

**Diet Composition and Fish Consumption of Double-Crested Cormorants
from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 2003**

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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 second largest eastern basin colony, have been ongoing annually since 1992 (Johnson et al. 2004), 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 (3,698) and SI (3,641) has represented about 45% 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 2003.

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 2003.

Approximately 150 pellets were collected from each island on each of five dates beginning in late May and ending in mid September. 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 nearby Little Galloo Island (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 (helicopter landings and shooting of cormorants) beginning in June again resulted in colony abandonment by July, when the last fresh pellets were collected (no young produced).

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 cormorants feeding we used annual nest counts (all nests counted) 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 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 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 consumption and daily fish consumption (i.e., the number of fish per pellet). Pre-chick feeding was from early April to early June, the chick feeding period from early June to late July, and the post-chick feeding period from early August to mid September. 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 cormorants feeding days by age-class as follows:

| | <u>Days</u> | | | <u>Total</u> |
|-----------|------------------|--------------|-------------------|--------------|
| | <u>Pre-chick</u> | <u>Chick</u> | <u>Post-chick</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 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 (1 lb) 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 at least 100 (in some cases <100 were in a sample) randomly selected otoliths 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 (R.M. Ross unpublished data) 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 ($C\lambda$) > 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

In all, 1,115 cormorant pellets were examined from PI (365) and SI (750) in 2003 (Tables 1 and 2). Similar to previous years, three distinct cormorant feeding periods were apparent, i.e. pre-chick feeding, chick feeding, and post-chick feeding, 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 15.7, a considerable drop from last year when three-spine stickleback (*Gasterosteus aculeatus*) comprised over half of cormorants' diets by number (Table 1). At SI an increasing seasonal consumption trend was observed for the first time ever, from 17.9 (pre-chick) to 21.8 (post-chick), with an average of 19.6 (Table 2). This increasing seasonal numeric consumption was correlated with a seasonal increase in percent composition of the exotic round goby (*Neogobius melanostomus*), from 5.3 to 54.0% (Table 2).

Diet Composition

The diet of cormorants from the PI colony consisted mostly of three-spine stickleback (42%), alewife (*Alosa pseudoharengus*, 22%), yellow perch (15%), slimy sculpin (*Cottus cognatus*, 9%), cyprinids (7%), and rock bass (3%) (Table 1). All other species combined comprised less than 5% of the cormorants' diet. Forage fish (i.e. alewife, three-spine stickleback, cyprinids, slimy sculpin, etc.) comprised 81% of the diet, panfish (i.e. yellow perch, rock bass, pumpkinseed, ictalurids etc.) composed 18%, and gamefish (mostly smallmouth bass) contributed <1% of the diet of PI cormorants (Table 1). The exotic round goby (<1%) appeared for the second year in a row in the diet of cormorants at PI. 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 most other species.

The principal prey of SI cormorants were round goby (29%), yellow perch (26%), cyprinids (12%), three-spine stickleback (12%), alewife (6%), pumpkinseed (5%), rock bass (4%), and slimy sculpin (3%) (Table 2). Three-spine stickleback dominated cormorant diets early in the season (26%), dropping to 5% or less late in the season, while yellow perch consistently comprised a quarter to a third of diets. In typical pattern, alewife increased dramatically during the chick-feeding period, declining in importance late in season (2 to 25 to 2%). The exotic round goby increased dramatically in importance late in the season (5 to 13 to 54%). Forage fish (cyprinids, alewife, three-spine stickleback, slimy sculpin) made up 63% of the diet of SI cormorants, panfish (yellow perch, rock bass, pumpkinseed, ictalurids) 36%, and gamefish (smallmouth bass, esocids, walleye) 1% (Table 2).

Diet Overlap

Diet overlap among cormorants from the PI, SI, and LGI colonies varied considerably both spatially and temporally, but was most similar between PI and SI (Table 3). For the entire season, diet overlap among the three colonies was not significant (i.e. $C\lambda < 0.60$) (Table 3). Significant temporal overlap was found for pre-chick and chick feeding periods at both SI and LGI, but only at LGI was additional temporal overlap found (Table 4).

Fish Consumption

Based on nest counts of 325 on PI and 874 on SI as well as fledgling productivities of 0 and 1.8 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 72,800 and 440,500 cormorant feeding days for these colonies, respectively, in 2003. Fish consumption for the PI colony was estimated at 1.1 million fish weighing 0.07 million pounds, and for the SI colony at 8.7 million fish weighing 0.44 million pounds (Table 5). Cormorants from PI consumed 0.9 million forage fish (including 0.5 million three-spine stickleback, 0.2 million alewife, 0.1 million slimy sculpin, and 0.1 million cyprinids), 0.2 million panfish (0.2 million yellow perch, <0.1 million rock bass, <0.1 million pumpkinseed, <0.1 million ictalurids, and <0.1 million white perch), and <0.1 million gamefish (mostly smallmouth bass) (Figure 1a). Cormorants from the SI colony consumed 5.4 million forage fish (2.6 million round goby, 1.0 million cyprinids,

0.8 million three-spine stickleback, 0.8 million alewife, and 0.2 million slimy sculpin), 3.1 million panfish (2.3 million yellow perch, 0.4 million rock bass, 0.3 million pumpkinseed and 0.1 million ictalurids), and 0.1 million gamefish (0.11 million smallmouth bass and 0.02 million esocids) (Figure 1b).

Size of fish consumed

Spatial differences in the size of fish consumed between colonies were observed only for smallmouth bass, which appeared much larger at PI than SI early in season (Table 6). Temporal changes in the size of fish consumed by cormorants were modest for all but smallmouth bass (smaller fish from early to late season) as well.

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 colony. For the entire feeding season, cormorants from PI and SI colonies consumed 750 and 5,500 pounds of smallmouth bass, 6,600 and 126,700 pounds of yellow perch, 2,100 and 28,600 pounds of rock bass, and 300 and 25,200 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

Ross et al. (2003) reported minimal annual variation in cormorant diets at SI from 1999 to 2001, but substantial annual variation there in 2002 and at PI from 1999-2002. The trend of substantial interannual variation continued for SI in 2003, due this year to sharply increased occurrence of the exotic round goby. Though round goby occurrence at PI increased also in 2003 (rank 15 to 7 in percent diet composition), late season samples, when round goby typically occurs in higher numbers in recent cormorant diets, were not obtained. Thus, three-spine stickleback retained its rank 1 at PI while falling to rank 4 for the season at SI. Since 1999 the dominant prey species at PI have been yellow perch, alewife, and three-spine stickleback. Since 1999 the contribution of these three species in the diet of PI cormorants has ranged from 13% to 29% for alewife, 9% to 55% for three-spine stickleback, and 6% to 38% for yellow perch. At SI, yellow perch and cyprinids outranked three-spine

stickleback, after round goby, as important prey of cormorants in 2003. Occurrence of round goby in cormorant chick regurgitant at Hamilton Harbor in western Lake Ontario (Somers et al. 2003) underscores the wide occurrence of this invasive species in Lake Ontario and its likely importance in aquatic food webs in the foreseeable future.

Ross et al. (2003) found considerable temporal and spatial variation in diet composition among the three colonies and attributed this to the seasonal occurrence of alewife and three-spine stickleback in the diet. We believe the same explanation for spatial and temporal variation continues to hold for 2003, with the round goby contributing to this variation through its differential invasion of near-shore (SI) and offshore (PI and LGI) benthic habitats. The pattern of decreasing three-spine stickleback occurrence in cormorant diets contrasts with increasing round goby seasonal occurrence.

Fish consumption by the PI colony continued to decline over the past 5 years, from 15.3 million fish and 1.06 million pounds in 1999 to 1.1 million fish and 0.06 million pounds in 2003 (Johnson et al. 2000, Ross et al. 2003). Fish consumption by the SI colony has generally held steady since 1999. Over the past 5 years we estimate that cormorants from PI and SI have consumed about 15.5 million fish per year weighing 1.0 million pounds per year. In 2003, cormorants from LGI (Johnson et al. 2004), PI, and SI consumed 25.7 million fish weighing 1.95 million pounds. Since 1999, we estimate that cormorants from these three colonies have eaten approximately 34 million fish per year weighing about 2.7 million pounds per year.

The size of smallmouth bass consumed by cormorants in 2003 appeared generally smaller than those of 2002. Few consistent changes in the size of yellow perch, rock bass, or pumpkinseed were observed, however. Similar to previous years, only smallmouth bass exhibited an inter-island difference in size, with PI bass considerably larger than SI bass.

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Table 1. Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 2003. Cormorant pellets were sampled during the pre-chick (22 May and 04 June 2003) and chick (02 July 2003) feeding periods.

| | <u>Pre-chick</u> | <u>Chick</u> | <u>Total</u> |
|-------------------------|------------------|--------------|--------------|
| No. of pellets | 250 | 115 | 365 |
| Fish/pellet (adjusted) | 17.9 | 10.9 | 15.7 |
| Three-spine stickleback | 48.5 | 15.0 | 41.7 |
| Alewife | 10.0 | 68.0 | 21.9 |
| Yellow perch | 16.1 | 8.7 | 14.6 |
| Slimy sculpin | 11.7 | 0.9 | 9.5 |
| Cyprinid | 8.2 | 2.7 | 7.1 |
| Rock bass | 2.7 | 2.6 | 2.7 |
| Round goby | 0.9 | 0.1 | 0.7 |
| Pumpkinseed | 0.7 | 0.1 | 0.6 |
| Smallmouth bass | 0.2 | 1.7 | 0.5 |
| Ictalurid | 0.4 | 0.3 | 0.4 |
| White perch | 0.2 | --- | 0.2 |
| Trout-perch | 0.1 | --- | 0.1 |
| Rainbow smelt | 0.1 | --- | 0.1 |
| Esocid | 0.1 | --- | 0.1 |
| Catostomid | <0.1 | --- | <0.1 |
| | 100 | 100 | 100 |

Table 2. Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 2003. Cormorant pellets were sampled during the pre-chick (22 May and 04 June 2003), chick (02 July 2003), and post-chick (14 August and 05 September 2003) feeding periods.

| | <u>Pre-chick</u> | <u>Chick</u> | <u>Post-chick</u> | <u>Total</u> |
|-------------------------|------------------|--------------|-------------------|--------------|
| No. of pellets | 300 | 150 | 300 | 750 |
| Fish/pellet (adjusted) | 17.9 | 18.5 | 21.8 | 19.6 |
| Round goby | 5.3 | 13.3 | 54.0 | 29.2 |
| Yellow perch | 26.3 | 33.4 | 23.0 | 26.1 |
| Cyprinid | 16.7 | 12.1 | 8.9 | 12.3 |
| Three-spine stickleback | 25.9 | 5.5 | 3.2 | 11.7 |
| Alewife | 1.9 | 24.9 | 1.5 | 5.9 |
| Pumpkinseed | 10.9 | 0.9 | 1.9 | 5.0 |
| Rock bass | 3.3 | 6.2 | 2.9 | 3.6 |
| Slimy sculpin | 7.5 | 0.7 | 1.2 | 3.4 |
| Ictalurid | 1.3 | 0.9 | 1.3 | 1.2 |
| Smallmouth bass | 0.3 | 1.6 | 1.6 | 1.1 |
| Esocid | 0.2 | 0.1 | 0.2 | 0.2 |
| Catostomid | 0.1 | 0.1 | 0.1 | 0.1 |
| Trout-perch | 0.1 | <0.1 | <0.1 | 0.1 |
| Rainbow smelt | 0.1 | --- | 0.1 | 0.1 |
| White perch | 0.1 | --- | <0.1 | <0.1 |
| Freshwater drum | <0.1 | --- | --- | <0.1 |
| Walleye | --- | --- | <0.1 | <0.1 |
| | 100 | 100 | 100 | 100 |

Table 3. Spatial diet overlap ($C\lambda$) among three eastern Lake Ontario cormorant colonies, 2003.

| <u>Feeding period</u> | <u>Colonies</u> | | <u>Colonies</u> |
|-----------------------|-------------------------------|------------------------------|---------------------------|
| | <u>L. Galloo I.-Pigeon I.</u> | <u>L. Galloo I.-Snake I.</u> | <u>Pigeon I.-Snake I.</u> |
| Pre-chick | 0.401 | 0.640 | 0.824 |
| Chick | 0.963 | 0.598 | 0.630 |
| Post-chick | ----- | 0.045 | ----- |
| Entire season | 0.557 | 0.494 | 0.514 |

Table 4. Temporal diet overlap ($C\lambda$) among feeding periods at each of the three eastern Lake Ontario cormorant colonies, 2003.

| <u>Feeding period</u> | <u>Little Galloo I.</u> | <u>Pigeon I.</u> | <u>Snake I.</u> |
|------------------------|-------------------------|------------------|-----------------|
| Pre-chick - Chick | 0.659 | 0.411 | 0.691 |
| Pre-chick - Post-chick | 0.521 | 0.000 | 0.431 |
| Chick - Post-chick | 0.701 | ----- | 0.589 |
| Seasonal average | 0.627 | 0.205 | 0.570 |

Table 5. Fish consumption estimates (in millions) for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 2003.

| <u>Period</u> | <u>Pigeon Island</u> | | <u>Snake Island</u> | |
|--------------------|----------------------|---------------|---------------------|---------------|
| | <u>Number</u> | <u>Pounds</u> | <u>Number</u> | <u>Pounds</u> |
| Pre-chick feeding | 0.8 | 0.04 | 2.1 | 0.12 |
| Chick feeding | 0.3 | 0.03 | 2.7 | 0.15 |
| Post-chick feeding | <u>0.0</u> | <u>0.00</u> | <u>3.9</u> | <u>0.18</u> |
| Total | 1.1 | 0.07 | 8.7 | 0.44 |

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 2003.

| Species | <u>Pigeon Island</u> | | | <u>Snake Island</u> | | |
|-----------------|----------------------|------------|------------|---------------------|------------|------------|
| | <u>Pre-chick</u> | | | | | |
| | <u>TL</u> | <u>Wt.</u> | <u>No.</u> | <u>TL</u> | <u>Wt.</u> | <u>No.</u> |
| Smallmouth Bass | 202 | 106 | 7 | 106 | 13 | 14 |
| Yellow perch | 126 | 21 | 100 | 125 | 21 | 100 |
| Rock bass | 123 | 36 | 100 | 118 | 31 | 100 |
| Pumpkinseed | 99 | 20 | 45 | 116 | 34 | 100 |

| Species | <u>Pigeon Island</u> | | | <u>Snake Island</u> | | |
|-----------------|----------------------|------------|------------|---------------------|------------|------------|
| | <u>Chick</u> | | | | | |
| | <u>TL</u> | <u>Wt.</u> | <u>No.</u> | <u>TL</u> | <u>Wt.</u> | <u>No.</u> |
| Smallmouth Bass | 141 | 32 | 16 | 132 | 26 | 35 |
| Yellow perch | 109 | 14 | 100 | 138 | 28 | 100 |
| Rock bass | 113 | 27 | 47 | 131 | 43 | 100 |
| Pumpkinseed | 110 | 28 | 2 | 97 | 18 | 32 |

| Species | <u>Pigeon Island</u> | | | <u>Snake Island</u> | | |
|-----------------|----------------------|------------|------------|---------------------|------------|------------|
| | <u>Post-chick</u> | | | | | |
| | <u>TL</u> | <u>Wt.</u> | <u>No.</u> | <u>TL</u> | <u>Wt.</u> | <u>No.</u> |
| Smallmouth Bass | --- | --- | 0 | 123 | 21 | 78 |
| Yellow perch | --- | --- | 0 | 128 | 23 | 100 |
| Rock bass | --- | --- | 0 | 119 | 32 | 100 |
| Pumpkinseed | --- | --- | 0 | 124 | 43 | 100 |

Figure 1. Estimated number (in millions) of fish consumed by cormorants from the Pigeon (a) and Snake (b) Island colonies in eastern Lake Ontario 2003.

