

**Diet Composition and Fish Consumption of Double-Crested Cormorants
from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 2005**

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Pigeon Island (PI) and Snake Island (SI) are home to intermediate-sized colonies of Double-crested cormorants (*Phalacrocorax auritus*) in the Eastern Basin of Lake Ontario. The proliferation of cormorant colonies in this area has created concern as to the effects that these piscivorous birds may have on local fish populations (Schneider et al. 1999). 2005 represents the 7th consecutive year of diet sampling of the nesting cormorants on PI and SI, based on regurgitated digestive pellets for prey enumeration. Since 1999 nearly 10,000 cormorant pellets have been collected on PI (4,429) and SI (5,162), while over 12,000 were examined at a neighboring island, Little Galloo (LGI). This paper reports on the diet composition and fish consumption of cormorants from the PI and SI colonies in 2005, and compares these results to previous years. We also estimate the size of four species of sport fish consumed by cormorants.

Methods

Prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants from the PI and SI colonies in 2005. On PI, 489 pellets were collected on four dates beginning in early May and ending in late September. On SI, 738 pellets were obtained on five dates spanning the same period. No known disturbances affected cormorant nesting this year.

The preferred sample size for a single sample date (150) was determined using power analysis based on sample variability from earlier work that used pellets to describe the diet of cormorants on nearby LGI (Ross and Johnson 1999). In the laboratory, diagnostic bones, all otoliths, and representative scales were removed from the pellets and identified under magnification. Fish eye lenses were also enumerated since, although they could not be used in species identification, their total number (i.e., number of lenses / 2) generated fish counts that exceeded those based on bones or otoliths in some pellets. Identification of prey species was accomplished through comparison of recovered bones, scales, and otoliths with known specimens held in the laboratory.

To estimate number of fish consumed annually by cormorants from the two cormorant colonies, we used a model similar to that of Weseloh and Casselman (unpublished report: Fish consumption by double-crested cormorants on Lake Ontario, Burlington, Ontario). This model incorporated cormorant age-class population size and seasonal residence time (time spent feeding in area) to estimate the number of cormorant feeding days, mean daily fish ingestion rates, a fecal pathway correction factor for fish not detected in pellets (Johnson and Ross 1996), and several

assumptions based on values from the literature or personal communication from colleagues. To estimate the number of cormorant feeding days, we used active nest counts (all nests actually counted, not estimated) provided by the Canadian Wildlife Service and assumed that (1) residence time for breeding adults, immatures, and young-of-year (YOY) was 158, 112, and 92 days, respectively (Weseloh and Casselman, unpublished report); (2) number of immatures was about 10% of adult population, which was taken as twice the number of nests; and (3) the number of YOY cormorants is the product of the fledgling productivity estimate for the year and the number of active nests. We did not account for bird mortality during the time of residence or for transient birds that spent unknown amounts of time on Lake Ontario. Incorporating bird mortality estimates into the model would reduce fish consumption estimates, whereas including migrant birds would increase estimated consumption. Although YOY cormorants are generally present for about 113 days, consumption by chicks during the first 3 weeks post-hatch is considered minimal, and for the remainder of the season their daily food intake approximates that of adults (Weseloh and Casselman, unpublished report). Immature cormorants are essentially fully grown, but non-reproductive birds.

Because of apparent seasonal differences in feeding patterns of cormorants, we identified three separate feeding phases, pre-chick (prior to chick hatch, mid April to mid June), chick (chicks present and being fed by adults, mid June to early August), and post-chick (cessation of feeding chicks by adults, early August to early October) feeding. These phases were characterized by differences in diet consumption and daily fish consumption (i.e., the number of fish per pellet). To examine cormorant fish consumption by feeding period (i.e., pre-chick, chick, and post-chick), we further broke down the number of cormorant feeding days in a single breeding season by age-class as follows:

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
Adults	64	42	52	158
Immatures	18	42	52	112
YOY	0	42	50	92

To estimate the number of fish consumed by cormorants during each feeding period, we multiplied the number of double-crested cormorant

feeding days by mean daily ingestion rates for that period. For estimates of mean daily ingestion rates, we used the mean number of fish per pellet multiplied by a fecal correction factor of 1.042 (Johnson and Ross 1996). Although variation in pellet production rates have been observed in cormorants (Carss et al. 1997), a single pellet is thought to be typically produced by adult cormorants each day (Craven and Lev 1987, Orta 1992, Derby and Lovvorn 1997). Pellet production rates greater than one per day would increase our fish consumption estimates, whereas rates less than one per day would reduce our estimates. Fish consumption estimates for each of the three feeding periods were summed to provide an annual fish consumption estimate. Species-specific fish consumption was estimated by multiplying the percent composition (by number, not weight) for each species in the diet and each feeding period by the total fish consumption estimate for that period. Consumption estimates were then summed for all three periods to provide annual consumption estimates for each species or taxon. The use of the Weseloh and Casselman model, which did not include variance estimates associated with the number of feeding days for each life stage, precluded us from generating standard error estimates for fish consumption estimates.

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), representing about 25% of their body weight (Dunn 1975). We estimated the size of smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), and pumpkinseed (*Lepomis gibbosus*) consumed during each cormorant feeding period by measuring all otoliths of these targeted species (randomly selected if >100 available) from each feeding period to the nearest 0.1 mm with calipers. Broken or chipped otoliths were not considered for measurement. We used otolith-length to fish-length relationships derived for smallmouth bass, yellow perch, rock bass, and pumpkinseed (Ross et al. 2005a) to estimate the length of these species eaten by cormorants. To estimate the weight of these species consumed by cormorants, we used length-weight regressions for eastern Lake Ontario populations (unpublished data).

We investigated whether cormorant diets were different between islands or feeding periods. To do this, spatial and temporal variation in diet composition for colonies at PI, SI, and, for comparison, LGI, was determined by using the overlap 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 ($C\lambda \geq 0.60$) are considered biologically significant (Zaret and Rand 1971).

Results

In all, 1,227 cormorant pellets were examined from PI (489) and SI (738) in 2005 (Tables 1 and 2). Similar to previous years, three distinct cormorant feeding periods were apparent, i.e. pre-chick, chick, and post-chick, characterized by differences in diet composition and daily fish consumption (fish/pellet). Daily fish consumption for the PI colony dropped during the chick-feeding period, then rose sharply during the post-chick feeding period, averaging 23 fish/pellet (Table 1). At SI an increasing seasonal consumption trend was again observed, from 24 (pre-chick) to 39 (post-chick), with an average of 32 (Table 2). Daily fish consumption (mean no. fish/pellet) increased by 33% at PI but only by 6% at SI over last year (Tables 1 and 2; Ross et al. 2005b).

Diet Composition

The diet of cormorants from the PI colony consisted mostly of round goby (*Neogobius melanostomus*, 88%), alewife (*Alosa pseudoharengus*, 5%), yellow perch (4%), and rock bass (1%) (Table 1). All other species combined comprised less than 3% of the cormorants' diet. Forage fish (i.e. round goby, alewife, three-spine stickleback, cyprinids, slimy sculpin, etc.) comprised 95% of the diet (up from 84% in 2004), panfish (i.e. yellow perch, rock bass, pumpkinseed, ictalurids etc.) composed 5% (down from 14% in 2004), and gamefish (mostly smallmouth bass) contributed <1% (from <2% in 2004) of the diet of PI cormorants (Table 1). The exotic round goby again rose sharply in cormorant diets this year (88%) over 2004 (36%). Seasonal trends repeated those of previous years: a great increase in the percent composition of alewife, and to a lesser degree yellow perch, during the chick feeding period.

The principal prey of SI cormorants were round goby (88%), yellow perch (7%), cyprinids (2%), and rock bass (1%) (Table 2). Round goby dominated cormorant diets the entire season, with only yellow perch exceeding 5% of the diet in any feeding period. Forage fish (round goby, cyprinids, alewife, three-spine stickleback, and slimy sculpin) made up 90% (92% in 2004) of the diet of SI cormorants, panfish (yellow perch, rock bass, pumpkinseed, and ictalurids) 7% (10% in 2004), and gamefish (smallmouth bass, esocids, and walleye) <1% (Table 2).

Diet Overlap

Diet overlap in cormorants was significant ($C\lambda \geq 0.60$) between PI and SI for all feeding periods, i.e., the prey of these two groups were essentially the same throughout the season (Table 3). However, spatial diet overlap between LGI and either PI or SI was low early, increasing as the season progressed. Significant diet overlap occurred only during the post-chick feeding period. Thus the diet of LGI cormorants was quite different from that of PI and SI cormorants early in the season and mid-season. Significant temporal diet overlap was observed at PI and SI but not at LGI (Table 4).

Fish Consumption

Based on nest counts of 1,315 on PI and 572 on SI as well as fledgling productivities of 1.8 for both islands (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 662,760 and 288,280 cormorant feeding days for these colonies, respectively, in 2005. Fish consumption for the PI colony was estimated at 15.7 million fish weighing 0.69 million pounds, and for the SI colony at 9.4 million fish weighing 0.30 million pounds (Table 5). Cormorants from PI consumed an estimated 14.7 million forage fish (round goby, alewife, three-spine stickleback, slimy sculpin, cyprinids, catostomids, and trout-perch), 0.9 million panfish (yellow perch, rock bass, pumpkinseed, and ictalurids), and 0.05 million gamefish (mostly smallmouth bass) (Figure 1a). Cormorants from the SI colony consumed 8.5 million forage fish, 0.9 million panfish, and <0.01 million gamefish (Figure 1b).

Size of fish consumed

Cormorants consumed smallmouth bass, yellow perch, rock bass, and pumpkinseed of sizes (total lengths) estimated in Table 6, based on

measurements of otoliths recovered from pellets. Small differences in the size of fish consumed between colonies were observed for the targeted species. Apparent exceptions are much larger smallmouth bass and pumpkinseed at SI than PI during the pre-chick feeding period, but the mean lengths were based on very small sample sizes. Temporal changes in the size of fish consumed by cormorants were small and inconsistent.

The average estimated weight of smallmouth bass, yellow perch, rock bass, and pumpkinseed (computed from otolith length-fish weight regressions) for each feeding period is also provided in Table 6. We estimated the biomass of each of these four species consumed by cormorants during each feeding period at the colonies. For the entire feeding season, cormorants from PI and SI colonies consumed 4,700 and 1,000 pounds of smallmouth bass, 10,700 and 10,700 pounds of yellow perch, 8,400 and 4,700 pounds of rock bass, and 0 and 3,700 pounds of pumpkinseed, respectively. These numbers are empirically derived estimates based on otolith recoveries, rather than on literature values such as average consumption of one pound of fish per day (e.g., Schramm et al. 1984, 1987; Weseloh and Casselman 1992).

Discussion

Considering 2004 (Ross et al. 2005) and 2005, very little interannual variation in cormorant diets is now occurring at either PI or SI. This loss of diet variability is clearly due to the expansion (PI) or continued domination (SI) of the round goby in foraging habitats. Round goby now comprises a surprisingly uniform 88% of the prey at both PI and SI. Changes in prey species composition between years were <4% at both islands overall. Since 1999 the dominant prey species at PI have been yellow perch (4 to 38%), alewife (5 to 30%), three-spine stickleback (1 to 55%), and round goby (0-88%). At SI, round goby has apparently saturated benthic communities and reached a plateau in abundance based on observed cormorant diets. With the exception of yellow perch at SI, all other prey species are now either insignificant or rare components of cormorant diets at these two islands.

In 2005, significant spatial variation in cormorant diets was limited to LGI in relation to PI and SI.

Significant temporal variation was also limited to LGI. The presence (PI and SI) or absence (LGI) of dominant round goby diet components probably explains these phenomena. Seasonal inshore movement of spawning alewife likely caused temporal diet variation at LGI. Nearly all spatial and temporal variation in cormorant diets was eliminated at PI and SI in 2005.

Perhaps because of the lack of anthropogenic disturbances which occurred from 2002-2004, fish consumption by the PI colony rebounded to near 1999 levels (Johnson et al. 2000), at 15.7 million fish and 0.69 million pounds. Fish consumption by the SI colony, though 20% lower than last year (Ross et al. 2005b), has generally held steady since 1999. Over the past 7 years, we estimate that cormorants from PI and SI have consumed about 15.3 million fish per year weighing 0.9 million pounds per year. In 2005, cormorants from LGI (Johnson et al. 2006), PI, and SI consumed 39.7 million fish weighing 2.09 million pounds. Since 1999, we estimate that cormorants from these three colonies have eaten approximately 34 million fish per year weighing about 2.5 million pounds per year.

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Table 1. Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 2005. Cormorant pellets were sampled during the pre-chick (05 May and 02 June 2005), chick (15 July 2005), and post-chick (30 September 2005) feeding periods.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	189	150	150	489
No. fish/pellet*	23.9	11.5	33.4	23.0
Round goby	93.5 %	58.8	92.0	87.8
Alewife	<0.1	29.0	1.1	4.7
Yellow perch	3.1	9.0	2.6	3.7
Rock bass	0.8	1.2	2.0	1.4
Three-spine stickleback	0.2	<0.1	1.7	0.9
Slimy sculpin	1.8	0.1	<0.1	0.8
Smallmouth bass	0.3	1.3	<0.1	0.3
Cyprinid	<0.1	0.3	0.3	0.2
Ictalurid	0.2	<0.1	0.1	0.1
Trout perch	----	<0.1	<0.1	<0.1
Catostomid	----	0.1	----	<0.1
Pumpkinseed	<0.1	----	----	<0.1
Esocid	<0.1	----	----	<0.1
White perch	<0.1	----	----	<0.1
	100	100	100	100

*Adjusted upward by fecal correction factor of 1.042 (see Methods).

Table 2. Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 2005. Cormorant pellets were sampled during the pre-chick (05 May and 02 June 2005), chick (15 July 2005), and post-chick (19 August and 30 September 2005) feeding periods.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	299	139	300	738
No. fish/pellet*	23.6	34.5	38.9	31.9
Round goby	88.0 %	86.1	88.3	87.8
Yellow perch	7.6	9.8	6.0	7.2
Cyprinid	0.6	0.2	2.6	1.5
Rock bass	1.0	0.9	1.6	1.3
Pumpkinseed	1.7	<0.1	0.7	0.9
Alewife	----	2.5	0.2	0.6
Ictalurid	0.6	0.4	0.5	0.5
Slimy sculpin	0.3	<0.1	----	<0.1
Smallmouth bass	0.1	<0.1	<0.1	<0.1
Catostomid	----	<0.1	<0.1	<0.1
Esocid	<0.1	----	<0.1	<0.1
Walleye	----	----	<0.1	<0.1
Trout-perch	----	----	<0.1	<0.1
Three-spine stickleback	<0.1	----	----	<0.1
White perch	<0.1	----	----	<0.1
Rainbow smelt	----	----	<0.1	<0.1
	100	100	100	100

*Adjusted upward by fecal correction factor of 1.042 (see Methods).

Table 3. Spatial diet overlap ($C\lambda$) among three eastern Lake Ontario cormorant colonies, 2005.

<u>Feeding period</u>	<u>Colonies</u>		<u>Colonies</u>	
	<u>L. Galloo I.</u>	<u>vs Pigeon I.</u>	<u>L. Galloo I.</u>	<u>vs Snake I.</u>
Pre-chick	0.086		0.133	
Chick	0.522		0.124	
Post-chick	0.982		0.990	
Entire season	0.580		0.583	

Table 4. Temporal diet overlap ($C\lambda$) among feeding periods at each of the three eastern Lake Ontario cormorant colonies, 2005.

<u>Feeding period</u>	<u>Little Galloo I.</u>	<u>Pigeon I.</u>	<u>Snake I.</u>
Pre-chick vs chick	0.410	0.840	1.000
Pre-chick vs post-chick	0.175	1.000	1.000
Chick vs post-chick	0.140	0.850	1.000
Seasonal average	0.242	0.900	1.000

Table 5. Fish consumption estimates (in millions) for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 2005.

<u>Feeding period</u>	<u>Pigeon Island</u>		<u>Snake Island</u>	
	<u>Number</u>	<u>Pounds</u>	<u>Number</u>	<u>Pounds</u>
Pre-chick	4.1	0.17	1.8	0.08
Chick	2.5	0.22	3.3	0.10
Post-chick	<u>9.0</u>	<u>0.27</u>	<u>4.3</u>	<u>0.12</u>
Total	15.7	0.66	9.4	0.29

Table 6. Estimated total length (TL, inches), average weight (Wt, pounds), and number examined (No.) of smallmouth bass, yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Pigeon Island and Snake Island in 2005.

<u>Species</u>	<u>Pigeon Island</u>			<u>Snake Island</u>		
	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>
Pre-chick						
Smallmouth Bass	6.9 (0.6)	0.14	7	9.4 (0.4)	0.41	4
Yellow perch	4.0 (1.6)	0.02	109	3.0 (1.5)	0.01	98
Rock bass	4.2 (1.1)	0.05	57	4.1 (1.3)	0.05	124
Pumpkinseed	2.5	0.01	1	4.1 (1.1)	0.05	90
Chick						
<u>Species</u>	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>
Smallmouth Bass	5.6 (1.5)	0.07	5	5.9 (0.06)	40	2
Yellow perch	3.6 (1.9)	0.02	100	3.3 (1.3)	6	100
Rock bass	4.2 (1.4)	0.05	32	4.5 (1.1)	29	74
Pumpkinseed	---	---	0	4.3 (0.6)	27	3
Post-chick						
<u>Species</u>	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>	<u>TL (SD)</u>	<u>Wt.</u>	<u>No.</u>
Smallmouth Bass	6.7 (3.0)	0.13	2	6.5 (4.9)	56	3
Yellow perch	3.5 (1.2)	0.02	100	3.7 (1.6)	9	100
Rock bass	3.5 (1.0)	0.03	106	3.5 (1.5)	13	135
Pumpkinseed	---	---	0	4.5 (1.1)	32	125

Figure 1. Estimated number (in millions) of fish consumed by cormorants from the Pigeon (a) and Snake (b) Island colonies in eastern Lake Ontario in 2005.

