

**Diet Composition and Fish Consumption of Double-Crested Cormorants
from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 2004**

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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). Although studies of diet and fish consumption at the Little Galloo Island (LGI) colony, the largest eastern basin colony, have been ongoing annually since 1992 (Johnson et al. 2005), prior to 1999 only a single year of diet information from a very small sample size existed for the PI and SI cormorant colonies (Neuman et al. 1997). Moderate-intensity diet and fish consumption information has been collected annually since 1999 for these two colonies. Since 1999 the number of cormorant pellets collected on PI (3,940) and SI (4,424) has represented about 44% of the combined pellets examined from the three colonies. This paper reports on the diet composition and fish consumption of cormorants from the PI and SI colonies in 2004.

Methods

Diagnostic prey remains recovered in regurgitated

pellets were used to describe the diet of double-crested cormorants from the PI and SI colonies in 2004. On SI, 150 pellets were collected on each of five dates beginning in mid May and ending in early October. On PI, only two samples were obtained (92 pellets in June and 150 in July). The preferred 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 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. 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. For prey species identified, diagnostic fish material recovered from cormorant pellets were compared with bones, scales, and otoliths from known specimens defleshed in NaOH.

This year, disturbances at PI beginning in June again resulted in colony abandonment by July, when the last fresh pellets were collected (no young fledged).

To estimate number of fish consumed 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) to estimate the number of fish eaten by cormorants annually. 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 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 reduce fish consumption estimates, whereas including migrant birds would increase estimated consumption. Although YOY cormorants are generally present for about 11 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 the apparent differences in feeding patterns of cormorants over the season, we identified three separate feeding phases, pre-chick (prior to chick hatch), chick (chicks present and being fed by adults), and post-chick (cessation of

feeding chicks by adults) feeding. These phases were characterized by differences in diet consumption and daily fish consumption (i.e., the number of fish per pellet). Pre-chick feeding was from mid April to mid June, chick feeding period from mid June to early August, and post-chick feeding period from early August to early October. Due to disturbances at PI, the post-chick feeding period was not sampled there. 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 by age-class as follows:

	<u>Days</u>			
	<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), some researchers consider that a single pellet is 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. Specific fish consumption was estimated by multiplying the percent composition (by number, not weight) for a species in the diet for 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 fish-length relationships derived for smallmouth bass (Adams et al. 1999), yellow perch (Burnett et al. 2000), and rock bass and pumpkinseed (Ross et al. in press) 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).

Spatial and temporal variation in diet composition for the PI, SI, and LGI colonies 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 ($C \geq 0.60$) are considered biologically significant (Zaret and Rand 1971).

Results

In all, 1,025 cormorant pellets were examined from PI (242) and SI (783) in 2004 (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, limited to the pre-chick and chick feeding periods, was 17.3,

similar to last year (Table 1). At SI an increasing seasonal consumption trend was again observed, from 25.5 (pre-chick) to 33.4 (post-chick), with an average of 30.1 (Table 2). Daily fish consumption (mean no. fish/pellet) increased by 10% at PI and by 54% at SI over last year (Tables 1 and 2; Ross et al. 2004b).

Diet Composition

The diet of cormorants from the PI colony consisted mostly of the exotic round goby (*Neogobius melanostomus*, 36%), alewife (*Alosa pseudoharengus*, 30%), three-spine stickleback (*Gasterosteus aculeatus*, 11%), yellow perch (10%), rock bass (4%), slimy sculpin (*Cottus cognatus*, 4%), and cyprinids (3%) (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 84% of the diet, panfish (i.e. yellow perch, rock bass, pumpkinseed, ictalurids etc.) composed 14%, and gamefish (mostly smallmouth bass) contributed <2% of the diet of PI cormorants (Table 1). The exotic round goby exploded in cormorant diets this year (36%) over last (1%), rising in rank from 7 to 1. Seasonal trends repeated those of previous years: a great increase in the percent composition of alewife from pre-chick to chick feeding periods, with declines for many other species (notable exceptions: three-spine stickleback and smallmouth bass also increased seasonally).

The principal prey of SI cormorants were round goby (83%), yellow perch (4%), alewife (4%), slimy sculpin (3%), and cyprinids (2%) (Table 2). Round goby completely dominated cormorant diets the entire season, with only slimy sculpin (10%) and yellow perch (6%) exceeding 5% of the diet in any feeding period. Forage fish (round goby, cyprinids, alewife, three-spine stickleback, and slimy sculpin) made up 92% of the diet of SI cormorants, panfish (yellow perch, rock bass, pumpkinseed, and ictalurids) 7%, and gamefish (smallmouth bass, esocids, and walleye) <1% (Table 2).

Diet Overlap

Modest spatial diet overlap in cormorants was

observed among the three islands, with LGI and SI showing very little overlap (Table 3). Significant temporal diet overlap ($C? \$0.60$) was observed at all three islands (Table 4).

Fish Consumption

Based on nest counts of 325 on PI and 738 on SI as well as fledgling productivities of 1 (for the chick-feeding period at PI), 0 (for the post-chick period after abandonment at PI), and 1.8 (SI) chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 115,472 and 371,960 cormorant feeding days for these colonies, respectively, in 2004. Fish consumption for the PI colony was estimated at 2.0 million fish weighing 0.12 million pounds, and for the SI colony at 11.5 million fish weighing 0.37 million pounds (Table 5). Cormorants from PI consumed an estimated 1.7 million forage fish (round goby, alewife, three-spine stickleback, slimy sculpin, cyprinids, and trout-perch), 0.3 million panfish (yellow perch, rock bass, pumpkinseed, and ictalurids), and 0.04 million gamefish (mostly smallmouth bass) (Figure 1a). Cormorants from the SI colony consumed 10.6 million forage fish, 0.80 million panfish, and 0.06 million gamefish (Figure 1b).

Size of fish consumed

Spatial differences in the size of fish consumed between colonies were not sizeable nor consistent for any of the targeted species (Table 6). Temporal changes in the size of fish consumed by cormorants were likewise small and inconsistent.

The average weight of smallmouth bass, yellow perch, rock bass, and pumpkinseed (computed from otolith length-fish weight regressions) for each feeding period is provided in Table 6. We determined 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 3,100 and 5,600 pounds of smallmouth bass, 4,800 and 10,300 pounds of yellow perch, 2,900 and 10,200 pounds of rock bass, and 300 and 3,200 pounds of pumpkinseed, respectively. These numbers are empirically derived estimates based on otolith recoveries, rather than literature values such

as average consumption of one pound of fish per day.

Discussion

A trend of continued substantial interannual variation in cormorant diets is occurring at both PI and SI, but this trend is clearly due primarily to the expansion of the round goby in foraging habitats. Round goby continued to rank first as a prey species at SI (increasing its percent composition overall from 29 to 83%), while moving from rank 7 to 1 at PI (< 1% to 36% for the year). The only other notable changes in percent composition from the previous year were three-spine stickleback at PI (42 to 11%) and yellow perch at SI (26 to 4%). Since 1999 the dominant prey species at PI have been yellow perch (6 to 38%), alewife (13 to 30%), and three-spine stickleback (9 to 55%). Round goby now joins this group of dominant prey species. At SI, round goby so completely dominated diets in 2004 that formerly important species, such as yellow perch (4%) and alewife (4%), are now insignificant components of the diet and most other species are rare components. Three fewer species were observed in diets at PI and one fewer at SI than the previous year.

Distance of a cormorant breeding colony from both point of introduction of round goby (mouth of Niagara River and Bay of Quinte) and lake shoreline appear to influence the magnitude of round goby contribution to the diet of resident cormorants (Ross et al. 2004a).

Ross et al. (2004b) found considerable temporal and spatial variation in diet composition among the three colonies and attributed this to the seasonal occurrence of alewife, three-spine stickleback, and round goby in the diet, with the round goby contributing also to spatial variation through its differential invasion of near-shore (SI) and offshore (PI and LGI) benthic habitats. In 2004, seasonal differences, even in alewife, were not as marked, explaining the high diet overlap and lack of temporal variation. Significant spatial variation was observed only between LGI and SI, a reflection of the minor presence of (LGI) or complete dominance by (SI) round goby.

Though nearly double last year's values, fish consumption by the PI colony remained low at 2.0 million fish and 0.12 million pounds in 2004, down from 15.3 million fish and 1.06 million pounds in 1999 (Johnson et al. 2000, Ross et al. 2004b). Fish consumption by the SI colony has generally held steady since 1999. Over the past 6 years, we estimate that cormorants from PI and SI have consumed about 15.2 million fish per year weighing 0.9 million pounds per year. In 2004, cormorants from LGI (Johnson et al. 2005), PI, and SI consumed 29.2 million fish weighing 1.85 million pounds. Since 1999, we estimate that cormorants from these three colonies have eaten approximately 33 million fish per year weighing about 2.6 million pounds per year.

Smallmouth bass consumed by cormorants in 2004 at SI were larger than those of 2003, reversing last year's trend. At PI, smallmouth bass were only slightly smaller. Yellow perch and rock bass were smaller than those a year ago, while pumpkinseed were about the same size at both islands. Consistent inter-island differences in size of these four species were not observed in 2004.

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Table 1. Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 2004. Cormorant pellets were sampled during the pre-chick (07 June 2004) and chick (13 July 2004) feeding periods.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Total</u>
No. of pellets	92	150	242
Fish/pellet (adjusted)	16.4	17.9 17.3	
Round goby	51.6	28.8	36.0
Alewife	15.6		37.2 30.3
Three-spine stickleback	3.7	14.6	11.1
Yellow perch	12.9	8.0	
9.6			
Rock bass	2.2	4.7	
3.9			
Slimy sculpin	8.1	1.6	
3.7			
Cyprinid	4.2	1.9	
2.7			
Smallmouth bass	0.8	2.4	1.9
Pumpkinseed	0.1	0.3	0.3
Ictalurid	0.2	0.2	
0.2			
Trout-perch	0.6	<0.1	
0.2			
Esocid	----	<0.1 <0.1	
	100	100	100

Table 2. Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 2004. Cormorant pellets were sampled during the pre-chick (18 May and 07 June 2004), chick (13 July 2004), and post-chick (17 August, 14 September, and 05 October 2004) feeding periods.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	300	150	333	783
Fish/pellet (adjusted)	25.5	32.1	33.4	30.1
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Round goby	75.0	88.0	85.3	82.7
Yellow perch	5.6	4.7	3.5	4.4
Alewife	3.5	2.9	4.1	3.6
Slimy sculpin	9.6	0.2	0.4	3.2
Cyprinid	0.9	1.1	4.1	2.5
Rock bass	2.1	1.8	1.8	1.9
Pumpkinseed	1.3	0.3	0.2	0.6
Smallmouth bass	0.4	0.8	0.3	0.4
Ictalurid	0.4	0.3	0.3	0.3
Three-spine stickleback	1.0	<0.1	<0.1	0.3
Trout-perch	<0.1	---	<0.1	<0.1
Esocid	<0.1	---	<0.1	<0.1
Catostomid	<0.1	---	<0.1	<0.1
White perch	<0.1	---	---	<0.1
Walleye	---	---	<0.1	<0.1
Rainbow smelt	<0.1	---	---	<0.1
	100	100	100	100

Table 3. Spatial diet overlap (C?) among three eastern Lake Ontario cormorant colonies, 2004.

<u>Feeding period</u>	Colonies <u>L. Galloo I.-Pigeon I.</u>	Colonies <u>L. Galloo I.-Snake I.</u>	Colonies <u>Pigeon I.-Snake I.</u>
Pre-chick	0.364	0.090	0.914
Chick	0.746	0.067	0.520
Post-chick	-----	0.098	-----
Entire season	0.617	0.083	0.680

Table 4. Temporal diet overlap (C?) among feeding periods at each of the three eastern Lake Ontario cormorant colonies, 2004.

<u>Feeding period</u>	<u>Little Galloo I.</u>	<u>Pigeon I.</u>	<u>Snake I.</u>
Pre-chick - Chick	0.929	0.790	0.981
Pre-chick - Post-chick	0.975	-----	0.984
Chick - Post-chick	0.973	-----	0.999

Seasonal average 0.959 0.790 0.987

Table 5. Fish consumption estimates (in millions) for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 2004.

<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	0.7	0.04	2.5	0.10
Chick	1.3	0.07	4.0	0.12
Post-chick	<u>0.0</u>	<u>0.00</u>	<u>5.0</u>	<u>0.15</u>
Total	2.0	0.12	11.5	0.37

Table 6. Estimated total length (TL, mm), average weight (Wt, g), 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 2004.

<u>Species</u>	<u>Pigeon Island</u>			<u>Snake Island</u>		
	<u>TL</u>	<u>Wt.</u>	<u>No.</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>
Pre-chick						
Smallmouth Bass	177	69	15	146	36	18
Yellow perch	115	16	50	95	9	100
Rock bass	89	13	37	108	24	100
Pumpkinseed	77	8	1	97	18	100
Chick						

<u>Species</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>
Smallmouth Bass	141	33	37	160	49	13
Yellow perch	88	7	59	92	8	49
Rock bass	99	18	72	106	23	45
Pumpkinseed	120	37	8	120	38	18

Post-chick

<u>Species</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>
Smallmouth Bass	---	---	0	151	41	14
Yellow perch	---	---	0	100	11	101
Rock bass	---	---	0	100	19	100
Pumpkinseed	---	---	0	124	42	23

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 2004.

