Diet Composition and Fish Consumption of Double-Crested Cormorants from the Little Galloo Island Colony of Eastern Lake Ontario in 2005

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Since the early 1990's increasing populations of double crested cormorants (*Phalacrocorax auritus*) in the eastern basin of Lake Ontario have concerned both members of the public and the New York State Department of Environmental Conservation (NYSDEC) in regards to impacts on fish populations. Although the number and size of cormorant colonies in the eastern basin has not increased for several years, the cormorant population in the area remains high, at levels where depletions of local fish populations may occur. Because it supports the largest cormorant colony in the eastern basin, Little Galloo Island (LGI) has received the most attention regarding cormorant-fish interactions with annual diet studies dating back 13 years (Johnson et al. 2002a,b). These studies together with other studies which examined the status of fish populations surrounding Little Galloo Island (Burnett et al. 2002, Lantry et al. 2002) have shown a significant relationship between increased cormorant numbers and decreased numbers of yellow perch and smallmouth bass.

The year 2005 marked the fourteenth year of study of the food habits and fish consumption of LGI cormorants. Johnson et al. (2002a) characterized these studies as minimal (1995 - 1997), moderate (1992-1994), and comprehensive (1998 - 2001). This paper reports the findings of work carried out in 2005, the eighth consecutive year of comprehensive work on diet composition and fish consumption on the LGI cormorant colony. An additional component was added to the cormorant research conducted at LGI in 2005, a comparative analysis of diets based on concurrent collections of pellets and stomachs.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants on LGI in 2005. Approximately 150 pellets were collected on each of 12 dates at approximately two week intervals beginning in late April and ending in early October. 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 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.

To estimate number of fish consumed by cormorants from the LGI colony, 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 cormorants feeding we used annual nest counts (all nests counted) provided by the Canadian Wildlife Service and NYSDEC 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 the 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 113 days, consumption by chicks during the first three 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). Although immature cormorants are essentially fully grown, they are 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 period was from early April to early June, the chick feeding period from mid June to late July, and the post-chick feeding period from early August to mid October. 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:

	Days			
	Pre-chick	Chick	Post-chick	Total
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) many 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 for LGI colony 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 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 prey 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 (1 pound) fish per day (Schramm et al. 1984, 1987; Weseloh and Casselman 1992), representing about 25% of their body weight (Dunn 1975).

In June 2005, concurrent collections of double-crested cormorant pellets and stomachs were made at LGI. Adult cormorants were shot on nests between 1000 and 1300 hours. Cormorant stomach samples were initially frozen then thawed and stored in 10% formalin. The contents of each stomach were weighed prior to sorting diagnostic material for identification. Stomach contents generally consisted of two types of material: undigested whole fish or large fish parts and highly digested material that accumulated at the bottom of the stomachs, including otoliths, eye lenses and scales. Because of reported taxonomic differences between digested and undigested remains in double-crested cormorant stomachs (Johnson et al. 2005a), we initially examined these materials separately. Similarity, cormorant diet composition estimated from pellet and stomach samples 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 ($C\lambda$) > 0.60 are considered biologically significant (Zaret and Rand 1971).

We estimated the size of yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*) and pumpkinseed (*Lepomis gibbosus*) consumed during each cormorant feeding period by measuring at least 100 (in a few cases <100 were in a sample) randomly selected otoliths from each species/period to the nearest 0.1 mm with calipers. Broken or chipped otoliths were not considered for measurement. For smallmouth bass (*Micropterus dolomieu*), we measured all unbroken otoliths from each feeding period even if the total exceeded 100. We used otolith-length to 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. 2005) 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).

Results

In all, 1,602 regurgitated cormorant pellets were examined from LGI in 2005. These pellets represented cormorant diets from April 26 to October 2. Similar to previous years we described the diet in terms of three distinct feeding periods, pre-chick feeding, chick feeding, and post-chick feeding periods. The three feeding periods are delineated by differences in diet composition and daily fish consumption. The number of fish per pellet (adjusted for fecal loss) was highest during the pre-chick feeding (15.1) and averaged 12.7 for the season (Table 1).

Diet Composition

Round gobies (29.3%) were the major prey of LGI cormorants in 2005 and increased in the diet from 3.5% during the pre-chick feeding period to 5.0% during the chick feeding period and to 78.2% during the post-chick feeding period (Table 1). Yellow perch (27.6%) and alewife (18.0%) were the second and third most abundant species in the diet. Pumpkinseed (7.4%), slimy sculpin (6.8%) and rock bass (5.5%) were the fourth, fifth and sixth most abundant prey in cormorant diets. Cyprinids (2.1%) and smallmouth bass (1.6%) were the only other prey species or groups that contributed at least 1% of the diet (Table 1). Yellow perch, pumpkinseed, cyprinids and slimy sculpin all decreased in the diet of LGI cormorants over the season. For the entire season forage species (i.e. round goby, alewife, cyprinids, slimy sculpin, etc.) contributed 57% of the diet of LGI cormorants while panfish (i.e. yellow perch, pumpkinseed, rock bass, ictalurids, etc.) and gamefish (smallmouth bass, esocids, walleye) composed 41% and 2%, respectively.

Pellet versus stomach diet comparison

We examined 150 double-crested cormorant pellets and 100 stomachs from LGI that were collected on June 15, 2005. The weight of the

contents of each stomach averaged 44.5 g (1.57 oz; se = 4.88, range 0.0-238.9 g [0-8.43 oz]). Examination of the undigested stomach contents yielded only 1.1 fish per stomach. Highly digested material in cormorant stomachs contained an average of 4.7 fish per sample. Consequently, examination of all material in stomachs yielded 5.8 fish per stomach. The mean number of fish per pellet on June 15 was 10.5 and was therefore substantially higher than the number of fish recovered in stomach samples.

Alewife was the major prey identified in undigested (77.6%) and digested (62.0%) cormorant stomachs collected on June 15 (Table 2). Rock bass (8.6% undigested and 12.0% digested) and round goby (6.0% undigested and 8.2% digested) were the second and third most important prey identified from cormorant stomachs. Overall alewife represented 68.0%, rock bass 10.7% and round goby 7.3% of cormorant diets based on stomach analysis in June. Diet overlap between undigested and digested stomach contents was very high($C\lambda$= 0.97).

Alewife (56.0%), yellow perch (12.4%), rock bass (9.0%), round goby (8.3%) and slimy sculpin (8.2%) were the main prey identified from cormorant pellets collected at LGI on June 15, 2005 (Table 2). There was little difference in cormorant diet as determined from pellets or stomach contents. Diet overlap was highest between pellets and digested fish material ($C\lambda$=0.97), followed by pellets-combined stomach contents ($C\lambda$= 0.95) and pellets-undigested fish material ($C\lambda$=0.92).

Fish Consumption

A peak count of 3,401 cormorant nests was observed on LGI in 2005 and chick productivity was estimated at about 0.09 chicks per nest (pers. comm. J. Farquhar, NYSDEC, Watertown, NY). Between 5/27/05 and 6/15/05 686 cormorants (mainly adults) were shot at LGI as part of a NYSDEC management program. To account for the absence of these birds in the fish consumption model the adult bird estimate was reduced from 6,802 to 6,116 for the chick and post-chick feeding periods. Using the Weseloh and Casselman model we estimate about 1.11 million feeding days for the LGI colony in 2005 and about 1.11 million pounds of fish consumed (Figure 1). Total numerical fish consumption by the LGI colony in 2005 was estimated at 14.6 million (Figure 1). Fish consumption by feeding period in 2005 included 6.76 million during the pre-chick feeding period, 2.83 million during the chick feeding period and 4.97 million during the post-chick feeding period.

In 2005, LGI cormorants consumed 8.31 million forage fish, including 4.26 million round goby, 2.62 million alewife, 0.99 million slimy sculpin and 0.30 million cyprinids (Figure 2). About 5.99 million panfish were eaten including 4.02 million yellow perch, 1.09 million pumpkinseed, 0.80 million rock bass and 0.07 million ictalurids. Cormorants consumed about 0.26 million game fish, mostly smallmouth bass (0.24 million) (Figure 2).

Size of fish consumed

We measured a total of 2,780 otoliths recovered from cormorant pellets in 2005. The size of smallmouth bass consumed by LGI cormorants in 2005 declined over the season from 251 mm (9.9 in) during the pre-chick feeding period to 134 mm (5.3 in) during the post-chick feeding period (Table 3). There was no apparent seasonal trend in the size of yellow perch, rock bass, and pumpkinseed consumed by LGI cormorants in 2005. The average weight of smallmouth bass, yellow perch, rock bass, and pumpkinseed (computed from length-weight regression) for each feeding period is provided in Table 3. We estimated the biomass of each of these four species consumed by cormorants during each feeding period. For the entire feeding season on LGI cormorants consumed an estimated 98,000 pounds of yellow perch, 51,000 pounds of pumpkinseed, 48,000 pounds of rock bass, and 48,000 pounds of smallmouth bass.

Discussion

Round gobies were first reported in the diet of cormorants at LGI in 2004, contributing about 1% of the diet (Johnson et al. 2005b). In 2005 through the chick feeding period round gobies contributed less than 5% of the diet of cormorants at LGI. However, round gobies dominated

cormorant diets (78.2%) during the post-chick feeding period and were the major prey fish consumed (29.3%) over the entire season in 2005. The contribution of yellow perch (27.6%) in the diet of cormorants at LGI in 2005 was consistent with previous years. However, the contribution of alewife (18.0%) and smallmouth bass (1.6%) was the lowest that has been observed since intensive cormorant diet studies were initiated annually at LGI in 1998. In 2005 cormorants at LGI consumed about 0.24 million smallmouth bass compared to an average of 0.62 million during the previous six years.

Double-crested cormorants consume about 470 g (1.04 lb) of fish per day (Schramm et al. 1984, 1987; Weseloh and Casselman 1992). Consequently, the stomachs of birds from LGI in 2005 ($\bar{x}$=45 g [1.6 oz] weight) represented substantially less than a daily meal. As a means of comparison cormorants are thought to regurgitate one pellet each day (Craven and Lev 1987; Orta 1992; Derby and Lovvorn 1997), and prey remains in a pellet may be more descriptive of daily feeding period than a stomach. At LGI in 2005 cormorant pellets contained an average of 4.7 more fish per sample than stomachs.

Johnson et al. (2005a) reported differences in the prey species composition of double-crested cormorants at High Bluff Island as determined from pellets and stomach contents. They also observed differences in species composition between undigested and digested fish remains in stomachs. This did not occur at LGI in 2005; cormorant diet composition as determined from pellets or stomachs was almost identical. A possible reason for this difference is the temporal scale of the collections at each island. At LGI in 2005 cormorant pellets and stomachs were collected on the same date whereas at High Bluff Island collections were not made concurrently and may have been separated by as much as two weeks.

Daily fish consumption has generally declined over the season at LGI (Johnson et al. 2005b). This did not occur in 2005 at LGI as daily fish consumption (i.e. number of fish per pellet) increased from 9.7 during the chick feeding period to 13.5 during the post-chick feeding period. From 1998 to 2004 the number of fish per pellet during the post-chick feeding period averaged 8.2 (range 6.4-11.1). The more than five fish per pellet increase in consumption during the post-chick feeding period in 2005 compared to previous years coincided with round gobies dominating cormorant diets.

Total fish consumption by the LGI colony in 2005 was the lowest (i.e. 14.6 million) observed since cormorant control measures were implemented on the island in 1999 (range 14.6 - 21.5 million). Since 1999, the number of fish consumed and the biomass of fish consumed has each been reduced by 52%, from the previous 7 year period (Figure 1).

Since 1992 we estimate that LGI cormorants have consumed about 379 million fish, weighing about 35 million pounds, including 126 million alewife, 97 million yellow perch, 45 million cyprinds, 26 million pumpkinseed, 23 million rock bass, and 14 million smallmouth bass. Of these species, predation by LGI cormorants has been tied to declines in smallmouth bass (Lantry et al. 2002) and yellow perch (Burnett et al. 2002) populations in the eastern basin of Lake Ontario.

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Table 1: Seasonal and total percent diet composition of double-crested cormorants from Little Galloo Island, 2005. Sample dates for the pre-chick, chick, and post-chick feeding periods were from 4/26/05 to 6/8/05, 6/15/05 to 7/19/05, and 8/19/05 to 10/2/05, respectively.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	559	557	486	1,602
Fish/pellet (adjusted)	15.1	9.7	13.5	12.7
Round goby	3.5	5.0	78.2	29.3
Yellow perch	46.9	13.6	9.3	27.6
Alewife	10.7	62.4	2.5	18.0
Pumpkinseed	15.2	1.0	0.6	7.4
Slimy sculpin	12.3	3.9	1.1	6.8
Rock bass	4.3	7.7	5.8	5.5
Cyprinids	3.7	1.1	0.4	2.1
Smallmouth bass	0.7	4.1	1.5	1.6
Ictalurid	0.8	0.1	0.3	0.5
Catostomid	0.7	0.4	0.1	0.4
Banded killifish	0.4	---	---	0.2
Darter	0.2	0.5	< 0.1	0.2
Trout-perch	0.4	0.1	---	0.2
Esocid	0.1	0.1	0.1	0.1
White perch	0.1	---	< 0.1	0.1
Bluegill	<0.1	---	<0.1	<0.1
Burbot	<0.1	---	<0.1	<0.1
Walleye	---	---	<0.1	<0.1
	100.0	100.0	100.0	100.0

Table 2: Percentage diet composition of double-crested cormorants based on stomach (undigested, digested, combined) and pellets analysis from Little Galloo Island, June 15, 2005.

		Stomachs			
		Undigested	Digested	Combined	Pellets
Prey	No. examined	100	101	101	150
Species	No. fish ($\bar{x}$)	1.1	4.7	5.8	10.5
Alewife		77.6	62.0	68.0	56.0
Yellow perch		0.9	4.9	3.3	12.4
Rock bass		8.6	12.0	10.7	9.0
Round goby		6.0	8.2	7.3	8.3
Slimy sculpin		---	3.7	2.3	8.2
Smallmouth bass		6.0	2.2	3.7	3.4
Cyprinids		---	3.3	2.0	1.4
Pumpkinseed		---	1.6	1.0	0.7
Trout-perch		---	---	---	0.3
Catostomid		---	1.6	1.0	0.3
Ictalurid		0.9	0.5	0.7	0.1
Darter		---	---	---	0.1

Table 3: Estimated total length (TL, mm), mean 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 Little Galloo Island in 2005.

	Feeding Period								
	Pre-chick			Chick			Post-chick		
	TL	Wt.	No.	TL	Wt.	No.	TL	Wt.	No.
Smallmouth bass	251	215	15	185	79	65	134	28	26
Yellow perch	101	11	400	97	10	345	104	12	400
Rock bass	108	24	377	118	32	377	112	27	321
Pumpkinseed	101	21	338	97	19	58	105	24	58

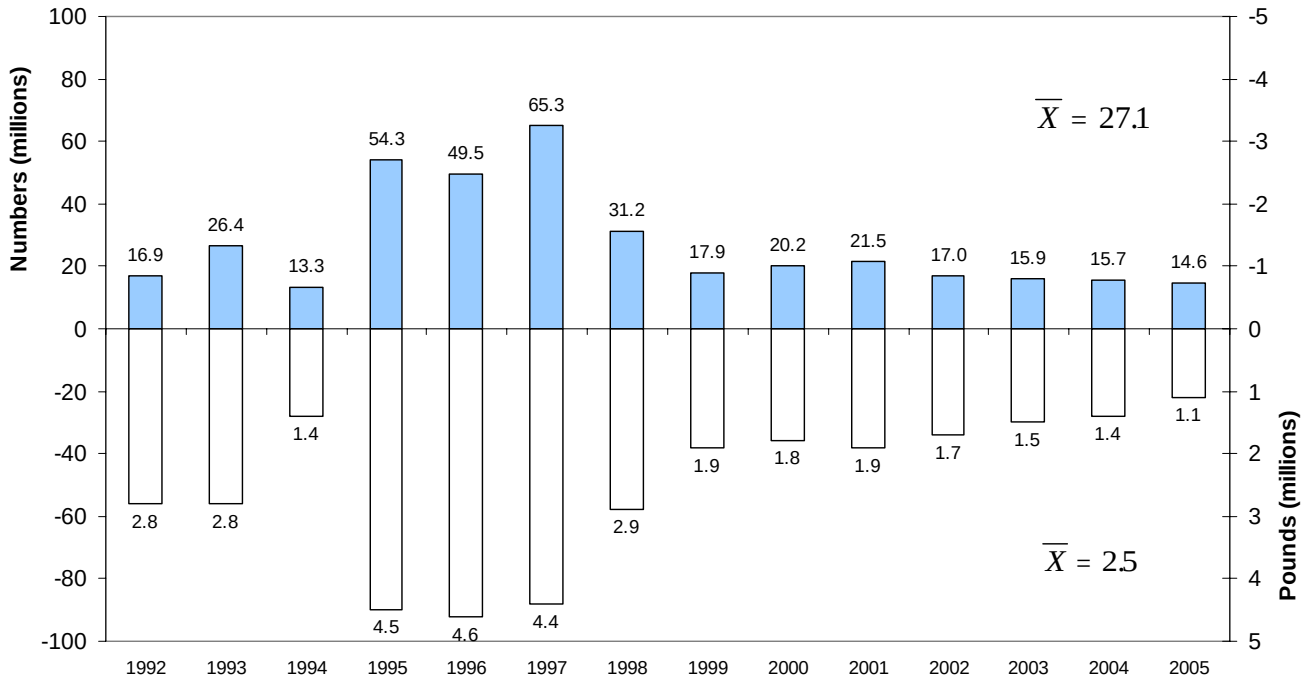

Figure 1: Estimated annual fish consumption in terms of numbers and pounds by the Little Galloo Island colony, 1992-2005.

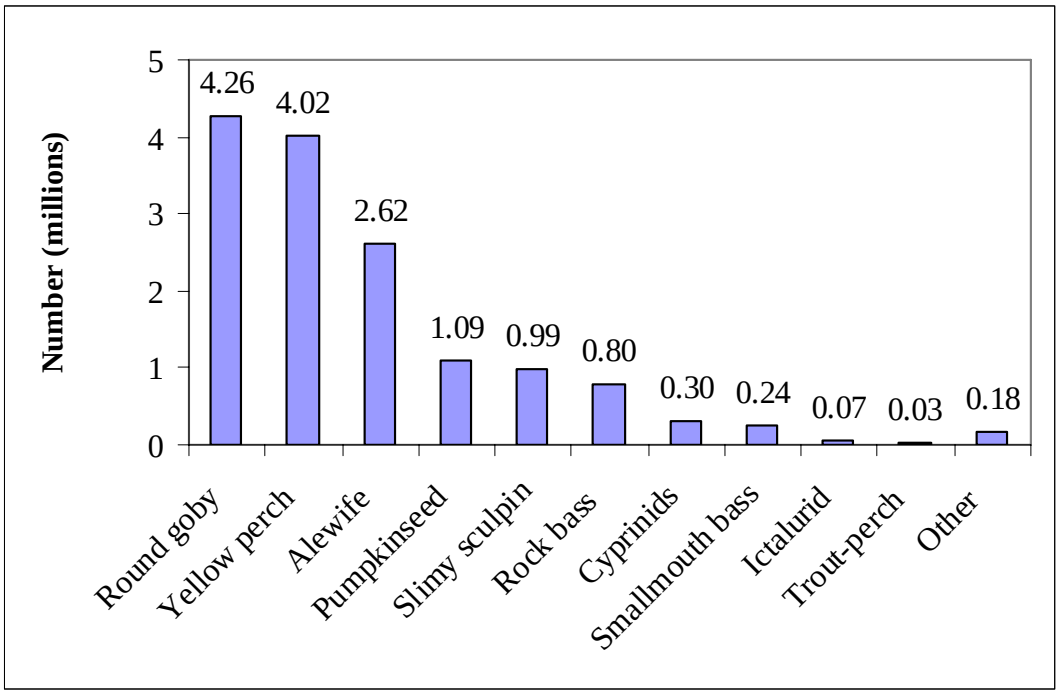

Figure 2: Estimated species-specific fish consumption by double-crested cormorants at the Little Galloo colony, 2005.