

**Diet Composition and Fish Consumption of Double-Crested Cormorants  
from Three St. Lawrence River Colonies in 2006**

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Double-crested cormorants (*Phalacrocorax auritus*) were first observed nesting in the upper St. Lawrence River at Strachan Island in 1992. Cormorants now nest at a number of islands in the Thousand Islands section on the river. The three largest colonies in the upper river are at Griswold, McNair, and Strachan islands where nest counts have remained relatively stable, ranging from 200 to 400 nests per colony. Although the size of cormorant colonies in the upper St. Lawrence River is smaller than those in the eastern basin of Lake Ontario, the close proximity of islands in the Thousand Islands region that have colonies may cause a cumulative fish consumption effect similar to a larger colony.

Because of increasing numbers of double-crested cormorants in the upper St. Lawrence River and the possible impacts on fish populations, studies were initiated in 1999 to quantify cormorant diet and fish consumption at the three largest colonies. From 1999 to 2005 these studies have shown that cormorants consumed about 43.5 million fish including 21.5 million yellow perch, 7.7 million rock bass and 0.43 million smallmouth bass (Johnson et al. 2006). During this same time period fish assessment studies near some of these islands have shown a major decrease in yellow perch populations. This occurrence is known as the halo effect and happens when piscivorous birds deplete local fish populations in areas immediately surrounding the colony (Ashmole 1963). Because

of continued concerns regarding cormorant impacts on fish populations in the upper St. Lawrence River, a series of four public information sessions were held (2 in Ontario, 2 in New York) in August, 2006 to disseminate the most recent fisheries and cormorant information to the public. This paper describes the diet and fish consumption of cormorants in the upper St. Lawrence River in 2006.

**Methods**

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants at St. Lawrence River colonies in 2006. Pellets were collected beginning in late May and ending in late September. 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 the number of fish consumed by cormorants from each 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 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 young-of-year (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). 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 late September. 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>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 has 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 each 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 (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 by feeding period by measuring 100 (in some cases <100 were in a sample) randomly selected otoliths from each species from each 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 each species (unpublished data).

Spatial and temporal variation in diet composition for the Griswold, McNair and Strachan 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 ( $C\lambda$ )  $\geq$  0.60 are considered biologically significant (Zaret and Rand 1971).

## Results

A total of 1,433 pellets were used to describe the feeding ecology of cormorants from Griswold (750 pellets), McNair (459 pellets), and Strachan (224 pellets) Islands in 2006 (Tables 1-3). For all the colonies the number of fish per pellet (adjusted for fecal loss) declined over the three feeding periods (Tables 1-3). Over the entire season the number of fish per pellet was highest at Strachan Island (12.2) followed by McNair (11.4) and Griswold (10.1) islands (Tables 1-3).

### Diet Composition

Yellow perch dominated the diet of cormorants from Griswold Island during each feeding period (i.e. 47.5% to 73.3%) and made up 59.3% of the total diet (Table 1). Pumpkinseed (12.3%), rock bass (11.3%), and cyprinids (7.5%) were the other major prey of Griswold Island cormorants. The invasive species round goby (*Neogobius melanostomus*)

contributed 4.6% of the diet of cormorants at Griswold Island in 2006. For the entire season, panfish (i.e., yellow perch, rock bass, pumpkinseed, ictalurids) contributed 84.1% of the diet, forage fish (cyprinids, slimy sculpin, darters, alewife) composed 14.1%, and gamefish (mainly esocids and smallmouth bass) comprised 1.8% of the diet of Griswold Island cormorants.

Round gobies (54.1%), yellow perch (21.5%), rock bass (8.8%), and pumpkinseed (8.8%) were the dominant prey in the diet of cormorants at McNair Island (Table 2). Cyprinids (2.7%) and smallmouth bass (1.4%) were the only other species that made up at least one percent of the diet. For the season panfish made up 40.0% of the diet of McNair Island cormorants, forage fish 58.3%, and gamefish (mostly smallmouth bass) 1.7% (Table 2).

Round goby (43.4%) and yellow perch (32.3%) were the main prey of Strachan Island cormorants (Table 3). Cyprinids (8.4%), rock bass (6.3%), darters (3.8%), pumpkinseed (3.0%) and ictalurids (1.4%) all contributed at least 1% to the diet. Panfish made up 42.6% of the seasonal diet, forage fish 56.9%, and gamefish 0.5% at Strachan Island in 2005 (Table 3).

### Diet Overlap

Diet overlap for the entire season varied (i.e.,  $C\lambda \geq$  0.60) among all three upper St. Lawrence River colonies in 2006 (Table 4). Diet was the most similar between cormorants from McNair and Strachan Islands ( $C\lambda = 0.92$ ) and least similar between Griswold and McNair Islands ( $C\lambda = 0.49$ ). When comparing the three colonies, diet overlap between cormorants from Griswold Island and the other two colonies was lowest ( $C\lambda = 0.56$ ). Diet overlap was lowest between cormorants among upper river colonies during the pre-chick feeding ( $C\lambda = 0.63$ ). Diet overlap was highest during the post-chick feeding ( $C\lambda = 0.74$ ) period (Table 4). Temporal variation in diet composition among feeding periods within each colony was minimal (Table 5).

### Fish Consumption

Based on nest counts of 120 on Griswold Island, 570 on McNair Island, and 313 on Strachan Island, and fledgling productivities of 1.8 chicks per nest

(pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.06, 0.27, and 0.15 million cormorant feeding days for these colonies, respectively, in 2006. Fish consumption for the Griswold Island colony was estimated at 0.64 million fish and 0.06 million pounds, for the McNair Island colony at 3.02 million fish and 0.27 million pounds, and for the Strachan Island colony at 2.11 million fish and 0.15 million pounds (Table 6).

We estimate that during 2006 cormorants from Griswold Island consumed 0.54 million panfish (including 0.38 million yellow perch, 0.08 million pumpkinseed and 0.07 million rock bass), 0.09 million forage fish (including 0.04 million cyprinids and 0.03 million round goby) and 0.01 million gamefish (primarily smallmouth bass) (Figure 1). We estimate that cormorants from McNair Island consumed 1.21 million panfish (mainly 0.65 million yellow perch and 0.27 million rock bass), 1.76 million forage fish (including 1.64 million round goby), and 0.05 million gamefish (mostly smallmouth bass). Double-crested cormorants from the Strachan Island colony consumed 0.90 million panfish (0.68 million yellow perch, 0.13 million rock bass, 0.06 million pumpkinseed), 1.20 million forage fish (0.92 million round gobies, 0.18 million cyprinids, 0.08 million darters), and 0.01 million gamefish (mainly smallmouth bass and walleye) (Figure 1).

#### Size of Fish Consumed

There were no seasonal trends in the size of smallmouth bass, yellow perch, rock bass and pumpkinseed consumed at St. Lawrence River colonies in 2006 (Table 7). Pumpkinseed consumed at Strachan Island (79.0 mm or 3.1 in) were smaller than those eaten at Griswold (95.7 mm or 3.8 in) or McNair (90.0 mm or 3.5 in) islands. Too few smallmouth bass otoliths were recovered in pellets to determine inter-colony differences in fish size.

### **Discussion**

Cormorant diet composition at the Griswold Island colony in 2006, where yellow perch was the primary prey, was similar to previous years (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005, 2006). Since 1999, yellow perch have contributed 57.2% of the

diet of cormorants at Griswold Island colony. Over this same period rock bass (13.4%), pumpkinseed (12.5%), and cyprinids (9.6%) have also been consistently important in the diet of cormorants from the Griswold Island colony.

Round gobies first appeared in the diet of cormorants nesting at these three colonies in 2003 when they contributed about 2% of the diet of birds at McNair Island (Johnson et al. 2004). In 2004 cormorants at all three colonies consumed round gobies with the diet contribution at McNair increasing to 15% and the contribution at Griswold Island and Strachan Island being 1.2% and 1.7%, respectively. In 2005 gobies were almost non-existent (0.1%) in the diet of cormorants at Griswold Island but were the second most consumed prey and represented 24.3% and 19.6% of cormorant diets at McNair and Strachan Island, respectively. In 2006, gobies were the main prey of cormorant at McNair (54%) and Strachan Islands (43.4%) but still only contributed 4.6% at Griswold Island. Since 2004, when round gobies first appeared in cormorant diets at all St. Lawrence River colonies, they have become the dominate prey at McNair (31.1%) and are the second ranked prey at Strachan (21.6%). Of the three eastern Lake Ontario cormorant colonies (i.e. Little Galloo, Pigeon, and Snake Islands) and the three upper St. Lawrence River colonies where cormorant diet studies are underway, Griswold Island is the only colony where round gobies have not become a major portion of cormorant diets (2004-2006,  $\bar{x}$ =2.0%). Cormorants at Griswold Island had the lowest diet overlap with the other two colonies because birds at Griswold are not yet feeding heavily on round gobies.

For the first time forage fish replaced panfish as the major group of fishes consumed by St. Lawrence River cormorants. This is attributed to the dominance of round gobies in the diet of cormorants at McNair and Strachan Islands. Forage fish made up 52.9% of cormorant diets at the three St. Lawrence River colonies compared to 45.9% panfish in 2006. From 1999 to 2005, panfish composed 77.6% and forage fish only 20.4% of cormorant diets. Since 1999, panfish have made up 73.6% (range 45.9% - 83.7%) and forage fish 24.6% (range 13.4% to 52.9%), of cormorant diets in the upper St. Lawrence River. Over the past 8 years

game fish have made up 1.8% (range 1.2% to 2.9%) of cormorant diets at these three river colonies (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005). The contribution of gamefish in cormorant diets in 2006 (1.2%) was the lowest recorded over the eight years of this study. As noted for panfish, reduced consumption of gamefish could be related to the dominance of round gobies in cormorant diets at McNair and Strachan Islands.

Average annual fish consumption by cormorants from Griswold, McNair, and Strachan Islands since 1999 is 6.16 million fish. Since 1999, we estimate that double-crested cormorants from these colonies have consumed 49.28 million fish including 23.18 million yellow perch, 8.12 million rock bass, 4.91 million cyprinids, 4.12 million pumpkinseed, 0.49 million smallmouth bass, and 0.31 million esocids.

Johnson et al. (2004) reported small annual variation in the size of fish consumed by cormorants from these three colonies since studies were initiated in 1999. However, Johnson et al. (2005) reported a drop in the mean length of yellow perch consumed by cormorants at these three colonies compared to previous years. Prior to 2004, the mean length of yellow perch consumed by cormorants was 103 mm (4.1 in), and had never been below 101 mm (4.0 in) on an annual basis. In 2004, the mean size of yellow perch consumed by cormorants in the upper St. Lawrence River was 92.2 mm (3.6 in), in 2005 it was 93.4 mm (3.7 in), and in 2006 was 90.3 mm (3.6 in).

#### Upper River Extrapolation

Comprehensive nest counts for all cormorant colonies in the upper St. Lawrence River have been made since 2003. We used the number of cormorant feeding days from the Weseloh and Casselman model to estimate the total number of feeding days in the upper river annually since 2003. We used the average number of fish per pellet derived from Griswold, McNair, and Strachan Islands each year to estimate food consumption. From 2000-2006 there have been 6 million cormorant feeding days in the upper St. Lawrence River and birds have consumed about 80 million fish (26 million Griswold, McNair and Strachan Islands, 54 million all other upper river colonies) (Table 8). Assuming

that cormorants consume one pound of fish per day, birds have consumed about 6 million pounds of fish during this period.

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#### **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.

Ashmole, N.P. 1963. The regulation of numbers of tropical ocean birds. *Ibis* 1036:458-473.

Burnett, J.A.D., N.H. Ringler, T.H. Eckert, and B.F. Lantry. 2001. Yellow perch abundance and life history in the eastern basin of Lake Ontario in relation to recent increase in double-crested cormorants. Section 19, *In* NYSDEC Annual Report 2000, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Carss, D.N. and 27 co-authors. 1997. Techniques for assessing cormorant diet and food intake: towards a consensus view. Pages 197-230, *in* N. Baccetti and G. Cherubini, editors, European Conference on Cormorants. Supplement alle. Ricerche di Biologia della Selvaggina, Volume XXVI.

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.

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., S.R. LaPan, and A. Bendig. 2000. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 1999. Section 17, In *NYSDEC Annual Report 1999*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., S.R. La Pan, B. Edmonds, and A. Bendig. 2001. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2000. Section 17, In *NYSDEC Annual Report 2000*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., R.M. Klindt, B. Edmonds, and A. Bendig. 2002. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2001. Section 17, In *NYSDEC Annual Report 2001*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., R.M. Klindt, B. Edmonds, and A. Bendig. 2003. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2002. Section 17, In *NYSDEC Annual Report 2002*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., R.M. Klindt, B. Edmonds, and A. Bendig. 2004. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2003. Section 17, In *NYSDEC Annual Report 2003*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., R.M. Klindt, B. Edmonds, and A. Bendig. 2005. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2004. Section 17, In *NYSDEC Annual Report 2004*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H., R.M. Klindt, B. Edmonds, and A. Bendig. 2006. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2005. Section 17, In *NYSDEC Annual Report 2005*, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

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

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., J.H. Johnson and C. Adams. 2005. Use of fish otolith-length regressions to infer size of double-crested cormorant prey fish from recovered otoliths in Lake Ontario. *Northeastern Naturalist* 12:133-140.

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* 16:63-64.

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 by number of double-crested cormorants from Griswold Island, 2006. Pre-chick feeding period includes pellets collected on 5/23/06, the chick feeding period includes pellets collected on 6/20/06, and the post-chick feeding period includes pellets collected on 7/26/06, 8/2/06 and 9/12/06.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	150	150	450	750
Fish/pellet (adjusted)	13.2	10.8	8.8	10.1
Yellow perch	47.5	73.3	56.5	59.3
Pumpkinseed	21.9	3.9	11.6	12.3
Rock bass	13.2	13.6	7.1	11.3
Cyprinids	8.6	2.3	11.7	7.5
Round goby	2.7	4.3	6.9	4.6
Ictalurid	0.2	0.3	3.1	1.2
Smallmouth bass	2.0	1.2	0.4	1.2
Darter	1.4	0.2	0.7	0.8
Esocid	1.3	0.3	0.2	0.6
Slimy sculpin	0.6	0.3	0.4	0.4
Catostomid	0.5	0.2	0.3	0.3
Alewife	<0.1	---	0.8	0.3
Banded killifish	---	---	0.3	0.1
Burbot	0.1	0.1	---	0.1
Walleye	---	---	<0.1	<0.1
	100.0	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition by number of double-crested cormorants from McNair Island, 2006. Pre-chick period includes pellets collected on 5/23/06, the chick feeding period includes pellets collected on 6/20/06, and the post-chick feeding period includes pellets collected on 7/25/06 and 8/2/06 and 9/12/06.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>	
No. of pellets	150	150	159	459	
Fish/pellet (adjusted)	12.0	14.6	7.7	11.4	
Round goby	51.6	57.7	51.2	54.1	
Yellow perch	12.5	29.9	16.9	21.5	
Rock bass	12.1	6.2	9.8	8.8	
Pumpkinseed	13.0	2.3	14.8	8.8	
Cyprinids	4.3	0.7	4.3	2.7	
Smallmouth bass	1.4	1.5	1.1	1.4	
Catostomid	2.1	0.3	0.3	0.8	
Darter	1.0	0.7	0.3	0.7	
Ictalurid	0.8	0.3	1.0	0.6	
Esocid	0.6	0.1	0.2	0.3	
Slimy sculpin	0.4	0.1	0.1	0.2	
Banded killifish	0.2	---	---	0.1	
Alewife	---	<0.1	<0.1	<0.1	
Burbot	---	---	0.1	---	< 0.1
Walleye	---	0.1	< 0.1	< 0.1	
	100.0	100.0	100.0	100.0	

Table 3. Seasonal and total percent diet composition by number of double-crested cormorants from Strachan Island, 2006. Pre-chick feeding periods includes pellets collected on 5/24/06, the chick feeding period includes pellets collected on 6/20/06, and the post-chick feeding period includes pellets collected on 7/26/06.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	12	64	148	224
Fish/pellet (adjusted)	14.5	16.3	10.3	12.2
Round goby	33.7	54.4	37.8	43.4
Yellow perch	42.2	36.3	18.0	32.3
Cyprinid	3.6	1.1	22.2	8.4
Rock bass	4.2	5.2	9.7	6.3
Darter	11.5	0.8	0.6	3.8
Pumpkinseed	1.2	1.3	6.9	3.0
Ictalurid	2.4	---	2.4	1.4
Catostomid	---	0.2	1.7	0.6
Smallmouth bass	0.6	0.4	0.4	0.5
Slimy sculpin	0.6	---	0.2	0.2
Walleye	---	---	0.1	< 0.1
Other	---	<u>0.3</u>	---	<u>0.1</u>
	100.0	100.0	100.0	100.0

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Table 4. Spatial diet overlap among three St. Lawrence River cormorant colonies, 2006.

<u>Feeding period</u>	<u>Colonies</u>		
	<u>Griswold I.-McNair I.</u>	<u>Griswold I.-Strachran I.</u>	<u>McNair I.-Strachan I.</u>
Pre-chick	0.40	0.73	0.76
Chick	0.51	0.60	0.99
Post-chick	0.75	0.57	0.90
Entire season	0.49	0.62	0.92

Table 5. Temporal diet overlap at each of the three St. Lawrence River cormorant colonies, 2006.

<u>Feeding period</u>	<u>Griswold I.</u>	<u>McNair I.</u>	<u>Strachan I.</u>
Pre-chick feeding-Chick feeding	0.88	0.93	0.92
Pre-chick feeding-Post-chick feeding	0.96	0.99	0.56
Chick feeding-Post-chick feeding	0.95	0.95	0.83
$\bar{x} =$	0.93	0.96	0.77

Table 6. Fish consumption estimates in millions for cormorants from three St. Lawrence River colonies, 2006.

<u>Period</u>	<u>Griswold Island</u>		<u>McNair Island</u>		<u>Strachan Island</u>	
	<u>Number</u>	<u>Pounds</u>	<u>Number</u>	<u>Pounds</u>	<u>Number</u>	<u>Pounds</u>
Pre-chick feeding	0.21	0.02	0.82	0.07	0.60	0.04
Chick feeding	0.22	0.02	1.34	0.09	0.86	0.05
Post-chick feeding	<u>0.21</u>	<u>0.02</u>	<u>0.86</u>	<u>0.11</u>	<u>0.66</u>	<u>0.06</u>
Total	0.64	0.06	3.02	0.27	2.11	0.15

Table 7. Estimated total length (TL, mm), weight (Wt., g), and number of otoliths examined (No.) for smallmouth bass, yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Griswold, McNair, and Strachan Islands in 2006.

	<u>Griswold</u>			<u>McNair</u>			<u>Strachan</u>		
	<u>TL</u>	<u>Wt.</u>	<u>No.</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>	<u>TL</u>	<u>Wt.</u>	<u>No.</u>
	Pre-chick								
Smallmouth bass	214	128	4	137	30	11	---	---	---
Yellow perch	92	8	100	89	7	100	---	---	---
Rock bass	92	15	100	88	13	100	---	---	---
Pumpkinseed	94	17	100	91	15	100	---	---	---
	Chick								
Smallmouth bass	155	45	8	103	12	15	---	---	---
Yellow perch	89	7	100	96	9	100	79	5	100
Rock bass	92	15	100	98	18	100	99	19	86
Pumpkinseed	97	19	100	82	11	100	79	9	22
	Post-chick								
Smallmouth bass	155	45	5	165	55	15	---	---	---
Yellow perch	101	11	100	87	7	100	89	7	100
Rock bass	91	14	100	95	16	100	88	13	100
Pumpkinseed	96	18	100	97	18	100	79	9	100

Table 8. Number of cormorant nests, average number of fish per pellet derived from Griswold (GI), McNair (MI) and Strachan (SI) Islands; number of cormorant feeding days, and fish consumption for GI, MI and SI and all other colonies in the upper St. Lawrence River, 2003-2006.

<u>Year</u>	<u>No. nests</u>	<u>Other Colonies</u>			<u>GI, MI, SI Colonies</u>		
		<u>̄ fish/ Pellet</u>	<u>No. feeding days</u>	<u>Fish consumption</u>	<u>No. Nests</u>	<u>No. feeding days</u>	<u>Fish consumption</u>
2003	2,455	14.2	1,180,000	17,600,000	889	450,000	6,400,000
2004	1,889	13.8	950,000	13,100,000	930	450,000	6,300,000
2005	1,846	14.0	930,000	13,000,000	1,151	590,000	7,400,000
2006	<u>1,845</u>	11.3	<u>930,000</u>	<u>10,500,000</u>	<u>1,003</u>	<u>480,000</u>	<u>5,800,000</u>
	8,035		3,990,000	54,200,000	3,973	1,970,000	25,900,000

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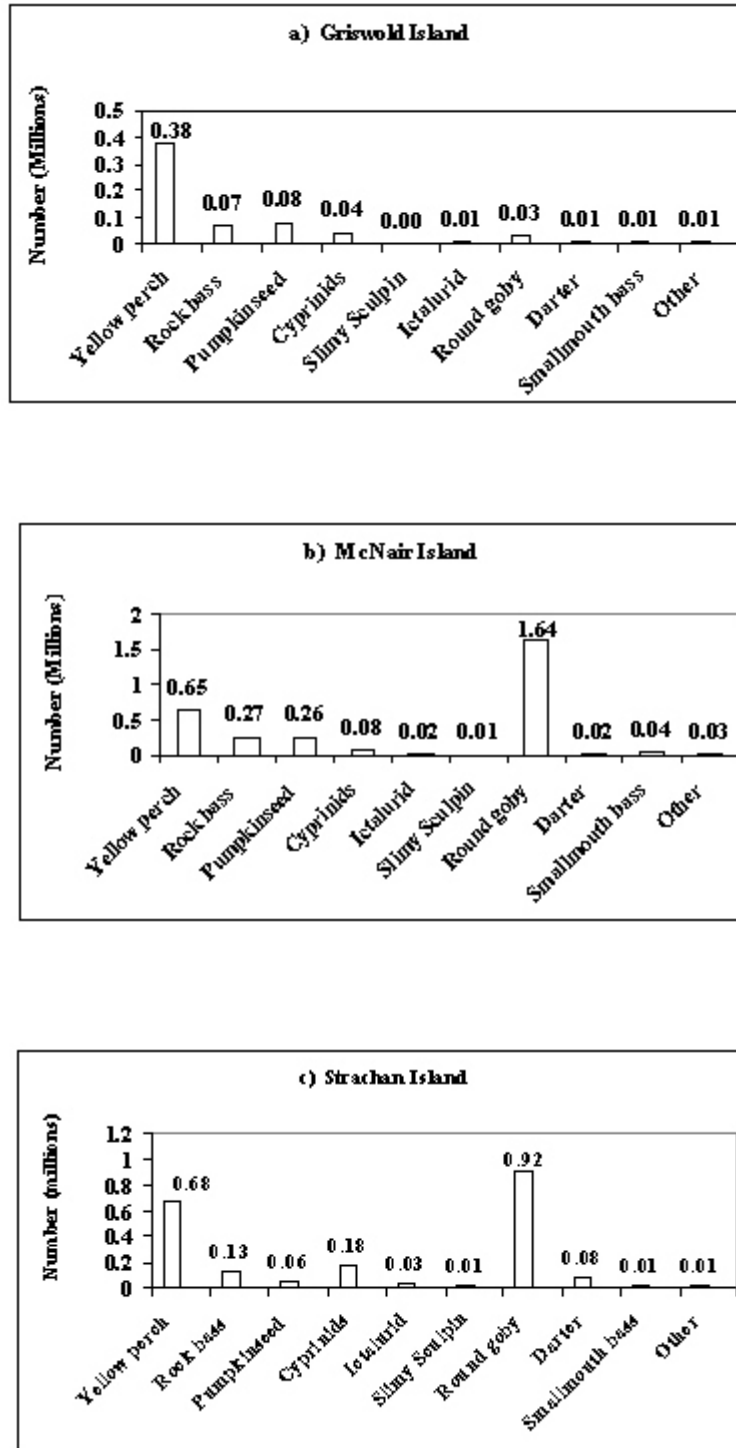


Figure 1. Estimated number of fish, in millions, consumed by cormorants from colonies at (a) Griswold, (b) McNair, and (c) Strachan Islands in the St. Lawrence River in 2006.