Diet Composition and Fish Consumption of Double-Crested Cormorants from Three St. Lawrence River Colonies in 2005

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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 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 2004 these studies have shown that cormorants consumed about 36 million fish including 18.6 million yellow perch, 6.5 million rock bass and 370,000 smallmouth bass (Johnson et al. 2005). 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 workshop was held in Ogdensburg NY, November 18, 2004, 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 2005.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants at St. Lawrence River colonies in 2005. 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 communications 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 the 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 three 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 adults) 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 period 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) 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 prey 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 tofish-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 1,015 pellets were used to describe the feeding ecology of cormorants from Griswold (319 pellets), McNair (489 pellets), and Strachan (207 pellets) Islands in 2005 (Tables 1-3). Because of apparent temporal differences in daily fish consumption (fish perpellet), three distinct periods of cormorant feeding were described, i.e., pre-chick feeding, chick feeding, and post-chick feeding. 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 Griswold Island (14.9) followed by Strachan (14.0) and McNair (13.0) islands (Tables 1-3).

Diet Composition

Yellow perch dominated the diet of cormorants from Griswold Island during each feeding period (i.e. 46.2% to 55.6%) and made up 53.1% of the total diet (Table 1). Pumpkinseed (18.7%) and rock bass (13.4%) were the other major prey of Griswold Island cormorants. The invasive species round goby (*Neogobius melanostomus*) only contributed 0.1% of the diet of cormorants at Griswold Island in 2005. For the entire season, panfish (i.e., yellow perch, rock bass, pumpkinseed, ictalurids) contributed 87.4% of the diet, forage fish (cyprinids, slimy sculpin, darters, alewife) composed 10.5%, and gamefish (mainly esocids and smallmouth bass) comprised 2.1% of the diet of Griswold Island cormorants.

Yellow perch (25.4%), round gobies (24.3%), rock bass (22.4%), and pumpkinseed (11.0%) dominated the diet of cormorants at McNair Island (Table 2). Slimy sculpin (4.6%), cyprinids (4.2%) and darters (4.0%) were the only other species that made up at least four percent of the diet. The contribution of round goby in the diet increased during each feeding period (21.2% - 27.16%). For the season, panfish made up 60.6% of the diet of McNair Island cormorants, forage fish 38.2%, and gamefish (mostly smallmouth bass) 1.2% (Table 2).

Yellow perch (50.3%), round goby (19.6%), and rock bass (10.3%) were the main prey of Strachan Island cormorants (Table 3). Panfish made up 65.9% of the seasonal diet, forage fish 33.2%, and gamefish 0.9% at Strachan Island in 2005 (Table 3).

Diet Overlap

Diet overlap for the entire season was significant (i.e., $C\lambda \geq 0.60$) among all three upper St. Lawrence River colonies in 2005 (Table 4). Diet was the most similar between cormorants from Griswold and Strachan Islands © $\lambda = 0.90$) and least similar between Griswold and McNair Islands ($C\lambda = 0.72$). When comparing the three colonies, diet overlap between cormorants from McNair Island and the other two colonies was lowest ($C\lambda = 0.78$), but still biologically significant. Diet overlap was lowest between cormorants among

upper river colonies during the chick feeding (Cλ = 0.78). Diet overlap was highest during the pre-chick feeding (Cλ $\bar{\times}$ = 0.82) 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 334 on Griswold Island, 536 on McNair Island, and 281 on Strachan Island, and fledgling productivities of 1.8 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.17, 0.27, and 0.15 million cormorant feeding days for these colonies, respectively, in 2005. Fish consumption for the Griswold Island colony was estimated at 1.85 million fish and 0.17 million pounds, for the McNair Island colony at 3.45 million fish and 0.27 million pounds, and for the Strachan Island colony at 2.02 million fish and 0.15 million pounds (Table 6).

We estimate that during 2005 cormorants from Griswold Island consumed 1.62 million panfish (including 0.98 million yellow perch, 0.35 million pumpkinseed and 0.25 million rock bass), 0.20 million forage fish (mostly cyprinids, 0.08 million), and 0.03 million gamefish (primarily smallmouth bass and esocids) (Figure 1). We estimate that cormorants from McNair Island consumed 2.08 million panfish (mainly 0.87 million yellow perch and 0.77 million rock bass), 1.38 million forage fish (including 0.84 million round goby, 0.16 million slimy sculpin and 0.14 million cyprinids), and 0.04 million gamefish (mostly smallmouth bass). Double-crested cormorants from the Strachan Island colony consumed 1.34 million panfish (including 1.02 million yellow perch, 0.21 million rock bass, 0.07 million pumpkinseed), 0.64 million forage fish (0.40 million round gobies, 0.12 million cyprinids, 0.09 million darters), and 0.02 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 2005 (Table 7). The average size of yellow perch consumed at Griswold Island were slightly smaller (88.5 mm or 3.5 in) than perch eaten at McNair (95 mm or 3.7 in) and Strachan (96.7 mm or 3.8 in) islands. Rock bass consumed at Strachan Island were smaller (86.7 mm or 3.4 in) than those eaten at Griswold (96.5 mm or 3.8 in) or Strachan (95.7 mm or 3.8 in) islands (Table 7). Pumpkinseed consumed at McNair island (96.7 mm or 3.8 in) were larger than those eaten at Griswold (84.5 mm or 3.3 in) or Strachan (80.3 mm or 3.2 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 and Strachan Island colonies in 2005, 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 56.9% of the diet of cormorants at both the Griswold and Strachan Island colonies, respectively. Over this same period rock bass (13.7% and 11.8%), cyprinids (9.9% and 11.7%), and pumpkinseed (12.5% and 5.3%) 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 2005, rock bass have been the major prey (33.6%) of McNair Island cormorants followed by yellow perch (30.6%), cyprinids (9.9%), pumpkinseed (6.0%), slimy sculpin (4.5%), and darters (4.0%).

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 Islands, respectively . Since 2003, when round gobies first appeared in cormorant diets at McNair Island, they have contributed 13.7% of the diet and are the third ranked species behind yellow perch and rock bass. Of the three eastern Lake Ontario cormorant colonies (i.e. Little Galloo, Pigeon, and Snake

Islands) and the three upper St. Lawrence River colonies, Griswold Island is the only colony where round gobies have not become a major portion of cormorant diets.

With yellow perch dominating the diet of cormorants during each feeding period at all three upper St. Lawrence River colonies in 2005, spatial and temporal variation in diet composition was low. 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.

Panfish dominated the diet of upper St. Lawrence River cormorants in 2005 as in previous years. (Johnson et al. 2001, 2002, 2003, 2004, and 2005). Panfish comprised 71.3% (range 60.6 to 87.4%) and forage fish 27.3% (range 10.5% to 38.2%) of the diet of cormorants at river colonies in 2005. Since 1999, panfish have composed 77.6% (range 71.3% to 83.7%) and forage fish 20.4% (range 13.4% to 27.3%) of cormorant diets in the upper St. Lawrence river. Over the past seven years game fish have made up 1.9% (range 1.4% to 2.9%) of cormorant diets at these three river colonies (Johnson et al. 2000, 2001,2002, 2003, and 2004). The contribution of gamefish in cormorant diets in (1.4%) was identical to 2005 and both values were the lowest recorded over the seven years of this study.

Estimated fish consumption by cormorants from the three upper St. Lawrence River colonies in 2005 (7.32 million fish - using the totals from Figure 1, the total is 7.38 million) was the highest reported from these three colonies over the last 6 years (Johnson et al. 2000, 2001, 2002, 2003, 2004, 2005). Average annual fish consumption by cormorants from Griswold, McNair, and Strachan Islands since 1999 is 6.21 million fish. Since 1999, we estimate that double-crested cormorants from these colonies have consumed 43.51 million fish including 21.47 million yellow perch, 7.65 million rock bass, 4.61 million cyprinids, 3.72 million pumpkinseed, 0.43 million smallmouth bass, and 0.29 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) and in 2005 it was 93.4 mm (3.7 in).

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Table 1. Seasonal and total percent diet composition by number of double-crested cormorants from Griswold Island, 2005. Pre-chick feeding period includes pellets collected on 5/26/05, the chick feeding period includes pellets collected on 6/22/05, and the post-chick feeding period includes pellets collected on 8/13/05 and 9/27/05.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	150	147	22	319
Fish/pellet (adjusted)	18.9	12.4	4.7	14.9
Yellow perch	53.6	55.6	46.2	53.1
Pumpkinseed	21.7	12.0	25.7	18.7
Rock bass	8.8	20.0	10.8	13.4
Cyprinids	6.0	3.3	2.2	4.3
Slimy sculpin	2.3	4.4	---	2.7
Ictalurid	0.6	1.7	7.5	2.2
Darter	2.6	---	1.1	1.4
Banded killifish	2.8	0.2	---	1.3
Esocid	0.6	0.6	4.3	1.2
Smallmouth bass	0.3	1.3	1.1	0.8
Catostomid	0.4	0.6	---	0.4
Alewife	---	0.2	1.1	0.3
Round goby	0.3	---	---	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, 2005. Pre-chick period includes pellets collected on 5/26/05, the chick feeding period includes pellets collected on 6/22/05, and the post-chick feeding period includes pellets collected on 8/3/05 and 9/27/05.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	150	64	275	489
Fish/pellet (adjusted)	18.1	11.2	10.6	13.0
Yellow perch	26.7	23.3	25.7	25.4
Round goby	21.2	25.1	27.1	24.3
Rock bass	12.6	32.8	24.2	22.4
Pumpkinseed	15.0	7.0	10.1	11.0
Slimy sculpin	4.3	4.3	5.1	4.6
Cyprinids	7.7	1.4	2.7	4.2
Darter	9.4	0.3	1.2	4.0
Ictalurid	1.2	1.4	2.7	1.8
Smallmouth bass	0.8	1.8	0.5	1.0
Alewife	0.1	1.7	---	0.4
Catostomid	0.3	---	0.6	0.3
Banded killifish	0.2	0.6	---	0.3
Esocid	0.4	0.1	0.1	0.2
Other	0.1	0.1	---	0.1
Walleye	---	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, 2005. Pre-chick feeding periods includes pellets collected on 5/26/05, the chick feeding period includes pellets collected on 6/28/05, and the post-chick feeding period includes pellets collected on 8/3/05.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	47	52	108	207
Fish/pellet (adjusted)	18.7	13.6	12.1	14.0
Yellow perch	39.7	61.4	50.6	50.3
Round goby	27.5	7.7	22.6	19.6
Rock bass	4.1	17.8	9.4	10.3
Cyprinid	5.5	5.6	6.4	5.8
Darter	11.2	1.5	1.0	4.7
Pumpkinseed	6.7	1.8	2.2	3.6
Ictalurid	0.2	1.2	3.7	1.7
Slimy sculpin	2.0	0.9	1.8	1.6
Catostomid	0.7	1.3	1.7	1.2
Smallmouth bass	1.0	0.3	0.2	0.5
Banded killifish	0.6	0.3	0.1	0.3
Esocid	0.5	---	0.2	0.2
Walleye	---	0.2	---	0.1
Other	0.3	---	0.1	0.1
	100.0	100.0	100.0	100.0

Table 4. Spatial diet overlap (Cλ value) among three St. Lawrence River cormorant colonies, 2005.

	Colonies		
Feeding period	Griswold I.-McNair I.	Griswold I.-Strachran I.	McNair I.-Strachan I.
Pre-chick	0.76	0.79	0.91
Chick	0.69	0.97	0.69
Post-chick	0.75	0.81	0.82
Entire season	0.72	0.90	0.83

Table 5. Temporal diet overlap at each of the three St. Lawrence River cormorant colonies, 2005.

Feeding period		Griswold I.	McNair I.	Strachan I.
Pre-chick feeding-Chick feeding		0.96	0.85	0.96
Pre-chick feeding-Post-chick feeding		0.95	0.92	0.95
Chick feeding-Post-chick feeding		0.94	0.98	0.94
	$\bar{x}$ =	0.95	0.92	0.95

Table 6. Fish consumption estimates in millions for cormorants from three St. Lawrence River colonies, 2005.

	Griswold Island		McNair Island		Strachan Island	
Period	Number	Pounds	Number	Pounds	Number	Pounds
Pre-chick feeding	0.83	0.04	1.28	0.07	0.69	0.04
Chick feeding	0.70	0.06	1.01	0.09	0.64	0.05
Post-chick feeding	0.32	0.07	1.16	0.11	0.69	0.06
Total	1.85	0.17	3.45	0.27	2.02	0.15

Table 7. Estimated mean 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 2005.

	Griswold			McNair			Strachan		
	TL	Wt.	No.	TL	Wt.	No.	TL	Wt.	No.
Pre-chick									
Smallmouth bass	262	247	5	211	122	13	163	53	5
Yellow perch	89	7	100	92	8	100	93	8	100
Rock bass	90	14	100	93	15	100	83	11	62
Pumpkinseed	81	10	100	85	12	100	79	9	89
Chick									
Smallmouth bass	190	87	7	139	31	1	178	70	1
Yellow perch	88	7	100	85	6	100	79	5	100
Rock bass	103	21	100	105	22	100	92	15	100
Pumpkinseed	88	13	100	104	24	84	78	9	19
Post-chick									
Smallmouth bass	---	---	---	139	31	5	---	---	---
Yellow perch	---	---	---	108	13	100	118	17	100
Rock bass	---	---	---	89	14	100	85	12	100
Pumpkinseed	---	---	---	101	21	100	84	12	31

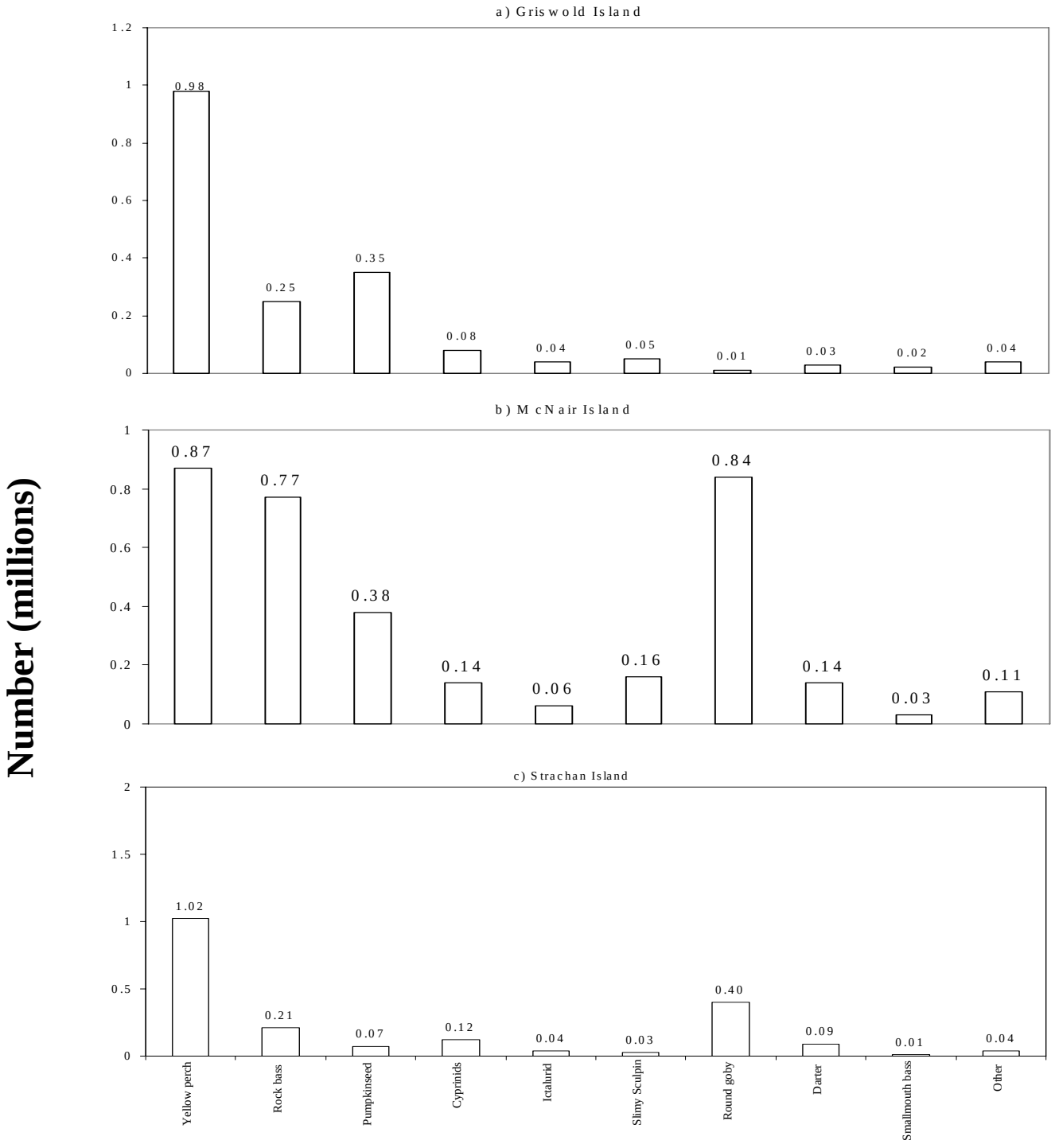

Figure 1. Estimated number of fish, in millions, of fish species consumed by cormorants from colonies (a) Griswold , (b) McNair, and ©) Strachan Islands in the St. Lawrence River in 2005.