Diet Composition and Fish Consumption of Double-Crested Cormorants from Three St. Lawrence River Colonies in 2004

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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 of 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 pose 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 2003 these studies have shown that cormorants consumed about 30 million fish including 15 million yellow perch, 5 million rock bass and 300,000 smallmouth bass (Johnson et al. 2004). 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 fish eating 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 workshop was held in Ogdensburg, NY on November 18, 2004. This forum shared all the most recent fisheries and cormorant information with the public. This paper describes the diet and fish consumption of cormorants in the upper St. Lawrence River in 2004.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants at St. Lawrence River colonies in 2004. 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:

	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) some researchers consider that a single pellet is typically produced by adult cormorants each day (Craven and Lev 1987, Orta 1992, Derby and Lovvorn 1997). Pellet production rates greater than one per day would increase our fish consumption estimates 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 at least 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. in press) 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?) $ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

A total of 1,542 pellets were used to describe the feeding ecology of cormorants from Griswold (750 pellets), McNair (481 pellets), and Strachan (311 pellets) Islands in 2004 (Tables 1-3). Because of apparent temporal differences in 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 Griswold Island colony the number of fish per pellet (adjusted for fecal loss) was similar over the three feeding periods ranging from 15.3 to 16.0 fish per pellet and averaged 15.6 for the entire period (Table 1). Cormorant pellets from the McNair Island colony contained the fewest number of fish per pellet (i.e., 11.7 for the entire season), and the number of fish per pellet ranged from 8.4 to 11.9 during all three feeding periods (Table 2). The number of fish per pellet for cormorants from the Strachan Island colony was highest during the pre-chick period (16.3) and lowest during the chick feeding period (12.6) and averaged 14.0 fish per pellet for the season (Table 3).

Diet Composition

Yellow perch dominated the diet of cormorants from Griswold Island during each feeding period (i.e. 53.8% to 67.2%) and made up 61.8% of the total diet (Table 1). Pumpkinseed (12.9%), rock bass (10.9%) and cyprinids (6.7%) were the other major prey of Griswold Island cormorants. No seasonal trends in consumption were evident for any fish species consumed by cormorants from Griswold Island. The invasive species round goby (*Neogobius melanostomus*) was first observed in the diet of cormorants at Griswold Island in 2004 and made up 1.2% of the fish consumed. For the entire season, panfish (i.e., yellow perch, rock bass, pumpkinseed, ictalurids) contributed 87.6% of the diet, forage fish (cyprinids, slimy sculpin, darters, alewife) composed 10.9%, and gamefish (mainly esocids and smallmouth bass) comprised 1.5% of the diet of Griswold Island cormorants.

Yellow perch (34.2%) and rock bass (28.6%) dominated the diet of cormorants at McNair Island (Table 2). Round goby (15.0%), pumpkinseed (7.0%) and cyprinids (6.7%) were the only other

species that made up at least five percent of the diet. Three species in the diet of McNair Island cormorants exhibited seasonal trends in consumption. The contribution of slimy sculpin in the diet decreased (17.0% to 1.8%) during each feeding period whereas that of cyprinids (4.5% to 7.6%) and pumpkinseed (3.5% to 8.7%) increased. For the season panfish made up 72.3% of the diet of McNair Island cormorants, forage fish 26.2%, and gamefish (mostly smallmouth bass) 1.5% (Table 2).

Yellow perch (53.0%), rock bass (12.4%), cyprinids (9.9%), and pumpkinseed (8.7%) were the main prey of Strachan Island cormorants (Table 3). Four prey species exhibited seasonal trends in consumption by cormorants at Strachan Island. Yellow perch (42.6% to 62.0%) and ictalurids (1.6% to 5.9%) both increased in importance in the diet over the season whereas pumpkinseed (12.9% to 4.9%) and slimy sculpin (3.1% to 0.6%) decreased. Panfish made up 77.6% of the seasonal diet, forage fish 21.2%, and gamefish 1.2% at Strachan Island in 2004 (Table 3).

Diet Overlap

Diet overlap for the entire season was significant (i.e.,C?$ 0.60) among all three upper St. Lawrence River colonies in 2004 (Table 4). Diet was the most similar between cormorants from Griswold and Strachan Islands (C?= 0.982) and least similar between Griswold and McNair Islands (C?= 0.789). When comparing the three colonies diet overlap between cormorants from McNair Island and the other two colonies was lowest (C?= 0.813), but still biologically significant. Diet overlap was lowest between cormorants among upper river colonies during the pre-chick feeding (C?= 0.759). Diet overlap was highest during the chick feeding (C?0= 0.915) 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 313 on Griswold Island, 373 on McNair Island, and 244 on Strachan Island, and fledgling productivities of 1.8 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.15, 0.18, and 0.12 million cormorant feeding days for these colonies, respectively, in 2004. Fish consumption for the Griswold Island colony was estimated at 2.45 million fish and 0.15 million pounds, for the McNair Island colony at 2.07 million fish and 0.18 million pounds, and for the Strachan Island colony at 1.74 million fish and 0.12 million pounds (Table 6).

We estimate that during 2004 cormorants from Griswold Island consumed 2.16 million panfish (including 1.52 million yellow perch, 0.32 million pumpkinseed and 0.27 million rock bass), 0.26 million forage fish (mostly cyprinids 0.17 million), and 0.03 million gamefish (primarily smallmouth bass and esocids) (Figure 1). We estimate that cormorants from McNair Island consumed 1.50 million panfish (mainly 0.71 million yellow perch and 0.59 million rock bass), 0.53 million forage fish (including 0.31million round goby, 0.14 million cyprinids and 0.06 million slimy sculpin), and 0.04 million gamefish (mostly smallmouth bass). Double-crested cormorants from the Strachan Island colony consumed 1.36 million panfish (yellow perch 0.93 million, rock bass 0.21 million, pumpkinseed 0.15 million), 0.35 million forage fish (0.17 million cyprinids, 0.10 million darters), and 0.03 million gamefish (mainly smallmouth bass and walleye) (Figure 1).

Size of fish consumed

At Griswold Island the size of smallmouth bass (233 mm to 162 mm or 9.2 to 6.4 in) and rock bass (108 mm to 93 mm or 4.3 to 3.7 in) consumed by cormorants declined over the season during 2004 whereas the size of pumpkinseed increased (86 mm to 99 mm or 3.4 to 3.9 in) (Table 7). At McNair Island the size of both yellow perch (78 mm to 104 mm or 3.1 to 4.1 in) and rock bass (91 mm to 97 mm or 3.6 to 3.8 in) increased over the season. At Strachan Island the size of yellow perch consumed by cormorants declined (99 mm to 82 mm or 3.9 to 3.2 in) from the pre-chick to the post-chick feeding period whereas the size of rock bass increased (89 mm to 97 mm or 3.5 to 3.8 in) (Table 7).

Discussion

Cormorant diet composition at the Griswold and

Strachan Island colonies in 2004, where yellow perch was the primary prey, was similar to the previous three years (Johnson et al. 2000, 2001, 2002, 2003, 2004). Since 1999 yellow perch have contributed 57.4% and 58.0% of the diet of cormorants at the Griswold and Strachan Island colonies, respectively. Over this same period rock bass (13.7% and 12.1%), cyprinids (10.8% and 12.7%), and pumpkinseed (11.5% and 5.6%) have also been consistently important in the diet of cormorants from the Griswold and Strachan Island colonies, respectively. Since 2002 yellow perch have replaced rock bass as the major prey of McNair Island cormorants. From 1999 to 2004, rock bass have been the major prey (35.5%) of McNair Island cormorants followed by yellow perch (31.5%), cyprinids (10.8%), pumpkinseed (5.2%), slimy sculpin (4.5%), and darters (4.0%).

With yellow perch dominating the diet of cormorants during each feeding period at all three upper St. Lawrence River colonies in 2004 spatial and temporal variation in diet composition was low. Similar to 2003 (Johnson et al. 2004), diet overlap among river colonies was lowest during the pre-chick feeding period largely due to the dominance of rock bass in the diet of cormorants at McNair Island at this time.

Panfish dominated the diet of upper St. Lawrence River cormorants in 2004 as in previous years. (Johnson et al. 2001, 2002, 2003, and 2004). Panfish comprised 79.2% (range 72.3 to 87.6%) and forage fish 19.4% (range 10.9% to 26.2%) of the diet of cormorants at river colonies in 2004. Since 1999, panfish have composed 78.6% (range 75.2% to 83.7%) and forage fish 19.3% (range 13.4% to 23.1%) of cormorant diets in the upper St. Lawrence river. Over the past six years game fish have made up 2.0% (range 1.4% to 2.9%) of the diet of cormorants at these three river colonies (Johnson et al. 2000, 2001,2002, 2003, and 2004). The contribution of gamefish in cormorant diets in 2004 (1.4%) was the lowest recorded over the six years of this study.

Estimated fish consumption by cormorants from the three upper St. Lawrence River colonies in 2004 (6.26 million fish) was within the range (4.79 to 6.64 million) reported for the four previous years (Johnson et al. 2000, 2001, 2002, 2003, 2004). Average annual fish consumption by cormorants from Griswold, McNair, and Strachan Islands since 1999 is 6.02 million fish. Since 1999, we estimate that double-crested cormorants from these colonies have consumed 36.13 million fish including 18.6 million yellow perch, 6.42 million rock bass, 4.27 million cyprinids, 2.92 million pumpkinseed, 0.37 million smallmouth bass and 0.27 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, in 2004 there was a large decrease in the size of yellow perch eaten 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 mm (3.6 in).

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Table 1. Seasonal and total percent diet composition of double-crested cormorants from Griswold Island, 2004. Pre-chick feeding period includes pellets collected on 5/24/04, the chick feeding period includes pellets collected on 6/29/04 and 7/29/04, and the post-chick feeding period includes pellets collected on 8/5/04 and 9/29/04.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	150	300	300	750
Fish/pellet (adjusted)	15.4	16.0	15.3	15.6
Yellow perch	53.8	67.2	60.0	61.8
Pumpkinseed	21.6	7.9	13.6	12.9
Rock bass	9.3	11.9	10.5	10.9
Cyprinids	6.0	6.4	7.6	6.7
Ictalurid	1.2	1.2	3.2	2.0
Slimy sculpin	2.6	1.3	1.7	1.7
Round goby	0.3	1.9	0.6	1.2
Smallmouth bass	1.1	0.6	0.9	0.8
Darter	2.5	0.3	0.4	0.7
Esocid	0.9	0.4	1.0	0.7
Banded killifish	0.6	0.3	0.1	0.3
Catostomid	<0.1	0.2	0.4	0.2
Alewife	<0.1	0.2	---	0.1
	100.0	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition of double-crested cormorants from McNair Island, 2004. Pre-chick period includes pellets collected on 5/24/04, the chick feeding period includes pellets collected on 6/29/04 and 7/29/04, and the post-chick feeding period includes pellets collected on 8/25/04 and 9/29/04.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	25	207	249	481
Fish/pellet (adjusted)	8.4	11.9	11.9	11.7
Yellow perch	25.0	40.3	29.7	34.2
Rock bass	37.5	28.0	28.3	28.6
Round goby	---	11.9	19.2	15.0
Pumpkinseed	3.5	5.3	8.7	7.0
Cyprinids	4.5	5.9	7.6	6.7
Slimy sculpin	17.0	3.1	1.8	2.9
Ictalurid	5.5	1.8	2.1	2.2
Smallmouth bass	1.5	1.7	1.1	1.3
Darter	4.5	0.9	0.6	0.9
Catostomid	1.0	0.6	0.7	0.6
Bluegill	---	0.5	---	0.2
Walleye	---	---	0.2	0.1
Esocid	---	< 0.1	---	<0.1
Other	---	0.9	---	0.3
	100.0	100.0	100.0	100.0

Table 3. Seasonal and total percent diet composition of double-crested cormorants from Strachan Island, 2004. Pre-chick feeding periods includes pellets collected on 5/24/04, the chick feeding period includes pellets collected on 6/29/04 and 7/29/04, and the post-chick feeding period includes pellets collected on 8/25/04.

	Pre-chick		Chick		Post-chick		Total	
No. of pellets	102		162		47		311	
Fish/pellet (adjusted)	16.3		12.6		14.0		14.0	
Yellow perch	42.6		58.5		62.0		53.0	
Rock bass	11.4		15.0		7.0		12.4	
Cyprinid	9.3		8.3		15.6		9.9	
Pumpkinseed	12.9		6.6		4.9		8.7	
Darter	14.2		0.5		1.3		5.8	
Ictalurid	1.6		4.4		5.9		3.5	
Slimy sculpin	3.1		1.9		0.6		2.2	
Round goby		2.5		1.7		0.3		1.7
Catostomid	0.5		1.8		0.4		1.1	
Smallmouth bass	0.5		0.7		0.5		0.6	
Banded killifish	1.0	0.1		0.2		0.5		
Esocid	0.4		0.2		1.0		0.4	
Walleye		---		0.3		0.3		0.2
	100.0		100.0		100.0		100.0	

Table 4. Spatial diet overlap among three St. Lawrence River cormorant colonies, 2004.

	Colonies		
Feeding period	Griswold I.-McNair I.	Griswold I.-Strachran I.	McNair I.-Strachan I.
Pre-chick	0.630	0.939	0.707
Chick	0.852	0.987	0.905
Post-chick	0.739	0.978	0.695
Entire season	0.789	0.982	0.837

Table 5. Temporal diet overlap at each of the three St. Lawrence River cormorant colonies, 2004.

Feeding period		Griswold I.	McNair I.	Strachan I.
Pre-chick feeding-Chick feeding		0.954	0.863	0.918
Pre-chick feeding-Post-chick feeding		0.998	0.833	0.873
Chick feeding-Post-chick feeding		0.989	0.962	0.982
	0 =	0.980	0.886	0.924

Table 6. Fish consumption estimates in millions for cormorants from three St. Lawrence River colonies, 2004.

	Griswold Island		McNair Island		Strachan Island	
Period	Number	Pounds	Number	Pounds	Number	Pounds
Pre-chick feeding	0.63	0.04	0.41	0.05	0.52	0.03
Chick feeding	0.84	0.05	0.75	0.06	0.52	0.04
Post-chick feeding	0.98	0.06	0.91	0.07	0.70	0.05
Total	2.45	0.15	2.07	0.18	1.74	0.12

Table 7. Estimated total length (TL, mm), weight (Wt., g), and number examined (No.) of smallmouth bass, yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Griswold, McNair, and Strachan Islands in 2004.

	Griswold			McNair			Strachan		
	TL	Wt.	No.	TL	Wt.	No.	TL	Wt.	No.
Pre-chick									
Smallmouth bass	233	168	5	---	---	---	---	---	---
Yellow perch	94	9	100	78	5	56	99	10	100
Rock bass	108	24	100	91	14	84	89	13	100
Pumpkinseed	86	12	100	102	2	11	79	9	100
Chick									
Smallmouth bass	179	71	11	180	72	9	---	---	---
Yellow perch	95	9	100	102	11	100	91	8	100
Rock bass	95	16	100	93	15	100	94	16	100
Pumpkinseed	89	14	99	97	18	100	74	7	100
Post-chick									
Smallmouth bass	162	51	4	---	---	---	---	---	---
Yellow perch	84	6	100	104	12	100	82	6	100
Rock bass	93	15	100	97	17	100	97	17	68
Pumpkinseed	99	20	100	118	36	100	90	14	51

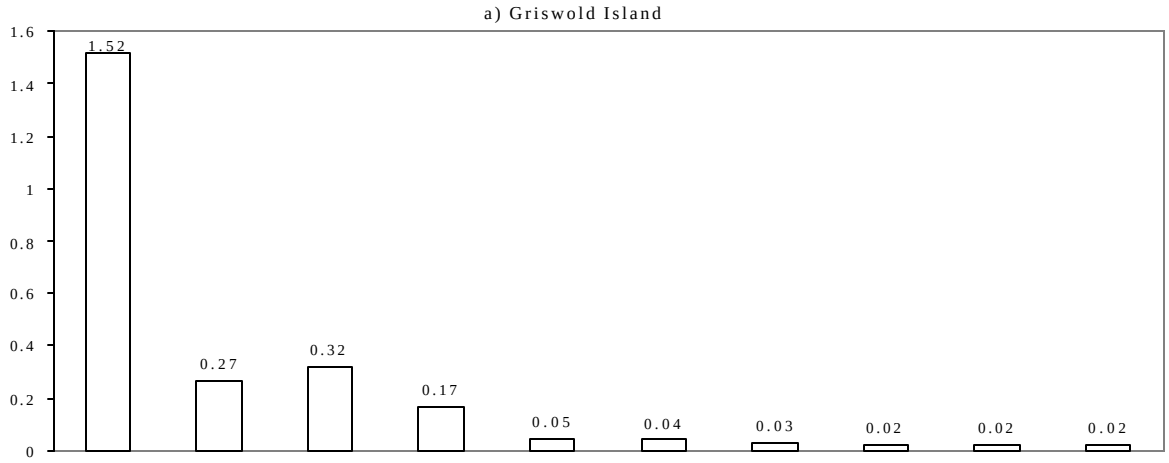
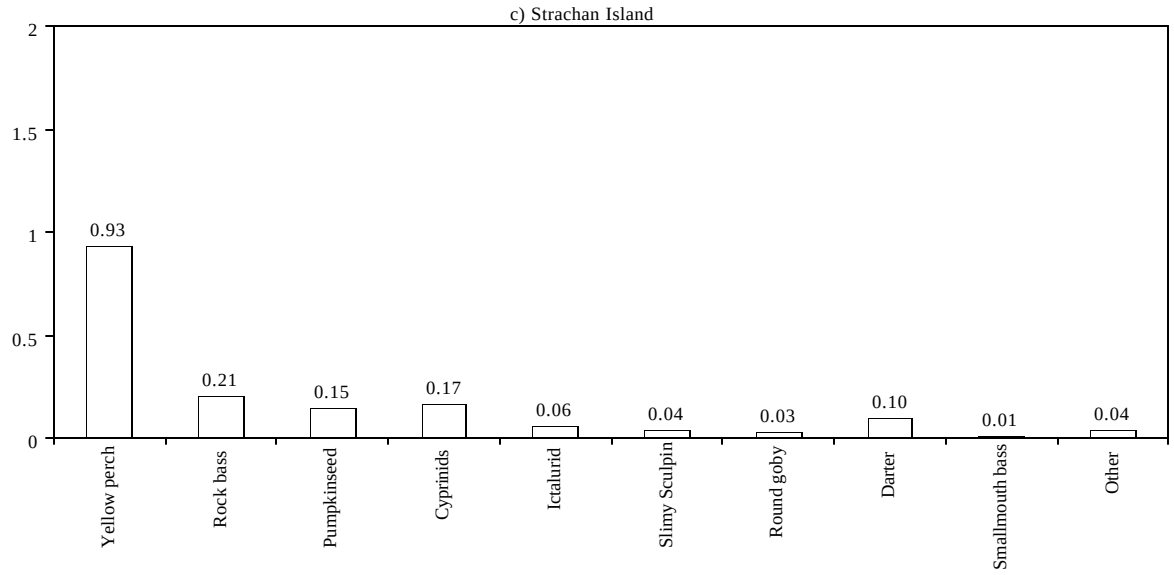
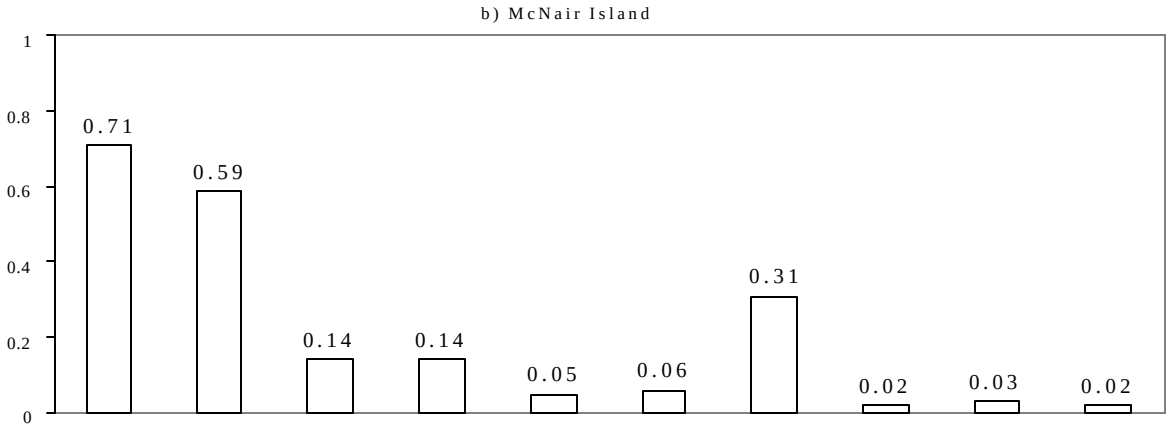


Figure 1. Estimated number, in millions, of fish consumed by species by cormorants from colonies (a) Griswold , (b) McNair, and (c) Strachan Islands in the St. Lawrence River in 2004.

Number (millions)




b) McNair Island
1
0.8
0.6
0.4
0.2
0
0.71
0.59
0.14
0.14
0.05
0.06
0.31
0.02
0.03
0.02