Diet Composition and Fish Consumption of Double-Crested Cormorants from Three St. Lawrence River Colonies in 2007

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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 2006 these studies have shown that cormorants consumed about 49.5 million fish including 23.2 million yellow perch, 8.2 million rock bass and 0.48 million smallmouth bass (Johnson et al. 2007). 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 2007.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants at St. Lawrence River colonies in 2007. Pellets were collected beginning in late May and ending in early October. 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 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:

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

To estimate the number of fish consumed by cormorants during each feeding period we multiplied the number of double-crested cormorant feeding days by mean daily ingestion rates for that period. For estimates of mean daily ingestion rates, we used the mean number of fish per pellet multiplied by a fecal correction factor of 1.042 (Johnson and Ross 1996). Although variation in pellet production rates 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 ($C\lambda$) ≥ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

A total of 705 pellets were used to describe the feeding ecology of cormorants from Griswold (252 pellets), McNair (304 pellets), and Strachan (149 pellets) Islands in 2007 (Tables 1-3). Pellets were not collected during the post-chick feeding period at Griswold and Strachan islands in 2007. Over the entire season the number of fish per pellet was highest at Strachan Island (20.3) followed by Griswold (15.3) and McNair (11.4) islands (Tables 1-3).

<u>Diet Composition</u>

Yellow perch dominated the diet of cormorants from Griswold Island during the pre-chick (68.3%) and chick (44.5%) feeding periods (Table 1). Round goby (*Neogobius melanostomus*) (13.1%), rock bass (12.1%), pumpkinseed (10.0%) and cyprinids (6.4%) were the other major prey of Griswold Island cormorants. For the entire season, panfish (i.e., yellow perch, rock bass, pumpkinseed, ictalurids) contributed 78.2% of the diet, forage fish (round goby, cyprinids, slimy sculpin (*Cottus cognatus*), darters) composed 20.9%, and gamefish (mainly smallmouth bass and esocids) comprised 0.9% of the diet of Griswold Island cormorants.

Round goby (30.3%), yellow perch (26.1%), rock bass (16.3%), pumpkinseed (15.3%) and cyprinids (7.2%) were the dominant prey in the diet of cormorants at McNair Island (Table 2). Ictalurids (1.9%) and smallmouth bass (1.2%) were the only other species that made up at least one percent of the diet. For the season panfish made up 59.6% of the diet of McNair Island cormorants, forage fish 39.0%, and gamefish (mostly smallmouth bass) 1.4% (Table 2).

Round goby (49.0%) and yellow perch (28.4%) were the main prey of Strachan Island cormorants (Table 3). Cyprinids (5.7%), rock bass (5.1%), darters (4.6%), and pumpkinseed (4.3%) all contributed at least 1% to the diet. Panfish made up 38.7% of the seasonal diet, forage fish 60.4%, and gamefish 0.9% at Strachan Island in 2007 (Table 3).

<u>Diet Overlap</u>

Diet overlap for the entire season varied (i.e.,$C\lambda \geq$ 0.60) among all three upper St. Lawrence River colonies in 2007 (Table 4). Diet was the most similar between cormorants from McNair and Strachan Islands ($C\lambda$= 0.82) and least similar between Griswold and Strachan Islands ($C\lambda$= 0.52). When comparing the three colonies diet overlap between cormorants from Griswold Island and the other two colonies was lowest ($C\lambda$= 0.67). Temporal variation in diet composition among feeding periods at the McNair colony was minimal (Table 5).

<u>Fish Consumption</u>

Based on nest counts of 322 on Griswold Island, 603 on McNair Island, and 286 on Strachan Island, and fledgling productivities of 1.8 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.16, 0.30, and 0.15 million cormorant feeding days for these colonies, respectively, in 2007. Fish consumption for the Griswold Island colony was estimated at 2.55 million fish and 0.16 million pounds, for the McNair Island colony at 3.23 million fish and 0.30 million pounds, and for the Strachan Island colony at 2.39 million fish and 0.15 million pounds (Table 6).

We estimate that during 2007, cormorants from Griswold Island consumed 1.99 million panfish (including 1.41 million yellow perch, 0.31 million rock bass and 0.25 million pumpkinseed), 0.53 million forage fish (including 0.33 million round goby, 0.16 million cyprinids and 0.02 million darters) and 0.02 million gamefish (primarily smallmouth bass) (Figure 1). We estimate that cormorants from McNair Island consumed 1.96 million panfish (mainly 0.86 million yellow perch 0.54 million rock bass, and 0.50 million pumpkinseed), 1.29 million forage fish (including 1.00 million round goby and 0.24 million cyprinids), and 0.04 million gamefish (mostly smallmouth bass). Double-crested cormorants from the Strachan Island colony consumed 0.92 million panfish (0.68 million yellow perch, 0.12 million rock bass, 0.10 million pumpkinseed), 1.45 million forage fish (1.17 million round gobies, 0.14 million cyprinids, 0.11 million darters), and 0.02 million gamefish (mainly smallmouth bass) (Figure 1).

<u>Size of Fish Consumed</u>

The size of rock bass consumed by cormorants at McNair Island in 2007 increased over the season from 3.0 inches during the pre-chick feeding period to 4.2 inches during the post-chick feeding period (Table 7). Conversely, the size of pumpkinseed consumed decreased at McNair over the season. Few smallmouth bass otoliths were recovered in pellets in 2007 at St. Lawrence River colonies, but during the pre-chick feeding period there was evidence of size differences among colonies with the smallest bass (4.4 inches) being consumed at Griswold Island and the largest bass (7.9 inches) at Strachan Island (Table 7).

Discussion

Cormorant diet composition at the Griswold Island colony in 2007, where yellow perch was the primary prey, was similar to previous years (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007). Since 1999, yellow perch have contributed 57.0% of the diet of cormorants at Griswold Island colony. Over this same period rock bass (13.3%), pumpkinseed (12.2%), and cyprinids (9.2%) 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 contibution 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 cormorants at McNair (54%) and Strachan Islands (43.4%), but still only contributed 4.6% at Griswold Island. In 2007, round gobies were again the major prey of cormorants at Strachan Island (49%) and increased to 13.1% (second most abundant fish species consumed) at Griswold Island. Although round gobies remained the main fish species consumed by cormorants at McNair Island in 2007, their contribution in the diet declined from 54% in 2006 to 30% in 2007. Since 2004, when round gobies first appeared in cormorant diets at all St. Lawrence River colonies, they have become the dominate prey at McNair (30.9%) and are the second ranked prey at Strachan (28.4%). 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 (2004-2007, x=4.8%). 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.

Forage fish have made up 46.3% of cormorant diets at the three St. Lawrence River colonies in 2006 and 2007 compared to panfish that have contributed 52.6%. From 1999 to 2004, panfish composed 78.6% and forage fish only 19.3% of cormorant diets. Since 2004, panfish have made up 58.8% and forage fish 40.0%, of cormorant diets in the upper St. Lawrence River. Over the past 9 years game fish have made up 1.7% (range 1.1% to 2.9%) of cormorant diets at these three river colonies (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007). The contribution of gamefish in cormorant diets in 2007 (1.1%) was the lowest recorded over the nine 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 was 6.39 million fish. Since 1999, we estimate that double-crested cormorants from these colonies have consumed 57.51 million fish including 26.13 million yellow perch, 9.09 million rock bass, 5.45 million cyprinids, 4.97 million pumpkinseed, 0.57 million smallmouth bass, and 0.33 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 (i.e. Cape Vincent to Akwesasne) 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 2000-2007 there have been 7.4 million cormorant feeding days in the upper St. Lawrence River and birds have consumed about 99 million fish (34 million Griswold, McNair and Strachan Islands, 55 million all other upper river colonies) (Table 8). Assuming that cormorants consume one pound of fish per day, birds have consumed about 7.4 million pounds of fish during this period.

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Table 1. Seasonal and total percent diet composition by number of double-crested cormorants from Griswold Island, 2007. Pre-chick feeding period includes pellets collected on 5/24/07and 6/12/07. The chick feeding period includes pellets collected on 7/23/07.

	Pre-chick	Chick	Total
No. of pellets	167	85	252
Fish/pellet (adjusted)	15.7	14.9	15.3
Yellow perch	68.3	44.5	55.3
Round goby	7.7	17.6	13.1
Rock bass	7.6	15.9	12.1
Pumpkinseed	6.9	11.8	10.0
Cyprinid	4.7	8.1	6.4
Ictalurid	0.2	1.4	0.8
Darter	1.6	0.2	0.7
Smallmouth bass	1.0	0.2	0.6
Banded killifish	0.9	0.1	0.4
Esocid	0.5	0.1	0.3
Slimy sculpin	0.5	---	0.2
Catostomid	0.1	0.1	0.1
	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition by number of double-crested cormorants from McNair Island, 2007. Pre-chick period includes pellets collected on 5/24/07 and 6/12/07, the chick feeding period includes pellets collected on 7/23/07, and the post-chick feeding period includes pellets collected on 8/30/07 and 10/1/07.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	168	85	51	304
Fish/pellet (adjusted)	13.3	8.7	11.0	11.4
Round goby	33.5	26.9	29.8	30.3
Yellow perch	41.1	25.7	14.6	26.1
Rock bass	10.7	27.9	13.1	16.3
Pumpkinseed	5.0	9.4	27.2	15.3
Cyprinid	4.1	5.7	10.6	7.2
Ictalurid	0.6	1.9	3.0	1.9
Smallmouth bass	1.5	1.1	1.1	1.2
Darter	2.2	0.3	---	0.8
Catostomid	0.7	0.9	0.4	0.6
Esocid	0.1	0.1	0.2	0.2
Slimy sculpin	0.3	0.1	---	0.1
Alewife	0.1	---	---	<0.1
Trout-perch	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, 2007. Pre-chick feeding periods includes pellets collected on 5/27/07 and 6/13/07, and the chick feeding period includes pellets collected on 7/17/07.

	Pre-chick	Chick	Total
No. of pellets	120	29	149
Fish/pellet (adjusted)	23.7	6.4	20.3
Round goby	60.9	14.6	49.0
Yellow perch	19.3	55.0	28.4
Cyprinid	4.2	10.1	5.7
Rock bass	3.6	9.5	5.1
Darter	6.0	0.6	4.6
Pumpkinseed	4.3	4.1	4.3
Ictalurid	0.2	3.0	0.9
Smallmouth bass	0.7	0.6	0.8
Catostomid	0.6	0.6	0.6
Lamprey	0.1	1.7	0.4
Banded killifish	0.1	---	0.1
Esocid	0.1	---	0.1
	100.0	100.0	100.0

Table 4. Spatial diet overlap among three St. Lawrence River cormorant colonies, 2007.

	Colonies		
Feeding period	Griswold I.-McNair I.	Griswold I.-Strachran I.	McNair I.-Strachan I.
Pre-chick	0.82	0.42	0.82
Chick	0.88	0.96	0.76
Post-chick	---	---	---
Average	0.82	0.52	0.84

Table 5. Temporal diet overlap at each of the three St. Lawrence River cormorant colonies, 2007.

Feeding period	Griswold I.	McNair I.	Strachan I.
Pre-chick feeding-Chick feeding	0.90	0.88	0.54
Pre-chick feeding-Post-chick feeding	---	0.75	---
Chick feeding-Post-chick feeding	0.95	0.84	---
$\bar{x}$ =	---	0.83	---

Table 6. Fish consumption estimates in millions for cormorants from three St. Lawrence River colonies, 2007.

	Griswold Island		McNair Island		Strachan Island	
Period	Number	Pounds	Number	Pounds	Number	Pounds
Pre-chick feeding	0.65	0.04	1.01	0.08	0.89	0.04
Chick feeding	0.81	0.05	0.88	0.10	0.31	0.05
Post-chick feeding	1.09	0.07	1.34	0.12	1.19	0.06
Total	2.55	0.16	3.23	0.30	2.39	0.15

Table 7. Estimated total length (TL, inches), weight (Wt., pounds), 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 2007.

	Griswold			McNair			Strachan		
	TL (SD)	Wt.	No.	TL (SD)	Wt.	No.	TL (SD)	Wt.	No.
Pre-chick									
Smallmouth bass	4.4 (1.7)	0.04	8	6.0 (0.9)	0.10	18	7.9 (0.7)	0.23	6
Yellow perch	3.5 (0.9)	0.02	100	3.7 (1.1)	0.02	100	3.6 (1.2)	0.02	100
Rock bass	4.0 (1.3)	0.05	100	3.0 (1.4)	0.02	100	3.6 (1.3)	0.03	93
Pumpkinseed	2.8 (1.0)	0.02	100	3.4 (1.3)	0.03	100	2.5 (0.7)	0.01	100
Chick									
Yellow perch	3.7 (0.9)	0.02	100	3.7 (0.9)	0.02	100	3.8 (1.1)	0.02	100
Rock bass	3.8 (1.3)	0.04	100	3.5 (1.4)	0.03	100	3.8 (0.9)	0.04	25
Pumpkinseed	3.6 (1.1)	0.04	100	3.2 (1.1)	0.03	100	3.8 (0.6)	0.04	11
Post-chick									
Yellow perch	---	---	---	4.5 (0.9)	0.03	100	---	---	---
Rock bass	---	---	---	4.2 (1.2)	0.05	100	---	---	---
Pumpkinseed	---	---	---	3.0 (1.1)	0.02	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.

	Other Colonies				GI, MI, SI Colonies		
Year	No. nests	$\bar{x}$ fish/ Pellet	No. feeding days	Fish consumption	No. Nests	No. feeding days	Fish consumption
2003	2,455	14.2	1,180,0000	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	1,845	11.3	930,000	10,500,000	1,003	480,000	5,800,000
	8,035		3,990,000	54,200,000	3,973	1,970,000	25,900,000

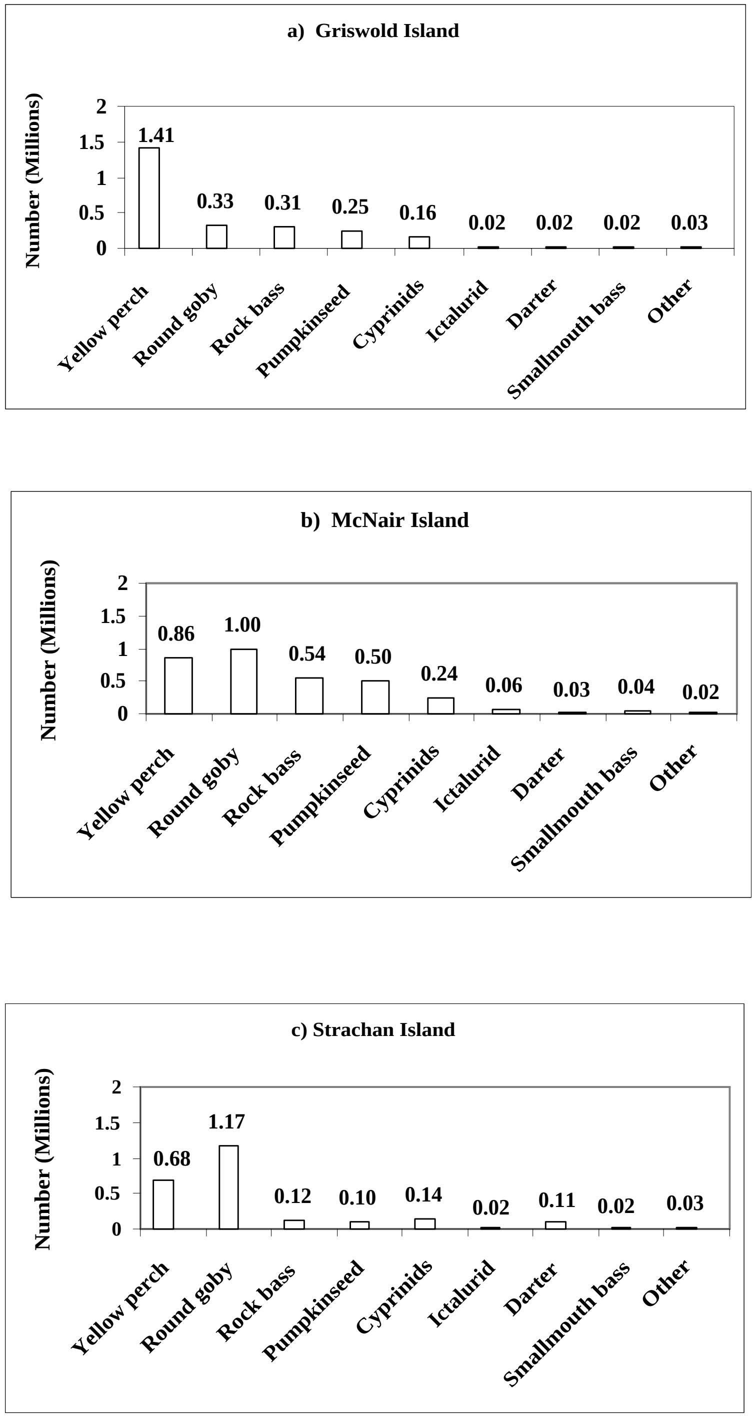

Figure 1. Estimated number of fish, in millions, consumed by cormorants from colonies at (a) Griswold, (b) McNair, and (c) Strachan Islands in the St. Lawrence River in 2007.