

**Diet Composition and Fish Consumption of Double-Crested Cormorants
from Three St. Lawrence River Colonies in 2008**

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

Rodger M. Klindt
*New York State Department of Environmental Conservation
Watertown, NY 13601*

Anne Bendig
*Ontario Ministry of Natural Resources
Kemptville, ON K0G 1J0*

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 603 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 upper river 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 2007 these studies have shown that cormorants consumed about 57.5 million fish including 26.1 million yellow perch, 9.1 million rock bass and 0.6 million smallmouth bass (Johnson et al. 2008). During this same time period fish assessment studies near some of these islands have shown a major decrease in yellow perch populations (Klindt 2007). 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). This paper describes the diet and fish consumption of cormorants in the upper St. Lawrence River in 2008.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants at St. Lawrence River colonies in 2008. Pellets were collected beginning in early June and ending in mid August. 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 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 mid 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>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 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. When pellets were not collected during a single feeding period a mean value was calculated from the two feeding periods to estimate total fish consumption. 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 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 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 yellow perch (Burnett et al. 2001), 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 ($C\lambda$) ≥ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

A total of 521 pellets was used to describe the feeding ecology of cormorants from Griswold (135 pellets), McNair (270 pellets), and Strachan (116 pellets) Islands in 2008 (Tables 1-3). Pellets were not collected during the post-chick feeding period at Griswold and Strachan islands in 2008. Over the entire season the number of fish per pellet was highest at Strachan Island (23.8) followed by Griswold (20.1) and McNair (16.8) islands (Tables 1-3).

Diet Composition

Yellow perch were the primary prey of cormorants at Griswold Island (42.2%) and round gobies (*Neogobius melanostomus*) (37.1%) were the second ranked prey (Table 1). Round gobies were the major prey consumed (46.0%) during the pre-chick feeding period and yellow perch were dominant during the chick feeding period (49.6%). Rock bass (7.9%), pumpkinseed (7.6%) and cyprinids (2.3%) were the other major prey of Griswold Island cormorants. For the entire season, panfish (i.e., yellow perch, rock bass, pumpkinseed, ictalurids) contributed 58.8% of the diet, forage fish (round goby, cyprinids [*Cottus cognatus*], darters) composed 40.4%, and gamefish (mainly smallmouth bass and esocids) comprised 0.8% of the diet of Griswold Island cormorants.

Round goby (39.5%), pumpkinseed (25.8%), yellow perch (19.9%), and rock bass (10.3%) were the dominant prey in the diet of cormorants at McNair

Island (Table 2). Ictalurids (1.1%) were the only other species that made up at least one percent of the diet. For the season panfish made up 57.1% of the diet of McNair Island cormorants, forage fish 42.2%, and gamefish (mostly smallmouth bass) 0.7% (Table 2).

Round goby (70.1%), rock bass (11.9%) and yellow perch (9.7%) were the main prey of Strachan Island cormorants (Table 3). Cyprinids (2.7%), pumpkinseed (1.9%), and Ictalurids (1.1%) all contributed at least 1% to the diet. Panfish made up 24.6% of the seasonal diet, forage fish 74.2%, and gamefish 1.2% at Strachan Island in 2008 (Table 3).

Diet Overlap

Diet overlap for the entire season among all three upper St. Lawrence River colonies in 2008 ranged from 0.72 to 0.90 (Table 4). Diet was the most similar between cormorants from McNair and Strachan Islands ($C\lambda = 0.90$) and least similar between Griswold and Strachan Islands ($C\lambda = 0.72$). When comparing the three colonies mean diet overlap between cormorants from Griswold Island and the other two colonies was lowest ($C\lambda = 0.79$) and McNair was highest (0.88). Temporal variation in diet composition among feeding periods at the McNair colony occurred with diet overlap between the pre-chick and chick feeding (0.97) being higher than the other feeding periods (Table 5).

Fish Consumption

Based on nest counts of 425 on Griswold Island, 540 on McNair Island, and 301 on Strachan Island, and fledgling productivities of 1.8 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.22, 0.27, and 0.15 million cormorant feeding days for these colonies, respectively, in 2008. Fish consumption for the Griswold Island colony was estimated at 3.40 million fish and 0.22 million pounds, for the McNair Island colony at 4.21 million fish and 0.27 million pounds, and for the Strachan Island colony at 2.49 million fish and 0.15 million pounds (Table 6).

We estimate that during 2008, cormorants from Griswold Island consumed 2.01 million panfish (including 1.44 million yellow perch, 0.27 million

rock bass and 0.26 million pumpkinseed), 1.37 million forage fish (including 1.26 million round goby, 0.08 million cyprinids and 0.01 million darters) and 0.02 million gamefish (primarily smallmouth bass) (Figure 1). We estimate that cormorants from McNair Island consumed 2.41 million panfish (mainly 1.09 million pumpkinseed, 0.84 million yellow perch and 0.43 million rock bass), 1.77 million forage fish (including 1.66 million round goby and 0.09 million cyprinids), and 0.03 million gamefish (smallmouth bass). Double-crested cormorants from the Strachan Island colony consumed 0.57 million panfish (0.25 million rock bass, 0.24 million yellow perch, 0.06 million pumpkinseed), 1.90 million forage fish (1.77 million round goby, 0.09 million cyprinids, 0.02 million darters), and 0.02 million gamefish (mainly smallmouth bass) (Figure 1).

Size of Fish Consumed

Seasonal trends in the size of fish consumed were not apparent at St. Lawrence River colonies in 2008 (Table 7). The size of yellow perch, rock bass, and pumpkinseed consumed was similar to previous years.

Discussion

Cormorant diet composition at the Griswold Island colony in 2008, where yellow perch was the primary prey, was similar to previous years (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008). Since 1999, yellow perch have contributed 55.5% of the diet of cormorants at Griswold Island colony. Over this same period rock bass (12.8%), pumpkinseed (11.7%), and cyprinids (8.5%) 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 and 2007, gobies were the main prey of cormorants at McNair (42%) and Strachan Islands (46.2%). At Griswold Island gobies increased in the diet to 4.6% in 2006 and 13.1% in 2007. In 2008, round gobies were again the major prey of cormorants at Strachan Island (70.1%) and McNair Island (39.5%) and increased to 37.1% (second most abundant fish species consumed) at Griswold Island. Since 2004, when round gobies first appeared in cormorant diets at all St. Lawrence River colonies, they have comprised 36.7% of the fish consumed at Strachan, 32.6% at McNair and 11.2% at Griswold. 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 over the last 5 years (2004-2008, \bar{x} =11.2%, but 37.1% in 2008). However, this may change if round gobies continue to increase in the diet of Griswold Island cormorants. 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.

From 1999 to 2004, panfish composed 78.6% and forage fish only 19.3% of cormorant diets at the three St. Lawrence River colonies. Since 2004, panfish have made up 56.4% and forage fish 42.5%, of cormorant diets in the upper St. Lawrence River. Over the past 10 years game fish have made up 1.6% (range 0.9% to 2.9%) of cormorant diets at these three river colonies (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008). The contribution of gamefish in cormorant diets in 2008 (0.9%) was the lowest recorded over the ten 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 6.76 million fish. Since 1999, we estimate that cormorants have consumed 67.6 million fish from these three colonies (Figure 2). This includes 28.6 million yellow perch (42.2%), 10.1 million

rock bass (14.9%), 9.4 million round goby (13.9%), 6.4 million pumpkinseed (9.5%), 5.7 million cyprinids (8.4%) and 0.6 million smallmouth bass (1.0%) (Figure 2).

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. Since 2004, the mean size of yellow perch consumed by cormorants in the upper St. Lawrence River is 92.4 mm (3.6 in).

Acknowledgements

We thank Aaron Harvill for collecting and processing samples; Tim Wallbridge for measuring otoliths and Chris Nack for data analysis.

References

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 depletions. *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.

Johnson, J.H. and R.M. Klindt. 2007. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2006. Section 17 *In* NYSDEC Annual Report 2006, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Johnson, J.H. and R.M. Klindt. 2008. Diet composition and fish consumption of double-crested cormorants from three St. Lawrence River colonies in 2007. Section 17 *In* NYSDEC Annual Report 2007, Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee.

Klindt, R.M. 2007. 2006 Lake St. Lawrence warmwater fisheries assessment. Section 7 *In* NYSDEC Annual Report 2006, 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, 2008. Pre-chick feeding period includes pellets collected on 6/3/08 and chick feeding period includes pellets collected on 7/11/08.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Total</u>
No. of pellets	100	35	135
Fish/pellet (adjusted x 1.042)	21.4	16.3	20.1
Yellow perch	35.1	49.6	42.2
Round goby	46.0	28.0	37.1
Rock bass	7.2	8.6	7.9
Pumpkinseed	7.9	7.3	7.6
Cyprinid	1.7	3.0	2.3
Ictalurid	---	2.3	1.1
Catostomid	0.6	0.2	0.4
Darter	0.5	0.2	0.4
Smallmouth bass	0.4	0.4	0.4
Esocid	0.3	0.4	0.4
Slimy sculpin	0.2	0.3	0.2
Banded killifish	<u>0.1</u>	---	<u>≤0.1</u>
	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition by number of double-crested cormorants from McNair Island, 2008. Pre-chick period includes pellets collected on 6/5/08, chick feeding period includes pellets collected on 7/11/08 and the post-chick feeding period includes pellets collected on 8/12/08.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Post-chick</u>	<u>Total</u>
No. of pellets	100	100	70	270
Fish/pellet (adjusted x 1.042)	20.7	15.0	13.7	16.8
Round goby	54.4	43.8	19.2	39.5
Pumpkinseed	16.6	17.6	43.8	25.8
Yellow perch	19.5	17.0	23.3	19.9
Rock bass	6.9	17.1	7.3	10.3
Cyprinid	1.0	2.2	3.0	2.0
Ictalurid	0.4	0.8	2.0	1.1
Smallmouth bass	0.4	1.0	0.4	0.6
Darter	0.4	---	0.7	0.4
Catostomid	0.1	0.4	0.1	0.2
Esocid	0.1	0.1	0.1	0.1
Slimy sculpin	0.1	---	---	<0.1
Banded killifish	0.1	---	---	<0.1
Walleye	---	---	0.1	<0.1
Lamprey	---	---	<u>0.1</u>	<u><0.1</u>
	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, 2008. Pre-chick feeding periods includes pellets collected on 6/4/08 and the chick feeding period includes pellets collected on 7/8/08.

	<u>Pre-chick</u>	<u>Chick</u>	<u>Total</u>
No. of pellets	98	18	116
Fish/pellet (adjusted x 1.042)	25.5	14.8	23.8
Round goby	73.1	68.4	70.1
Rock bass	3.8	16.6	11.9
Yellow perch	10.0	9.5	9.7
Cyprinid	6.1	0.8	2.7
Pumpkinseed	3.9	0.8	1.9
Ictalurid	0.2	1.6	1.1
Darter	1.2	0.4	0.6
Smallmouth bass	0.9	0.4	0.6
Catostomid	0.3	0.8	0.6
Walleye	---	0.8	0.5
Trout-perch	0.3	---	0.1
Esocid	0.1	---	0.1
Banded killifish	<u>0.1</u>	---	<u>0.1</u>
	100.0	100.0	100.0

Table 4. Spatial diet overlap among three St. Lawrence River cormorant colonies, 2008.

<u>Feeding period</u>	<u>Colonies</u>		
	<u>Griswold I.-McNair I.</u>	<u>Griswold I.-Strachran I.</u>	<u>McNair I.-Strachran I.</u>
Pre-chick	0.95	0.84	0.93
Chick	0.76	0.60	0.88
Post-chick	---	---	---
Average	0.85	0.72	0.90

Table 5. Temporal diet overlap at each of the three St. Lawrence River cormorant colonies, 2008.

<u>Feeding period</u>	<u>Griswold I.</u>	<u>McNair I.</u>	<u>Strachan I.</u>
Pre-chick feeding-Chick feeding	0.91	0.97	0.59
Pre-chick feeding-Post-chick feeding	---	0.70	---
Chick feeding-Post-chick feeding	---	0.75	---
$\bar{x} =$	---	0.80	---

Table 6. Fish consumption estimates in millions for cormorants from three St. Lawrence River colonies, 2008.

<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	1.20	0.06	1.47	0.07	1.00	0.04
Chick feeding	1.16	0.07	1.36	0.09	0.75	0.05
Post-chick feeding	<u>1.04</u>	<u>0.09</u>	<u>1.38</u>	<u>0.11</u>	<u>0.74</u>	<u>0.06</u>
Total	3.40	0.22	4.21	0.27	2.49	0.15

Table 7. Estimated total length (TL, inches), weight (Wt., pounds), and number of otoliths examined (No.) for yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Griswold, McNair, and Strachan Islands in 2008. Values in parentheses represent the standard deviation (SD) for mean total lengths.

	<u>Griswold</u>			<u>McNair</u>			<u>Strachan</u>		
	<u>TL</u> (SD)	<u>Wt.</u>	<u>No.</u>	<u>TL</u> (SD)	<u>Wt.</u>	<u>No.</u>	<u>TL</u> (SD)	<u>Wt.</u>	<u>No.</u>
				Pre-chick					
Yellow perch	---	---	---	3.2 (1.1)	0.01	100	3.3 (1.1)	0.02	100
Rock bass	---	---	---	3.4 (1.5)	0.03	100	3.7 (1.1)	0.04	100
Pumpkinseed	---	---	---	2.9 (1.2)	0.02	100	2.9 (1.0)	0.02	100
				Chick					
Yellow perch	3.5 (1.4)	0.02	100	3.2 (1.1)	0.01	100	3.2 (0.9)	0.01	38
Rock bass	4.0 (1.2)	0.04	100	3.7 (1.5)	0.03	100	3.8 (1.4)	0.04	72
Pumpkinseed	3.7 (1.4)	0.04	100	3.1 (1.2)	0.02	100	---	---	---
				Post-chick					
Yellow perch	3.7 (1.3)	0.02	100	4.4 (1.1)	0.03	100	---	---	---
Rock bass	3.8 (1.3)	0.04	77	3.5 (1.2)	0.03	100	---	---	---
Pumpkinseed	3.0 (1.1)	0.02	64	3.0 (1.2)	0.02	98	---	---	---

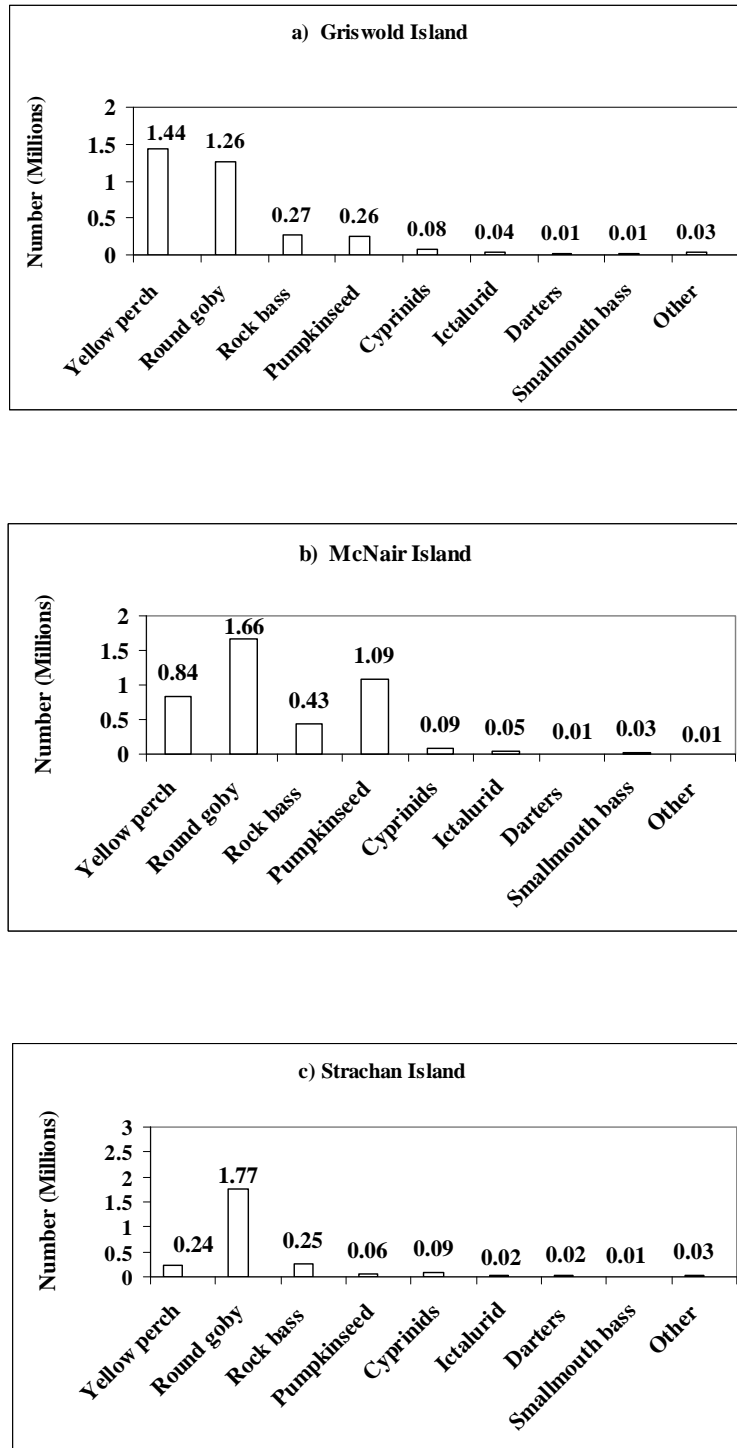


Figure 1. Estimated number of fish, in millions, consumed by cormorants from colonies at (a) Griswold, (b) McNair, and (c) Strachan Islands in the St. Lawrence River in 2008.

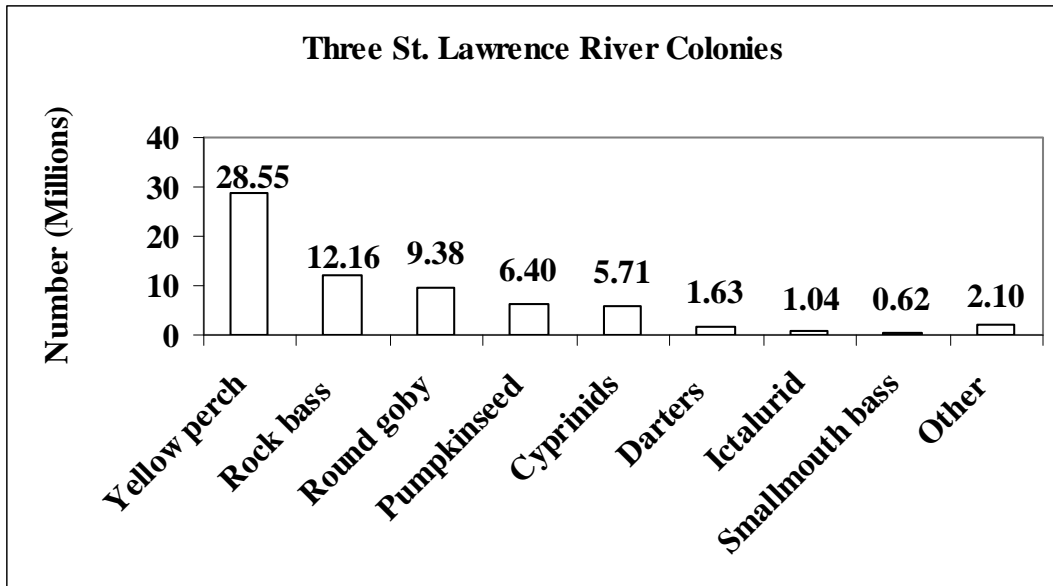


Figure 2. Estimated number of fish, in millions, consumed by cormorants at the three St. Lawrence River colonies 1999 to 2008.