Diet Composition and Fish Consumption of Double-Crested Cormorants from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 1999

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Introduction

Over the last thirty years populations of double-crested cormorants (Phalacrocorax auritus) have increased dramatically in the Great Lakes region (Weseloh et al. 1995). Beginning in the early 1990's, the population of cormorants in the eastern basin of Lake Ontario created sufficient concern regarding their impacts on local fish populations that a study was conducted on their diets (Karwowski et al. 1994, Neuman et al. 1997). That study examined the food habits of cormorants from Little Galloo, Pigeon, and Snake Islands, the three largest cormorant colonies in the eastern basin. Since 1992, cormorant diet studies have only been carried out for the Little Galloo colony (Ross and Johnson 1995, Johnson and Ross 1996, Ross and Johnson, in press, Johnson et al. 1997, Johnson et al. 1999). This paper reports on the diet composition and fish consumption of cormorants from the Pigeon and Snake Island colonies in 1999.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants on Pigeon and Snake Islands in 1999. Except for one occasion (i.e., Pigeon Island on May 12 when only 91 pellets were collected), approximately 150 pellets were collected on each of 5 dates on each island beginning in late April and ending mid (Pigeon Island) to late (Snake Island) August. The sample size (150) was determined using power analysis based on sample variability from earlier work that used pellets to describe the diet of cormorants on Little Galloo Island (Ross and Johnson, in press). In the laboratory, diagnostic bones, all otoliths, and representative scales were removed from the pellets and identified under magnification. Eye lenses were also enumerated since, although they could not be used in species identification, their total number (number of lenses/2) generated fish counts that exceeded fish counts based on bones or otoliths in some pellets. For prey species identified, diagnostic fish material recovered from cormorant pellets were compared with bones, scales, and otoliths from known specimens that had been defleshed in a NaOH solution.

To estimate number of fish consumed by cormorants, we used a model similar to that of

Weseloh and Casselman (unpublished report: Fish consumption by double-crested cormorants on Lake Ontario, Burlington, Ontario) to estimate the annual number of fish eaten by cormorants. This model incorporated cormorant age-class population size and seasonal residence time (time spent feeding in area), mean daily fish ingestion rates, a fecal pathway correction factor for fish not detected in pellets, and several assumptions based on values from the literature or personal communication from colleagues. We assumed that (1) residence time for breeding adults, immatures, and young of year (YOY) was 158, 112, and 92 days, respectively (Weseloh and Casselman, report cited above); (2) number of immatures was approximately 10% of adult population; and (3) the number of young-of-year (YOY) cormorants is the product of the fledgling productivity estimate for the year and the number of active nests. The model does not account for bird mortality during the time of residence or the migrant double-crested cormorant population (transient birds that stay an unknown amount of time on Lake Ontario). Incorporating bird mortality estimates into the model would decrease fish consumption estimates whereas adding migrant birds would increase consumption estimates. To examine cormorant fish consumption by feeding period (i.e., pre-chick, chick, and post-chick) we further broke down the number of cormorants feeding days by age-class as follows:

	Days			
	Pre-chick	**Chick**	**Post-chick**	**Total**
Adults	64	42	52	158
Immatures	18	42	52	112
YOY	0	42	50	92

For estimates of mean daily ingestion rates, we used the mean number of fish per pellet multiplied by a fecal correction factor (1.042) (Johnson and Ross 1996). Although there is some variation, a single pellet is usually produced by adult cormorants each day (Craven and Lev 1987, Orta 1992, Derby and Lovvorn 1997). Consequently, we considered the contents of a pellet to represent daily fish consumption. Fish consumption estimates were derived for each of the three feeding periods using our estimates of the number of days each age-class of cormorants fed in that period (see text table above) and the specific mean daily ingestion rates (number of fish per pellet) for that period. To estimate the biomass of fish eaten, we assumed that cormorants consumed 0.47 kg fish per day (Schramm et al. 1984, 1987; Weseloh and Casselman 1992). This represents about 25% of their body weight (Dunn 1975). Since 0.47 kg is about 1 pound, a straight forward estimator of biomass consumed, in pounds, is the number of cormorant feeding days (i.e., 1 cormorant feeding day equals 1 pound of fish consumed). To estimate the length of smallmouth bass consumed in 1999, we followed the technique described by Adams et al. 1999 and measured (with calipers) only those otoliths that exhibited little wear (i.e., levels 1 and 2). We used annual length-weight regressions for smallmouth bass in the eastern basin (pers. comm. and unpublished data, Tom Eckert, NYSDEC, Cape Vincent) to estimate the weight of smallmouth bass consumed by cormorants. Diet overlap between cormorants from the Pigeon and Snake Island colonies and between feeding periods was determined by using the equation of Morisita (1959) as modified by Horn (1966). Overlap values can range from 0, when samples contain no food in common, to 1, when there is identical representation of food between samples. When using this formula, overlap values (C8) $ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

A total of 1,417 pellets were used to describe the feeding ecology of cormorants from Pigeon (676 pellets) and Snake Island (741 pellets) in 1999 (Tables 1 and 2). Because of apparent temporal differences in diet composition and daily fish consumption (fish/pellet), three distinct periods of cormorant feeding are described, i.e., pre-chick feeding, chick feeding, and post-chick feeding. For the Pigeon Island colony, the number of fish per pellet (adjusted for fecal loss) declined from 20.5 during the pre-chick feeding period to 10.8 during the post-chick feeding period and averaged 15.5 for the entire period (Table 1). Cormorant pellets from the Snake Island colony contained fewer fish

(0=12.5) that those from Pigeon island with the lowest consumption rate (9.7 fish/pellet) occurring during the chick feeding period (Table 2).

Diet Composition

Yellow perch was the major prey of cormorants from the Pigeon (38.4%) and Snake (47.7%) Island colonies (Tables 1 and 2). Alewife (24.4% and 8.5%) and cyprinids (10.5% and 15.8%) were either the second or third most abundant prey in the diet of cormorants from these two colonies (Tables 1 and 2). The contribution of alewife in the diet increased greatly during the chick-feeding period at both colonies though to a greater extent at the Pigeon Island colony. Slimy sculpin and threespine stickleback were generally more abundant in the diet of cormorants from both colonies during the pre-chick feeding period. For the entire period, forage fish (i.e., alewife, cyprinids, threespine stickleback, slimy sculpin, etc.) species contributed 49.9% and 38.8% of the diet of cormorants compared to 48.0% and 60.0% for panfish (i.e., yellow perch, rock bass, pumpkinseed) and 2.1% and 1.2% for gamefish for the Pigeon and Snake Island colonies, respectively (Tables 1 and 2).

Diet Overlap

For the entire season, diet overlap was high (C8=0.91) between cormorants from the Pigeon and Snake Island colonies (Table 3A). Diet overlap was highest during the post-chick feeding period (C8=0.96) and lowest during the chick feeding period (C8=0.70). Diet overlap values between feeding periods for each colony indicated there was substantially less temporal variation in the diet of cormorants from the Snake Island (C80=0.81) than the Pigeon Island (C8=0.52) colony (Table 3B).

Fish Consumption

Based on nest counts, 2,228 on Pigeon Island and 1,122 on Snake Island and fledgling productivities of 1.5 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 1.06 million and 0.53 million cormorant feeding days for these colonies, respectively, in 1999. Fish consumption for the Pigeon Island colony was estimated at 15.31 million fish and 1.06 million pounds, and for the Snake Island colony at 6.66 million fish and 0.53 million pounds (Table 4). The number of forage fish (7.66 million, mainly alewife-3.77 million, cyprinids-1.62 million, threespine stickleback-1.43 million, and slimy sculpin 0.77 million) and panfish (7.33 million, mostly yellow perch-5.88 million, rock bass-0.88 million, and pumpkinseed-0.50 million) consumed by cormorants from Pigeon Island was similar (Table 5). Cormorants from Pigeon Island consumed an estimated 0.32 million gamefish in 1999 which were mostly smallmouth bass (0.26 million). The majority of the fish (3.97 million) consumed by cormorant from the Snake Island colony were panfish, primarily yellow perch (3.17 million), pumpkinseed (0.39 million), and rock bass (0.35 million) (Table 5). Cormorants from Snake Island also consumed 2.61 million forage fish (mostly cyprinids-1.05 million, alewife-0.57 million, slimy sculpin-0.55 million, and threespine stickleback-0.30 million) as well as 0.08 million gamefish (mainly smallmouth bass-0.05 million) (Table 5).

Smallmouth Bass

Besides the percent contribution in the diet by number, we were also able to estimate the percent contribution by weight of smallmouth bass in cormorant diet using the relationship between otolith length and bass length. A total of 27 minimally or uneroded smallmouth bass otoliths (Pigeon Island-17, Snake Island-10) were recovered from cormorant pellets and measured in 1999. The mean length of otoliths from Pigeon and Snake Islands was 5.6 mm and 5.4 mm, respectively. Using the otolith length-fish length relationship for smallmouth bass developed for eastern Lake Ontario (Schneider and Adams 1999), the mean total length of bass consumed by cormorants from the Pigeon and Snake Island colonies would be 195 and 187 mm, respectively. Smallmouth bass of these lengths in eastern Lake Ontario would weigh 0.207 (Pigeon Island) and 0.181 (Snake Island) lbs. Consequently, the total biomass of smallmouth bass

consumed by the Pigeon and Snake Island cormorant colonies was 54,000 (i.e., 0.207 lbs x 260,000 bass consumed) and 9,000 (i.e., 0.181 lbs x 50,000 bass consumed) lbs, respectively. Smallmouth bass contributed 5.1% and 1.7% of the diet by weight (versus 1.7% and 0.7% by number) of the cormorant colonies on Pigeon and Snake Islands, respectively.

Discussion

This study, which includes the identification of fish remains from of 1,417 pellets, represents the most comprehensive examination of cormorant feeding ecology for the Pigeon and Snake Island colonies to date. Previous work examining the food habits of cormorants from these two colonies used 190 pellets and 164 chick boli to describe diets (Neuman et al. 1997). Neuman et al. 1997 reported significant differences in diet composition during the egg stage between cormorants from Pigeon and Snake Islands and nearby Little Galloo Island. However, using cormorant diet information from Little Galloo Island in 1999 (Johnson et al. 2000), we computed diet overlap values (C_8) between Little Galloo, Pigeon, and Snake Islands for each of the three feeding periods (i.e., pre-chick, chick, and post-chick) and found all values to indicate significant overlap in diet (i.e., all C_8 values were $ 0.60). Temporal variation in diet composition was evident for Pigeon Island ($C_8$0=0.52), but not for Snake Island ($C_8$0=0.81). Consequently, our data suggest that in 1999, cormorant diets among the three eastern basin colonies were not significantly different. However, at some colonies, some temporal variation was apparent.

We estimate that cormorants from Pigeon and Snake Islands consumed 15.31 and 6.66 million fish (1.06 and 0.53 million lbs), respectively, in 1999. Cormorants from nearby Little Galloo Island consumed an estimated 17.94 million fish (1.94 million lbs) in 1999. Consequently, cormorants from these three colonies consumed approximately 39.91 million fish totaling 3.53 million pounds. Based on cormorant nest counts, this represents about 96% of the fish consumption for all eastern basin colonies in 1999. Presently it is unknown as to what extent cormorants from these 3 colonies feed in U.S. versus Canadian waters. However, Newman et al. (1997) found that foraging distances of cormorants at Little Galloo Island ranged from 3.7 to 20 km (averaging 13 km). Based on these data and the proximity of all three colonies to U.S. and Canadian waters, it is likely that a portion of the birds from each of these colonies feed in both U.S. and Canadian waters.

Presently, smallmouth bass is the only species in eastern Lake Ontario where there is sufficient information to estimate fish length from otolith length (Schneider and Adams 1999). Although there needs to be caution when attempting to estimate fish length using otoliths recovered in pellets (Jobling and Breiby 1986), we believe that the criteria that we used (i.e., very little wear) in selecting otoliths for measurement is effective in reducing bias. However, what bias that remains probably resulted in an underestimation of fish size consumed by cormorants. Incorporating biomass estimates of smallmouth bass consumed into cormorant food habit data helped to better document the overall contribution of this species in the diet. Specifically, the contribution of smallmouth bass, presumably one of the larger species eaten by cormorants, was greater by biomass than by number for both colonies.

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Table 1: Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 1999. The pre-chick feeding period includes pellets collected on 4/30/99 and 5/12/99, the Chick feeding period includes pellets collected on 6/9/99 and 7/13/99, and the post-chick feeding period includes pellets collected on 8/12/99.

	Pre-chick	**Chick**	**Post-chick**	**Total**
No. of pellets	239	288	149	676
Fish/pellet (adjusted)	20.5	13.7	10.8	15.5 (mean)
Yellow perch	49.1	13.1	50.6	38.4
Alewife	0.1	63.5	15.9	24.4
Cyprinid	9.5	5.7	17.1	10.5
Threespine stickleback	19.8	5.1	---	9.3
Rock bass	4.5	4.6	8.6	5.7
Slimy sculpin	8.1	3.8	2.2	5.0
Pumpkinseed	6.1	0.4	2.5	3.3
Smallmouth bass	0.2	2.8	2.5	1.7
Ictalurid	0.7	0.3	0.1	0.4
Esocid	0.8	0.1	---	0.3
Darter	0.3	0.1	---	0.2
Trout perch	0.1	0.3	---	0.1
Walleye	0.1	---	0.1	0.1
Centrarchid	0.1	0.1	---	0.1
Rainbow smelt	0.1	0.1	---	0.1
Catostomid	0.2	---	0.1	0.1
Gizzard shad	---	---	0.3	0.1
White perch	0.1	---	---	0.1
Freshwater drum	0.1	---	---	0.1
	100.0	100.0	100.0	100.0

Table 2: Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 1999. The pre-chick feeding period includes pellets collected on 4/30/99 and 5/12/99, the Chick feeding period includes pellets collected on 6/9/99 and 7/13/99, and the post-chick feeding period includes pellets collected on 8/25/99.

	Pre-chick	**Chick**	**Post-chick**	**Total**
No. of pellets	297	295	149	741
Fish/pellet (adjusted)	14.9	9.7	13.0	12.5 (mean)
Yellow perch	39.9	43.3	56.5	47.7
Cyprinid	11.8	13.7	20.3	15.8
Alewife	---	29.1	2.7	8.5
Slimy sculpin	21.3	3.1	1.1	8.3
Pumpkinseed	11.3	0.9	4.6	5.8
Rock bass	3.2	7.5	6.1	5.5
Threespine stickleback	8.8	0.2	---	3.0
Gizzard shad	---	---	6.2	2.5
Smallmouth bass	0.1	1.2	0.9	0.7
Ictalurid	0.9	0.1	0.8	0.7
Esocid	1.3	0.1	0.2	0.5
Catostomid	0.2	0.1	0.4	0.3
Centrarchid	0.4	0.4	---	0.3
Trout perch	0.5	0.1	0.1	0.2
Rainbow smelt	0.1	---	0.1	0.1
Darter	0.1	---	---	<0.1
White perch	0.1	---	---	<0.1
Coregonid	---	0.1	---	<0.1
Burbot	---	0.1	---	<0.1
	100.0	100.0	100.0	100.0

Table 3A: Diet overlap between cormorants from the Pigeon and Snake Island colonies of eastern Lake Ontario, 1999.

Season	**C8**
Post-chick feeding	0.96
Pre-chick feeding	0.92
Entire	0.91
Chick feeding	0.70

Table 3B: Diet overlap between feeding periods for each cormorant colony, 1999.

Comparison	Pigeon Island	Snake Island
Pre-chick feeding-Chick feeding	0.23	0.74
Pre-chick feeding-Post-chick feeding	0.88	0.85
Chick feeding-Post-chick feeding	0.46	0.85
	Θ = 0.52	Θ = 0.81

Table 4: Fish consumption estimates in millions for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 1999.

	Pigeon Island		Snake Island	
Period	Numbers	Pounds	Numbers	Pounds
Pre-chick feeding	6.0	0.29	2.2	0.15
Chick feeding	4.7	0.35	1.7	0.17
Post-chick feeding	4.6	0.42	2.8	0.21
Total	15.3	1.06	6.7	0.53

Table 5: Estimated numbers in millions of fish consumed by species by cormorants from the Pigeon and Snake Island colonies in 1999.

Species	Pigeon Island	Snake Island
Yellow perch	5.88	3.17
Alewife	3.74	0.57
Cyprinids	1.62	1.05
Threespine stickleback	1.43	0.30
Rock bass	0.88	0.35
Pumpkinseed	0.50	0.39
Slimy sculpin	0.77	0.55
Smallmouth bass	0.26	0.05
Other	0.22	0.27
Total	15.30	6.70