Diet Composition and Fish Consumption of Double-Crested Cormorants from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 2000

James H. Johnson
Tunison Laboratory of Aquatic Science
U.S. Geological Survey
Cortland, NY 13045

Robert M. Ross
Northern Appalachian Research Laboratory
U.S. Geological Survey
Wellsboro, PA 16901

Russell D. McCullough
New York State Department of Environmental Conservation
Watertown, NY 13601

Brian Edmonds
New York State Department of Environmental Conservation
Cape Vincent Fisheries Station
Cape Vincent, NY 13618

Because of concerns regarding the potential effects of double-crested cormorant (*Phalacrocorax auritus*) predation on gamefish populations, examination of the diet composition and fish consumption of cormorants has been underway since 1992 on the Little Galloo Island colony in eastern Lake Ontario (Ross and Johnson 1995, Johnson and Ross 1996, Johnson et al. 1997, 1999, 2000a, Newman et al. 1997, Ross and Johnson 1999a, 1999b). Johnson et al. (2000) categorized the intensity of the studies carried out on Little Galloo Island since 1992 that have examined cormorant/fish relationships as minimal, moderate, and comprehensive in terms of effort and intensity. Although the Little Galloo Island colony has been in recent years the largest cormorant colony in the eastern basin, other sizeable colonies exist, including those on Pigeon and Snake Islands. Investigations on the food habits of cormorants from Pigeon and Snake Islands have been minimal (Newman et al. 1997) and moderate (Johnson et al. 2000b) in terms of intensity. This paper reports on the findings of the second consecutive year of moderate intensity to quantify cormorant/fish interactions associated with the Pigeon and Snake Island colonies.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants on Pigeon and Snake Islands in 2000. Except for one occasion (i.e., Snake Island on September 14 when only 68 pellets were collected), approximately 150 pellets were collected on each of 5 (Snake Island) or 6 (Pigeon Island) dates beginning in late May and ending mid-September (Snake Island) and early October (Pigeon Island). 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 Little Galloo Island (Ross and Johnson, 1999b). 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 (number of lenses/2) generated fish counts that exceeded fish counts 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 a NaOH solution.

To estimate number of fish consumed by cormorants, 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 annual number of fish eaten by

cormorants. This model incorporated cormorant age-class population size and seasonal residence time (time spent feeding in area), mean daily fish ingestion rates, a fecal pathway correction factor for fish not detected in pellets, and several assumptions based on values from the literature or personal communication from colleagues. We assumed that (1) residence time for breeding adults, immatures, and young of year (YOY) was 158, 112, and 92 days, respectively (Weseloh and Casselman, report cited above); (2) number of immatures was approximately 10% of adult population; and (3) the number of young-of-year (YOY) cormorants is the product of the fledgling productivity estimate for the year and the number of active nests. The model does 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 decrease fish consumption estimates whereas adding migrant birds would increase consumption estimates. 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:

	Days			
	Pre-chick	Chick	Post-chick	Total
Adults	64	42	52	158
Immatures	18	42	52	112
YOY	0	42	50	92

For estimates of mean daily ingestion rates, we used the mean number of fish per pellet multiplied by a fecal correction factor (1.042) (Johnson and Ross 1996). Although there is some variation, a single pellet is usually produced by adult cormorants each day (Craven and Lev 1987, Orta 1992, Derby and Lovvorn 1997). Consequently, we considered the contents of a pellet to represent daily fish consumption. Fish consumption estimates were derived for each of the three feeding periods using our estimates of the number of days each age-class of cormorants fed in that period (see text table above) and the specific mean daily ingestion rates (number of fish per pellet) for that period. 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). This represents about 25% of their body weight (Dunn 1975). Since 0.47 kg is about 1 pound, a straight forward estimator of biomass consumed, in pounds, is the number of cormorant feeding days (i.e., 1 cormorant feeding day equals 1 pound of fish consumed). To estimate the size of yellow perch, rock bass, and pumpkinseed consumed in 2000, we measured 100 randomly selected otoliths from each of the three fish species for each feeding period. The only otoliths that were not considered for measurement were those that were broken. For smallmouth bass, we measured all unbroken otoliths from each of the feeding periods even if the total exceeded 100. 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 and Johnson 2000) 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 Pigeon, Snake, and Little Galloo Island 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 (Cë) $ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

A total of 1,587 pellets were used to describe the feeding ecology of cormorants from Pigeon (899 pellets) and Snake Island (688 pellets) in 1999 (Tables 1 and 2). Because of apparent temporal differences in diet composition and daily fish consumption (fish/pellet), three distinct periods of cormorant feeding are described, i.e., pre-chick feeding, chick feeding, and post-chick feeding. For the Pigeon Island colony the number of fish per pellet (adjusted for fecal loss) declined from 27.4 during the pre-chick feeding period, to 17.8 during the chick feeding period, to 10.7 during the post-chick feeding period, and averaged 19.5 for the entire period (Table 1). Cormorant pellets from the Snake Island colony contained fewer fish than those from Pigeon Island. Fish consumption also declined over the season with a high of 17.3 fish/pellet during the pre-chick feeding period, to 15.1 during the chick feeding period, to 12.9 during the post-chick feeding period, and averaged 15.3 for the season (Table 2).

Diet Composition

Three-spine stickleback (45.5%) were the major fish

species consumed by cormorants from the Pigeon Island colony (Table 1). The contribution of stickleback in the diet declined over the season from 70.1% during the pre-chick feeding period, to 43.9% during the chick feeding period to zero during the post-chick feeding period. Yellow perch (15.8%) and alewife (13.5%) were the second and third ranked prey of cormorants from the Pigeon Island colony with yellow perch being more abundant in the diet during the post-chick feeding period (43.3%) and alewife during the chick feeding period (30.8%) (Table 1). Smallmouth bass (2.2%) was the major gamefish consumed by Pigeon Island cormorants and the contribution of bass to the diet increased from 0.6% during the pre-chick feeding period, to 2.3% during the chick feeding period, to 5.2% during the post-chick feeding period. For the entire season, forage fishes (i.e., three-spine stickleback, alewife, cyprinids, slimy sculpin, etc.) contributed 71.5% of the diet of Pigeon Island cormorants, compared to 26.2% by panfish (mainly yellow perch, rock bass, and pumpkinseed), and 2.3% by gamefish (mostly smallmouth bass) (Table 1).

Yellow perch (43.3%) dominated the diet of cormorants from the Snake Island colony but no seasonal trend in consumption was apparent (Table 2). Cyprinids (15.1%), three-spine stickleback (14.5%), and alewife (10.1%) were the second, third, and fourth most abundant species in the diet. As at Pigeon Island, stickleback were more abundant in the diet earlier in the season (pre-chick and chick feeding periods), whereas alewife were more common later in the season (chick and post-chick feeding periods). Smallmouth bass (1.0%) was the principal gamefish consumed by Snake Island cormorants and the contribution of smallmouth to the diet increased from 0.1% during the pre-chick feeding period, to 0.3% during the chick feeding period, to 1.8% during the post-chick feeding period (Table 2). For the entire three feeding periods panfish (yellow perch, rock bass, pumpkinseed, etc.) contributed 55.4% of the diet, forage fish (cyprinids, stickleback, alewife, slimy sculpin, etc.) contributed 43.4%, and gamefish (mainly smallmouth bass) 1.2% of the diet of Snake Island cormorants (Table 2).

Diet Overlap

Diet overlap between cormorants from Pigeon and Snake Islands increased over the season, peaking at 0.967 during the post-chick feeding period (Table 3). For the entire season, spatial diet overlap between the two cormorant colonies was significant (i.e., 0.644). Cormorants from Pigeon Island (Θ = 0.413) exhibited substantially more temporal variation in diet composition than birds from Snake Island (Θ = 0.843) (Table 4). Generally temporal diet overlap within a colony was greatest when comparing the pre-chick and chick feeding periods.

Fish Consumption

Based on nest counts, 1,431 on Pigeon Island and 1,344 on Snake Island and fledgling productivities of 1.2 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.64 million and 0.60 million cormorant feeding days for these colonies, respectively, in 2000. Fish consumption for the Pigeon Island colony was estimated at 11.5 million fish and 0.64 million pounds, and for the Snake Island colony at 9.0 million fish and 0.60 million pounds (Table 5). Cormorants from Pigeon Island consumed 8.33 million forage fish (including 5.21 million stickleback, 1.55 million alewife, 0.83 million cyprinids, and 0.55 million slimy sculpin), 2.91 million panfish (1.81 million yellow perch, 0.90 million rock bass, and 0.20 million pumpkinseed), and 0.26 million gamefish (mostly smallmouth bass, 0.25 million) (Table 6). Cormorants from the Snake Island colony consumed 4.69 million panfish (3.61 million yellow perch, 0.59 million pumpkinseed, and 0.44 million rock bass), 4.22 million forage fish (1.73 million three-spine stickleback, 1.28 million cyprinids, 0.85 million alewife, and 0.26 million slimy sculpin), and 0.09 million gamefish (smallmouth bass, 0.07 million) (Table 6).

Size of fish consumed

There was no apparent seasonal trend in the size of yellow perch, rock bass, and pumpkinseed consumed by cormorants for either Pigeon or Snake Island (Table 7). At both cormorant colonies the size of smallmouth bass consumed declined over the feeding season (there were insufficient numbers of intact smallmouth bass otoliths to determine the size consumed during the pre-chick feeding period at Snake Island) (Table 7).

The average weight of smallmouth bass, yellow perch, rock bass, and pumpkinseed (computed from length-weight regressions) for each feeding period is provided in Table 7. We determined the biomass of each of these four species consumed by cormorants during each feeding period at each colony. For the entire feeding season, cormorants from the Pigeon and Snake Island colonies consumed 30,000 and 7,000 pounds of smallmouth bass, 67,000 and 76,000 pounds of yellow

perch, 90,000 and 31,000 pounds of rock bass, and 9,000 and 31,000 pounds of pumpkinseed, respectively. At the Pigeon Island colony, smallmouth bass contributed 4.7% of the diet by biomass, yellow perch 10.5%, rock bass 14.1%, and pumpkinseed 1.4%. At the Snake Island colony, smallmouth bass contributed 1.2% of the diet by biomass, yellow perch 12.7%, rock bass 5.2%, and pumpkinseed 5.2%.

Discussion

The diet composition of cormorants on Snake Island in 2000 was similar to what was observed at the colony in 1999 with yellow perch and cyprinids being the major prey (Johnson et al. 2000b). Substantial variation in the diet composition of cormorants at Pigeon Island occurred between 1999 and 2000. In 2000, three-spine stickleback comprised 45.5% of the diet compared to 9.3% in 1999. Concurrent with the increase of stickleback in the diet of cormorants from Pigeon Island in 2000, was a reduction in contribution of yellow perch and alewife from 1999 (i.e., yellow perch 38.4% to 15.8%, alewife 24.4% to 13.5%).

Similar to 1999, substantially more temporal variation in diet composition was exhibited by cormorants from the Pigeon Island colony than the Snake Island colony (Johnson et al. 2000b). Cormorants from the Snake Island colony also exhibited less temporal variation in diet composition than birds from the Little Galloo Island colony (Table 4). Temporal variation in diet composition at the Little Galloo and Pigeon Island colonies was largely due to the seasonal occurrence of alewife and three-spine stickleback in the diet. Diet overlap among the three eastern basin colonies was highest during the post-chick feeding period ($\theta = 0.95$) (Table 3). For the entire season diet overlap was significant (i.e., Cë $ 0.60) among all three colonies and was highest between Little Galloo and Snake Islands (0.88) (Table 3).

Fish consumption by cormorants from the Snake Island colony in 2000 was higher than in 1999 (9.0 million fish and 0.60 million pounds in 2000 compared to 6.7 million fish and 0.53 million pounds in 1999), but was lower in 2000 at Pigeon Island (11.5 million fish and 0.64 million pounds in 2000 versus 15.3 million fish and 1.06 million pounds in 1999). Overall fish consumption by cormorants from these two colonies was slightly less in 2000 (20.5 million fish and 1.24 million pounds in 2000 compared to 22.0 million fish and 1.59 million pounds in 1999). Because of the dominance of three-spine stickleback in the diet of Pigeon Island cormorants in 2000, consumption of stickleback increased by 3.78 million fish. The increased consumption of stickleback in 2000, in part, resulted in major reductions in the consumption of yellow perch (4.07 million) and alewife (2.19 million), compared to 1999 by cormorants from the Pigeon Island colony (Johnson et al. 2000b). Increased consumption of stickleback (1.43 million fish) by cormorants from Snake Island in 2000 (versus 1999) was the major change in the diet of birds from this colony.

Cormorants from Little Galloo Island consumed an estimated 20.2 million fish totaling 1.75 million pounds in 2000 (Johnson et al. 2001). Consequently, cormorants from these three colonies consumed approximately 40.7 million fish with a biomass of 2.99 million pounds in 2000. These estimates are similar to those reported in 1999 for these three colonies (39.9 million fish and 3.53 million pounds) (Johnson et al. 2000b). Although almost identical numbers of fish were estimated to be consumed by cormorants between years, a higher biomass estimate in 1999 (3.53 million pounds in 1999 compared to 2.99 million pounds in 2000) suggests that the average size of fish consumed in 2000 was smaller than in 1999. The increased abundance in the diet of three-spine stickleback, possibly the smallest species in the diet of cormorants from eastern Lake Ontario, at each of the three colonies in 2000 (especially Pigeon Island) is likely the major reason for a reduction in the size of fish consumed in 2000.

Prior to the 2000 season, cormorant prey size determinations used pellet derived otoliths that showed little to moderate wear (Adams et al. 1999, Burnett et al. 2000, Johnson et al. 2000a). After reviewing the literature, and after much debate, starting in 2000 we decided to measure a random sample of intact otoliths, regardless of wear. We determined that measuring otoliths with little wear may lead to an overestimation of fish size. Otoliths of smaller fish would be more worn than those of larger fish since the otoliths of smaller fish would be more quickly exposed to digestive process in the stomach. It is generally thought that using otoliths recovered in pellets to estimate fish size leads to an underestimation of size because the otoliths have been exposed to digestive processes (Jobling and Breiby 1986). Beginning with the 2000 season, our fish size estimates are likely conservative due to otolith wear.

Prior to 2000, because of our otolith selection criteria, we may have overestimated prey size if there was a bias for selecting otoliths of larger fish for measurement, or underestimated prey size if there was no bias for selecting larger fish since we measured lightly to moderately worn otoliths.

The size of smallmouth bass consumed by cormorants from Pigeon and Snake Islands in 2000 was similar to the size consumed by cormorants from Little Galloo Island (Johnson et al. 2001). However, the size of bass consumed by cormorants from these two colonies in 2000 was smaller than observed in 1999 at Pigeon and Snake Islands (Johnson et al. 2000b). As stated previously, some of this size difference when comparing between 1999 and 2000 may be attributed to changes in our otolith selection criteria. This is the fish year that information is reported on the size of yellow perch, rock bass and pumpkinseed consumed by cormorants from Pigeon and Snake Islands. No temporal trends in the size of these species consumed by cormorants was evident. The size of yellow perch and rock bass consumed by cormorants in 2000 was similar among Pigeon, Snake, and Little Galloo Islands (Johnson et al. 2001). The size of pumpkinseed consumed by cormorants at Pigeon Island was smaller than at the other two eastern basin colonies.

Acknowledgements

We thank Gerard Goulette, Stacy Vega, Katie Clough, Laura Brown, David Gordon, and Molly Connerton for their efforts in collecting and processing double-crested cormorant pellets. We also thank Tim Wallbridge, Chris Remaley, Jehanna Howe, Kira Hawk, and Lindsay Gutekunst for their efforts in measuring otoliths.

References

Adams, C.M., C.P. Schneider, and J.H. Johnson. 1999. Predicting the size and age of smallmouth bass consumed by double-crested cormorants in eastern Lake Ontario, 1993-94. Section 6-1 to 6-8 in Final Report: To assess the impact of double-crested cormorant predation on the smallmouth bass and other fishes of the eastern basin of Lake Ontario. New York State Department of Environmental Conservation, Albany, NY.

Burnett, J.A.D., N.H. Ringler, T.H. Eckert, and B.F. Lantry. 2000. Yellow perch abundance and life history in the eastern basin of Lake Ontario in relation to recent increase in double-crested cormorants. Report to Lake Ontario Committee of the Great Lakes Fishery Commission, Section 191, pages 1-7.

Craven, S.R. and E. Lev. 1987. Double-crested cormorants in the Apostle Islands, Wisconsin, USA: population trends, food habits, and fishery depredations. Colonial Waterbirds 10:64-71.

Derby, C.E. and J.R. Lovvorn. 1997. Comparison of pellets versus collected birds for sampling diets of double-crested cormorants. Condor 99:549-553.

Dunn, E.H. 1975. Caloric intake of nesting double-crested cormorants. Auk. 92:553-565.

Horn, H.S. 1966. Measurement of “overlap” in comparative ecological studies. American Naturalist 100:419-424.

Jobling, M. and A. Breiby. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. Sarsia 71:265-274.

Johnson, J.H. and R.M. Ross. 1996. Pellets versus feces: their relative importance in describing the food habits of double-crested cormorants. Journal of Great Lakes Research 22:795-798.

Johnson, J.H., R.M. Ross, and D.R. Smith. 1997. Evidence of secondary consumption of invertebrate prey by double-crested cormorants. Colonial Waterbirds 20:547-551.

Johnson, J.H., R.M. Ross, and C.M. Adams. 1999. Diet composition and fish consumption of double-crested cormorants in eastern Lake Ontario, 1998. Section 5-1 to 5-7 in Final Report: To assess the impact of double-crested cormorant predation on the smallmouth bass and other fishes of the eastern basin of Lake Ontario. New York State Department of Environmental Conservation, Albany, NY.

Johnson, J.H., R.M. Ross and R.D. McCullough. 2000a. Diet composition and fish consumption of double-crested cormorants from the Little Galloo Island colony of eastern Lake Ontario in 2000. Report to Lake Ontario Committee of the Great Lakes Fishery Commission, Section 14, pages 1-10.

Johnson, J.H., R.M. Ross and R.D. McCullough. 2000b. Diet composition and fish consumption of double-crested cormorants from the Pigeon and Snake Island colonies of eastern Lake Ontario in 1999. Report to Lake Ontario Committee of the Great Lakes Fishery Commission, Section 16, pages 1-12.

Johnson, J.H., R.M. Ross, R.D. McCullough, and B. Edmonds. 2001 (This vol.). Diet composition and fish consumption of double-crested cormorants from the Little Galloo Island colony of eastern Lake Ontario in 2000.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Memeroirs. Faculty of Science Kyusshu University, Series E (Biology) 3:65-80.

Neuman J., D.L. Pearl, P.J. Ewins, R. Black, D. V. Weseloh, M. Pike, and K. Karwowski. 1997. Spatial and temporal variations in the diet of double-crested cormorants (Phalacrocorax auritus) breeding on the lower Great Lakes in the early 1990s. Canadian Journal of Fisheries and Aquatic Science 54:1569-1584.

Orta, J. 1992. Family Phalacrocoracidae (Cormorants). Pages 326-353 in J. Del Hoyo, A. Elliott, and J. Sargatal (eds.), Handbook of the Birds of the World, Vol. 1. Lynx Edicions, Barcelona. 696 pp.

Ross, R.M. and J.H. Johnson. 1995. Seasonal and annual changes in the diet of double-crested cormorants: implications for Lake Ontario's fishery. Great Lakes Research Review 2:1-9.

Ross, R.M, and J.H. Johnson. 1999a. Effect of altered salmonid stocking methods on cormorant predation in eastern lake Ontario. Section 11-1 to 11-3 in Final Report: To assess the impact of double-crested cormorant predation on the smallmouth bass and other fishes of the eastern basin of Lake Ontario. New York State Department of Environmental Conservation, Albany, NY.

Ross, R.M. and J.H. Johnson. 1999b. Fish losses to double-crested cormorants in eastern Lake Ontario, 1992-1997. Pages 61-70 in M.E. Tobin (ed.). Symposium on Double-crested Cormorants: Population Status and Management Issues in the Midwest (9 December 1997, Milwaukee, Wisconsin). U.S. Department of Agriculture Technical Bulletin.

Ross, R.M. and J.H. Johnson. 2000. Error and bias in otolith-based estimates of prey fish size caused by digestion in cormorants. The DCCO-Fisheries Conflict in North America, Waterbird Society's 24th Annual Meeting, November, Plymouth, MA.

Schramm, H.L., B. French, and M. Ednoff. 1984. Predation of channel catfish, Ictalurus punctatus by Florida double-crested cormorants, Phalacrocorax auritus floridanus. Progressive Fish Culturist 46:41-43.

Schramm, H.L., M.W. Callopy, and E.A. Okrah. 1987. Potential problems of bird predation for fish culture in Florida. Progressive Fish Culturist 49:44-49.

Weseloh, D.V. and J. Casselman. 1992. Calculated fish consumption by double-crested cormorants in eastern Lake Ontario. Colonial Waterbird Society Bulletin 16(2):63-64.

Zaret, T.M. and A.S. Rand. 1971. Competition in tropical streams: support for the competitive exclusion principle. Ecology 52:336-342.

Table 1. Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 2000. The pre-chick period includes pellets collected on 5/23/00, the chick feeding period includes pellets collected on 6/7/00 and 7/5/00, and the post-chick feeding period includes pellets collected on 8/14/00, 9/14/00, and 10/4/00.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	150	299	450	899
Fish/pellet (adjusted)	27.4	17.8	10.7	19.5
Three-spine stickleback	70.1	43.9	---	45.5
Yellow perch	7.6	7.1	43.3	15.8
Alewife	3.4	30.8	9.5	13.5
Rock bass	4.3	7.8	14.8	7.9
Cyprinid	3.5	3.3	19.9	7.2
Slimy sculpin	6.9	4.0	1.9	4.8
Smallmouth bass	0.6	2.3	5.2	2.2
Pumpkinseed	2.1	0.3	3.8	1.9
Ictalurid	0.6	0.1	1.1	0.6
Darter	0.4	0.1	---	0.2
Esocid	0.1	---	0.1	0.1
Catostomid	0.1	---	0.1	0.1
Trout-perch	0.2	0.2	---	0.1
Other	0.1	0.1	0.3	0.1
	100.0	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 2000. The pre-chick period includes pellets collected on 5/23/00, the chick feeding period includes pellets collected on 6/7/00, and the post-chick feeding period includes pellets collected on 7/5/00, 8/4/00, and 9/14/00.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	150	150	368	688
Fish/pellet (adjusted)	17.3	15.1	12.9	15.3
Yellow perch	37.5	29.8	52.9	43.3
Cyprinids	14.0	10.9	17.7	15.1
Three-spine stickleback	28.2	29.4	----	14.5
Alewife	2.7	12.8	13.1	10.1
Pumpkinseed	7.9	6.5	5.1	6.1
Rock bass	3.4	5.2	6.1	5.1
Slimy sculpin	3.7	3.0	1.8	2.6
Smallmouth bass	0.1	0.3	1.8	1.0
Ictalurid	1.0	0.8	0.7	0.8
Trout-perch	0.6	0.3	0.2	0.4
Catostomid	0.4	0.1	0.3	0.3
Centrarchid	0.1	0.1	0.2	0.2
Esocid	0.2	0.2	0.1	0.2
Other	0.2	0.6	---	0.3
	100.0	100.0	100.0	100.0

Table 3. Spatial diet overlap (Cë) among three eastern Lake Ontario cormorant colonies, 2000.

Feeding period	Colonies L. Galloo I.-Pigeon I.	Colonies L. Galloo I.-Snake I.	Colonies Pigeon I.-Snake I.
Pre-chick	0.582	0.900	0.629
Chick	0.646	0.503	0.771
Post-chick	0.940	0.936	0.967
Entire season	0.659	0.881	0.644

Table 4. Temporal diet overlap (Cë) among feeding periods at each of the three eastern Lake Ontario cormorant colonies, 2000.

Feeding period	Little Galloo I.	Pigeon I.	Snake I.
Pre-chick - Chick	0.357	0.819	0.985
Pre-chick - Post-chick	0.733	0.135	0.799
Chick - Post-chick	0.621	0.284	0.744
	0 = 0.570	0.413	0.843

Table 5. Fish consumption estimates (in millions) for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 2000.

	Pigeon Island		Snake Island	
Period	Number	Pounds	Number	Pounds
Pre-chick feeding	5.2	0.19	3.1	0.18
Chick feeding	3.6	0.20	2.9	0.19
Post-chick feeding	2.7	0.25	3.0	0.23
Total	11.5	0.64	9.0	0.60

Table 6. Estimated number (in millions) of fish consumed by cormorants from the Pigeon and Snake Island colonies in 2000.

Species	Pigeon Island	Snake Island
Three-spine stickleback	5.21	1.73
Yellow perch	1.81	3.61
Alewife	1.55	0.85
Rock bass	0.90	0.44
Cyprinid	0.83	1.28
Slimy sculpin	0.55	0.26
Smallmouth bass	0.25	0.07
Pumpkinseed	0.20	0.59
Other	0.20	0.17
	11.50	9.0

Table 7. Estimated length (total length, mm) and weight (g) of smallmouth bass, yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Pigeon and Snake Islands in 2000.

	Feeding Period											
	Pre-chick				Chick				Post-chick			
Species	Pigeon I.		Snake I.		Pigeon I.		Snake I.		Pigeon I.		Snake I.	
	mm	g	mm	g	mm	g	mm	g	mm	g	mm	g
Smallmouth bass	235	173	----	----	155	45	166	55	137	30	145	37
Yellow perch	101	11	94	9	114	16	111	15	120	19	122	20
Rock bass	118	31	138	50	109	25	121	34	152	68	101	20
Pumpkinseed	91	15	103	23	86	12	101	21	101	21	112	30