SAS Institute, Inc. 956 p.

Schoener, T. W. 1970. Non-synchronous spatial overlap of lizards in patchy habitats. Ecology 51: 408–418.

Trautman, M. B. 1981. The fishes of Ohio. Columbus, OH: The Ohio State University Press.

Vermeer, K.; Rankin, L. 1984. Population trends in nesting double-crested and pelagic cormorants in Canada. Murrelet 65: 1–9.

Wallace, R. K., Jr. 1981. An assessment of diet-overlap indexes. Transactions of the American Fisheries Society 110: 72–76.

Weseloh, D. V.; Ewins, P. J.; Struger, J; Mineau, P.; Bishop, C. A.; Postupalsky, S.; Ludwig, J. P. 1995. Double-crested cormorants of the Great Lakes: changes in population size, breeding distribution, and reproductive output between 1913 and 1991. Colonial Waterbirds 18 (Spec. Publ. 1): 48–59.

Zaret, T. M.; Rand, A. S. 1971. Competition in tropical stream fishes: support for the competitive exclusion principle. Ecology 62: 236–342.

Directory of Personal Communications

K. Kayle
Ohio Dept. of Natural Resources
421 High Street
Fairport Harbor, OH 44077

M. Kershner
Aquatic Ecology Labororatory
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212

M. Shieldcastle
Ohio Division of Wildlife
13229 W. State Route 2
Oak Harbor, OH 43449

J. Trapp
U.S. Dept. of the Interior,
U.S. Fish and Wildlife Service
Office of Migratory Bird Management
4401 N. Fairfax Drive, mail stop 634
Arlington, VA 22203

D. V. Weseloh
Canadian Wildlife Service
P.O. Box 5050
Burlington, ON L7R 4A6