Diet Composition and Fish Consumption of Double-Crested Cormorants from the Little Galloo Island Colony of Eastern Lake Ontario in 2007

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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 16 years. These studies (Johnson et al. 2002a,b) 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 2007 marked the sixteenth 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 2007, the tenth consecutive year of comprehensive work on diet composition and fish consumption of the LGI cormorant colony.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants on LGI in 2007. Approximately 85 pellets were collected on each of 12 dates at approximately 2 week intervals beginning in late April and ending in early October. Prior to 2007 a sample size of 150 was established 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). Because of the dominance of round goby in cormorant diets in recent years power analysis was again used to estimate sample size based on 2005 and 2006 diet data. Based on this analysis sample size was reduced to 85. In the laboratory, diagnostic bones, all otoliths, and representative scales were removed from the pellets and identified under magnification. Eye lenses were also enumerated and, 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 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. Residence times at LGI may actually be shorter because of annual management activities at the colony. Mazzocchi et al. (2003) found that the departure date of cormorants was 16 days later for a sub-colony of cormorants at LGI where no management activities occurred compared to a sub-colony in the managed area. 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 adult) feeding. These phases were characterized by differences in diet composition and daily fish consumption (i.e. the number of fish per pellet). Pre-chick feeding was from late April to early June, the chick feeding period from mid June to late July, and the post-chick feeding period from early August to early 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 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 (approximately 1 pound) 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 yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*) and pumpkinseed (*Lepomis gibbosus*) consumed during each cormorant feeding period by measuring up to 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. 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. 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, 966 regurgitated cormorant pellets were examined from LGI in 2007. These pellets represented cormorant diets from April 23 to October 10. The number of fish per pellet (adjusted for fecal loss) was highest during the pre-chick feeding period (16.0) and averaged 13.5 for the season (Table 1).

Diet Composition

Round goby (71.9%) were the major prey of LGI cormorants in 2007 and dominated the diet during all feeding periods (Table 1). Yellow perch (9.4%) and alewife (7.8%) were the second and third most abundant species in the diet. Pumpkinseed (5.7%) and cyprinids (2.3%) were the fourth and fifth most abundant prey in cormorant diets. Rock bass (1.7%), was the only other prey species that contributed at least 1% of the diet (Table 1). Smallmouth bass contributed 0.8% of the diet. For the entire season forage species (i.e. round goby, alewife, cyprinids, slimy sculpin, etc.) contributed 82% of the diet of LGI cormorants while panfish (i.e. yellow perch, pumpkinseed, rock bass, ictalurids, etc.) and gamefish (smallmouth bass, esocids, walleye) composed 17% and 1%, respectively.

Fish Consumption

A peak count of 2,959 cormorant nests was observed on LGI in 2007 and chick productivity was estimated at about 0.15 chicks per nest (pers. comm. J. Farquhar, NYSDEC, Watertown, NY). On June 11, 2007, 709 cormorants (mainly adults) were shot at LGI as part of NYSDEC management programs. To account for the absence of these birds in the fish consumption model the adult bird estimate was reduced from 5,918 to 5,209 for the chick and post-chick feeding periods. Using the Weseloh and Casselman model we estimate about 0.97 million feeding days for the LGI colony in 2007 and about 0.97 million pounds of fish consumed (Figure 1). Numbers of fish consumed by feeding period in 2007 included 7.20 million during the pre-chick feeding period, 2.76 million during the chick feeding period and 4.50 million during the post-chick feeding period.

In 2007, LGI cormorants consumed 11.88 million forage fish including 10.39 million round goby and 1.12 million alewife (Figure 2). About 2.47 million panfish were eaten including 1.36 million yellow perch, 0.82 million pumpkinseed, 0.25 million rock bass, and 0.03 million ictalurids. Cormorants consumed about 0.11 million game fish, mostly smallmouth bass (Figure 2).

Size of fish consumed

A total of 688 otoliths recovered from cormorant pellets were measured in 2007. There was no apparent seasonal trend in the size of smallmouth bass, or pumpkinseed consumed by LGI cormorants in 2007. 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 2. 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 37,000 pounds of yellow perch, 23,000 pounds of pumpkinseed, 20,000 pounds of smallmouth bass, and 10,000 pounds of rock 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. 2005). Gobies increased to 29.3% of the diet of LGI cormorants in 2005 (Johnson et al. 2006) and dominated the diet in 2006 (68.3%) and 2007 (71.9%) (Johnson et al. 2007). Because of the dominance of round goby in cormorant diets since 2006 the contribution of virtually every other species is the lowest that has been observed since intensive cormorant diet studies were initiated annually at LGI in 1998. Since round gobies became abundant in the diet at the LGI colony in 2005, cormorants have consumed about 0.16 million smallmouth bass annually compared to an average of 0.62 million during the previous 6 years. This 74% reduction in smallmouth bass that were eaten is likely due to the high percentage of round goby in the diet as well as the overall reduction in fish consumption due to the cumulative effects of the egg oiling program.

Prior to 2005 average daily consumption of fish generally declined over the season at LGI (Johnson et al. 2005). This did not occur in 2007 as average daily fish consumption (i.e. number of fish per pellet) was lowest (10.6) during the 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) compared to an average of 14.4 in 2005-2007. These marked increases in the number of fish per pellet during the post-chick feeding period in 2005-2007 compared to previous years coincided with round gobies dominating cormorant diet.

Total fish consumption by the LGI colony in 2007 was the second lowest (i.e. 14.46 million) observed since cormorant control measures were implemented on the island in 1999 (range 10.1 - 21.5 million). Since 1999, the number and biomass of fish consumed have been reduced by 55% and 54%, respectively, from the previous 9 year period (Figure 1).

Since 1992 we estimate that LGI cormorants have consumed about 404 million fish, weighing about 37 million pounds, including 128 million alewife, 100 million yellow perch, 45 million cyprinids, 28 million pumpkinseed, 24 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, 2007. Sample dates for the pre-chick, chick, and post-chick feeding periods were from 4/23/07 to 6/6/07, 6/18/07 to 7/31/07, and 8/20/07 to 10/10/07, respectively.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	339	340	287	966
Fish/pellet (adjusted)	16.0	10.6	14.0	13.5
Round goby	69.0	75.2	73.5	71.9
Alewife	1.9	13.0	11.8	7.8
Yellow perch	11.3	5.6	9.4	9.4
Rock bass	2.5	1.8	0.7	1.7
Pumpkinseed	13.0	0.3	---	5.7
Cyprinids	1.3	1.6	3.9	2.3
Smallmouth bass	0.3	2.4	0.3	0.8
Slimy sculpin	---	<0.1	<0.1	<0.1
Ictalurid	0.2	---	0.3	0.2
Catostomid	0.2	---	0.1	0.1
Esocid	<0.1	---	---	<0.1
Trout-perch	0.3	---	---	0.1
Darter	<0.1	---	---	<0.1
White perch	<0.1	0.1	<0.1	<0.1
Walleye	---	<0.1	---	<0.1
Gizzard shad	<0.1	---	---	<0.1
Coregonid	---	<0.1	<0.1	<0.1
	100.0	100.0	100.0	100.0

Table 2. Estimated total length (TL, inches), mean 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 Little Galloo Island in 2007.

	Feeding Period								
	Pre-chick			Chick			Post-chick		
	TL(SD)	Wt.	No.	TL(SD)	Wt.	No.	TL(SD)	Wt.	No.
Smallmouth bass	8.0 (0.8)	0.24	5	7.1 (0.5)	0.16	21	8.2 (0.9)	0.26	4
Yellow perch	4.3(1.1)	0.03	100	4.3 (0.9)	0.03	100	4.3 (1.1)	0.03	100
Rock bass	3.9(1.4)	0.04	100	4.5 (1.2)	0.06	100	3.9 (1.1)	0.04	40
Pumpkinseed	3.5(1.1)	0.03	100	4.0 (1.2)	0.05	18			

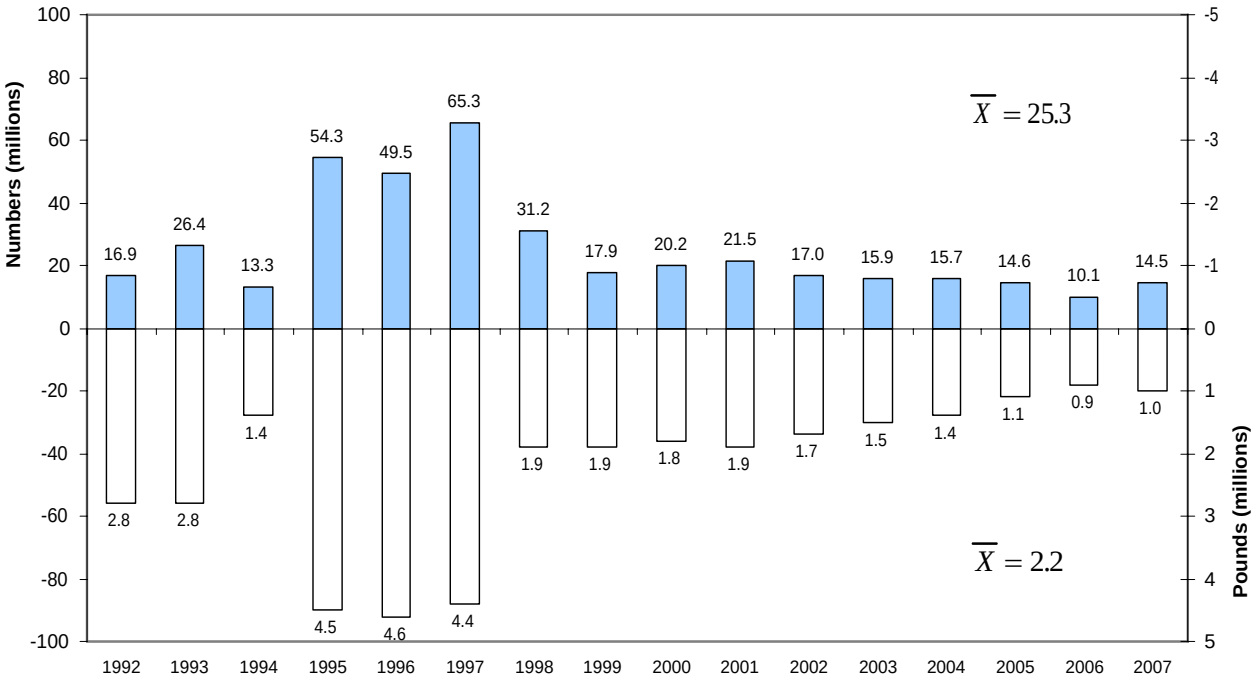

Figure 1: Estimated annual fish consumption in terms of numbers and pounds by the Little Galloo Island colony, 1992-2007.

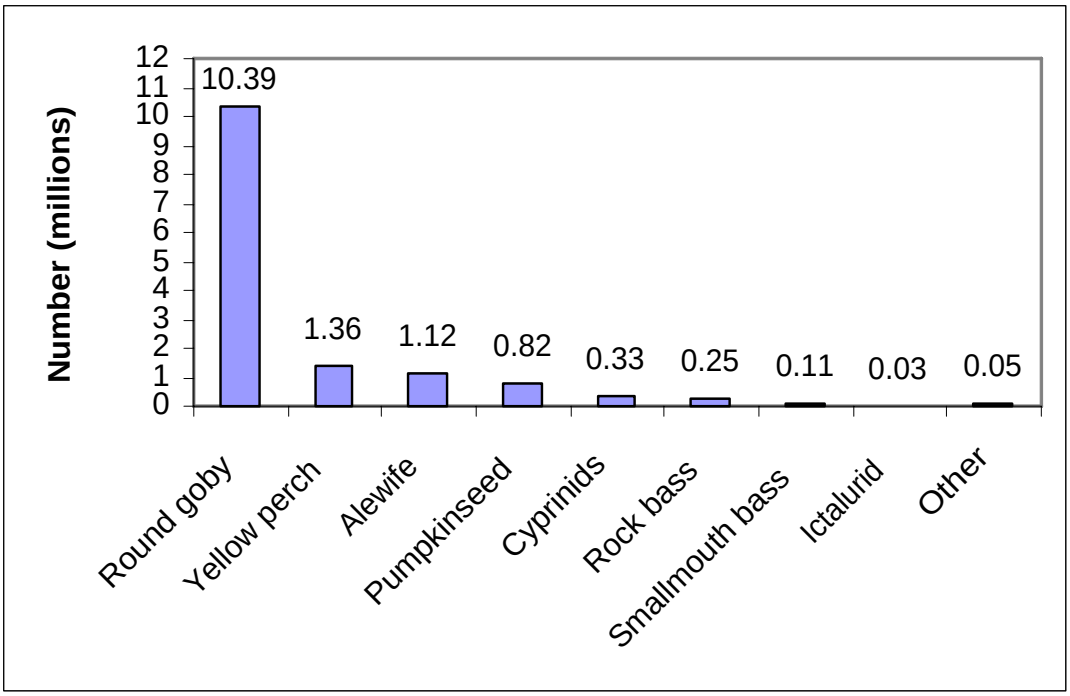

Figure 2: Estimated species-specific fish consumption by double-crested cormorants at the Little Galloo colony, 2007.