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Eating the Invaders: The Prevalence of Round Goby (*Apollonia melanostomus*) in the Diet of Double-crested Cormorants on the Niagara River

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Abstract.—The Round Goby (*Apollonia melanostomus*) is a small benthic fish, native to the Eurasian Ponto-Caspian region, that has rapidly spread through the entire Laurentian Great Lakes system since its 1990 discovery in Lake St. Clair. Tolerant of high population densities, the exotic Round Goby competes aggressively with native fish for food and habitat, and has increasingly been exploited by endemic Great Lakes predators. A management program for the Upper Niagara River, initiated in 2004, has provided an opportunity to study the interactions between these invaders and the Double-crested Cormorant (*Phalacrocorax auritus*), a native top predator. The gut contents of 1,119 cormorants nesting at two sites in the Upper Niagara River from 2004 to 2007 were examined, and the species composition of ingested prey (by number and weight) was quantified for the 600 stomachs that contained identifiable prey. Results of these analyses indicate that Round Goby can constitute up to 85% of the biomass in cormorant diet during periods of the breeding season, and that gobies are consumed by cormorants through all dates sampled (May through August). Lengths of Round Gobies recovered in the cormorant diet were skewed towards larger members of the goby population, suggesting non-random selection relative to the range of size possibilities, and displayed significant declines in length between and within seasons. *Received November 2007, accepted 12 December 2009.*

Key words.—*Apollonia melanostomus*, diet, Double-crested Cormorant, exotic, invasive, Niagara River, *Phalacrocorax auritus*, Round Goby.

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The Round Goby (*Apollonia melanostomus*, formerly *Neogobius melanostomus*) has rapidly spread throughout the entire Laurentian Great Lakes region since first being observed in the St. Clair River in 1990 (Jude *et al.* 1992; Weimer and Keppner 2000). A native of the Ponto-Caspian region, this benthic fish is one of several Eurasian species to invade the Great Lakes in the last 25 years. As of 2000, 70% of the exotic species identified in the Great Lakes have been introduced from the Black, Caspian and Azov Seas (Ricciardi and MacIsaac 2000), mostly through ballast water from transoceanic shipping (Mills *et al.* 1993; Ricciardi and MacIsaac 2000; Holeck *et al.* 2004). These many exotic organisms have led to profound ecological changes in their new ecosystems and have had incalculable consequences to native aquatic fauna (Vanderploeg *et al.* 2002; Mills *et al.* 2003). A prominent constituent of this wave of invaders, the Round Goby competes aggressively with native fish for prey and habitat, depredates fish eggs and larvae, and is highly fecund due to multiple annual spawning capabilities (Jude *et al.* 1992; MacInnis and Corkum 2000; Corkum *et al.* 2004). The goby lives approximately three to five years, and reaches a maximum size of 215 to 250 mm (Jude *et al.* 1992). During the summer months, Round Gobies are found in rock and cobble substrates (Jude and DeBoe 1996), generally in shallow nearshore areas, with maximum densities ranging from 9 fish/m^2 (Ray and Corkum 2001) to >100 fish/m^2 (Steinhart *et al.* 2004).

The Double-crested Cormorant (*Phalacrocorax auritus*) is an opportunistic predator that also prefers to forage in shallow and rocky habitats (Stapanian *et al.* 2002;

Coleman *et al.* 2005), and often preys upon demersal fish and amphibians. In the Baltic Sea's Gulf of Gdańsk, where the Round Goby was also first observed in 1990, 70% of the total biomass consumed in 1998 and 1999 by the Great Cormorant (*Phalacrocorax carbo*) was Round Goby, with >90% of the diet consisting of Round Goby during the spawning period (April to October; Bzoma and Meissner 2005). Recent accounts of Double-crested Cormorant (hereafter cormorant) diet in regions that overlap with Round Goby populations in the Great Lakes indicate that cormorants are exploiting this new food resource (Somers *et al.* 2003; Ross *et al.* 2004), but not to the same degree as Great Cormorants have in the Baltic Sea. Given the rapid growth and distribution of Round Goby populations throughout the Great Lakes region, and the potential threats they pose to predators, including humans, due to the bioaccumulation of toxins, heavy metals and possibly type-E avian botulism through consumption of dreissenid mussels (Morrison *et al.* 2000; Corkum *et al.* 2004; Ruffing 2004; Bunnell *et al.* 2005; Yule *et al.* 2006; Hogan *et al.* 2007), it is increasingly important to monitor their impacts on established foodwebs.

The Round Goby was first detected in the Buffalo Harbor area of Lake Erie in 1998 (Weimer and Keppner 2000), and likely permeated the Niagara River at that same time. Cormorants had arrived a few years earlier (1992), and began nesting on structures and islands in the upper sections of the Niagara River. A management plan enacted in 2004 to control breeding cormorants provided an opportunity to study trophic interactions between avian predators and prey species in the Niagara River through diet analysis of culled birds. Given that cormorants are opportunistic foragers, diet samples can serve as important indices of fish species abundance, providing data that might not otherwise be available through established fisheries sampling procedures. Thus, the purpose of this paper is to describe the species composition of cormorant diet at two nesting sites in the Upper Niagara River, with a focus on detailing the contributions of the exotic Round Goby to the diet of this native predator.

METHODS

Study Area

We conducted this study over four summers, from 2004 to 2007, and examined cormorants from two breeding sites in the Upper Niagara River: Motor Island (42°57'N, 078°56'W) and Strawberry Island (42°57'N, 078°55'W). Cormorants first nested on these islands in 1997 and compete for space with Great Blue Herons (*Ardea herodias*), Black-crowned Night Herons (*Nycticorax nycticorax*) and Great Egrets (*Ardea alba*). Concern over spatial competition with these species, as well as the detrimental impact of cormorant guano on the vegetation that protects these islands from erosion, resulted in the implementation of a cormorant management program by New York State Department of Environmental Conservation (NYSDEC). The birds examined for this study were culled in accordance with the goals of this program, namely to prevent cormorants from nesting on Motor Island and Strawberry Island, and to manage cormorant population growth in the Niagara River and Buffalo Harbor (NYSDEC 2004).

Diet Analysis

Cormorants were generally shot during morning hours, and over several days, using a rifle and .22-caliber, 60-grain subsonic rounds. Sampling dates ranged from mid-May to mid-June in 2004 and 2005, but extended from 7 May to 30 August in 2006 and 2007. The stomachs of birds that were not to be processed on site at the time of collection were infused with a 70% ethyl alcohol solution and stored on ice until frozen to preserve the contents. We identified stomach contents to species, and recorded lengths for all intact fish. All fish too digested to measure directly were assigned the average length of all conspecifics taken the same day, or within adjacent days if samples were small. In 2004, we estimated total length of digested Round Gobies from the length of intact tails, and regressed caudal fin length on body length for gobies (N = 110) taken from Lake Erie and the Niagara River to establish the relationship. Caudal fin length represents the length of the longest fin ray, from the origin at the caudal peduncle to the edge of the margin. The margin of the Round Goby caudal fin has a light colored band, and only specimens that retained this band were measured. In subsequent years, partially digested Round Gobies were treated like all other species, and assigned the average length of measurable gobies consumed that same day. Lengths of intact Round Gobies were analyzed using linear regression to examine the effects of year and day of year on the size of gobies consumed.

The weight of prey samples was determined for all fish species based on existing length-weight (wet) relationships developed for Lake Erie (Ohio Department of Natural Resources, unpublished data). Weights for

Common Mudpuppies (*Necturus maculosus*) were determined using a length-weight regression developed for the species from 24 specimens captured at Oneida Lake, New York (VanDeValk and Coleman 2010). Species composition by number and weight was then calculated for all sampling dates.

This research was conducted under the following permits: Cornell IACUC Protocol # 01-01 and U.S. Fish and Wildlife Service Scientific Collecting Permit MB047758-0.

RESULTS

We examined the stomachs of 1,119 cormorants over the four years of this study, 448 of which were empty and 600 of which contained identifiable contents (Table 1). In total, we identified 2,288 prey items comprised of 22 different species/genera (Table 2). There were 89 individual specimens (fish) that we could not identify. In 2004 and 2005, Round Gobies were found in over 70% of the birds examined in which prey were identifiable. The proportion of cormorants containing Round Goby dropped to 53% and 39% in 2006 and 2007, respectively, corresponding with the profusion of pelagic forage species in early May samples, namely sub-adult Gizzard Shad (*Dorosoma cepedianum*) in 2006 and Emerald Shiner (*Notropis atherinoides*) in 2007. No Gizzard Shad was present in samples from 2004 and 2005. In all years, Round Goby constituted a considerable proportion of the sampled diets on all days except for 30 August 2006, when three stomachs revealed Emerald Shiner and Smallmouth Bass (*Micropterus dolomieui*; Table 3).

The average length of all prey items that could be measured directly was 117.5 mm (median = 98 mm, range = 44-320 mm, SE = 1.4, N = 1,185). The average length of intact Round Gobies in the diet was 156.1 mm (median = 160 mm, range = 60-250 mm, SE = 2.1, N = 286), with 74% of intact gobies ranging between 120 and 199 mm (Fig. 1). Approximately 11% (31/286) of the intact Round Gobies recovered were ≥200 mm in total length (TL). Regressing goby lengths on year and day of year produced a model with poor fit ($R^2 = 0.20$), but the overall relationship was significant ($F_{2,283} = 35.88$, $P < 0.001$). Peaking in 2005, Round Goby lengths in the cormorant diet declined between seasons ($\beta = -0.31$, $t_{283} = 5.40$, $P < 0.001$) and also within season, with smaller fish being more prevalent in the samples collected later in the season ($\beta = -0.23$, $t_{283} = 4.09$, $P < 0.001$; Table 4). Caudal fin length (CL) significantly predicted total body length for the Round Gobies sampled ($\delta = 0.99$, $t_{108} = 73.87$, $P < 0.001$), and CL explained a significant proportion of the variance in TL ($R^2 = 0.98$, $F_{1,108} = 5{,}456.28$, $P < 0.001$). Total length was derived for 70 digested Round Gobies in 2004 using the linear equation: $TL = 5.627(CL) - 5.588$, and all lengths were used to calculate weight of individual fish. The average length of Round Gobies determined by regression in 2004 was 155.2 mm (range = 77-195 mm, SE = 3.2).

Species composition by prey weight revealed a substantial contribution of Round Goby to annual cormorant diet in the Niagara River, ranging from 38% in 2007 to 85% in 2005 (Table 2). Averaging proportional prey composition across all four years (treating each year independently) resulted in 62% of the biomass in cormorant diets sampled consisting of Round Goby, followed by Gizzard Shad at 8% and Emerald Shiner at approximately 7% (Fig. 2). The average length of all measurable Gizzard Shad recovered in May 2006 was 151.2 mm (range = 109-200 mm, SE = 1.8, N = 105). The average length of all

Table 1. Diet data summary for Double-crested Cormorants collected on the Niagara River, 2004-2007.

Year	Collection period	No. days birds collected	No. birds examined	Total no. stomachs w/identifiable contents	No. stomachs w/ Round Goby (proportion of total)	Total no. prey items	Total no. species
2004	12 May - 25 June	11	162	72	55 (0.76)	192	9
2005	18 May - 9 June	7	279	126	91 (0.72)	541	10
2006	9 May - 30 Aug	10	340	199	106 (0.53)	438	14
2007	7 May - 28 Aug	7	338	203	79 (0.39)	1117	20

Table 2. Species composition for identifiable prey of Double-crested Cormorants on the Niagara River, 2004-2007.

	2004			2005			2006			2007		
Species	No.	% by number	% by mass	No.	% by number	% by mass	No.	% by number	% by mass	No.	% by number	% by mass
Round Goby *Neogobius melanostomus*	98	51.04	75.86	128	23.66	85.43	146	33.33	49.20	145	12.98	37.54
Gizzard Shad *Dorosoma cepedianum*	0	0	0	0	0	0	142	32.42	27.24	35	3.13	4.51
Emerald Shiner *Notropis atherinoides*	74	38.54	3.38	400	73.94	7.92	41	9.36	1.18	694	62.13	14.34
Common Shiner *Luxilus cornutus*	0	0	0	0	0	0	30	6.85	2.34	36	3.22	1.62
Rock Bass *Ambloplites rupestris*	2	1.04	2.73	2	0.37	1.66	29	6.62	11.48	21	1.88	7.44
Smallmouth Bass *Micropterus dolomieui*	3	1.56	2.67	1	0.18	0.69	21	4.79	4.31	17	1.52	6.01
Logperch *Percina caprodes*	0	0	0	1	0.18	0.02	14	3.20	0.58	19	1.70	0.82
Pumpkinseed *Lepomis gibbosus*	0	0	0	0	0	0	4	0.91	0.18	1	0.09	0.03
Pike/pickerel *Esox* spp.	0	0	0	0	0	0	3	0.68	1.22	0	0	0
Yellow Perch *Perca flavescens*	3	1.56	0.06	1	0.18	0.01	3	0.68	0.48	5	0.45	0.77
Bullhead *Ameiurus* spp.	6	3.13	12.35	3	0.55	1.65	2	0.46	0.86	4	0.36	3.29
White Sucker *Catostomus commersonii*	0	0	0	0	0	0	1	0.23	0.88	1	0.09	1.28
Spottail Shiner *Notropis hudsonius*	0	0	0	0	0	0	1	0.23	0.05	115	10.30	8.17
Johnny Darter *Etheostoma nigrum*	0	0	0	1	0.18	0.01	1	0.23	0.01	1	0.09	0.01
Sea Lamprey *Petromyzon marinus*	3	1.56	0.32	0	0	0	0	0	0	0	0	0
White Perch *Morone americana*	1	0.52	0.02	0	0	0	0	0	0	5	0.45	4.98
Freshwater Drum *Aplodinotus grunniens*	0	0	0	1	0.18	0.91	0	0	0	1	0.09	0.94
Common Mudpuppy *Necturus maculosus*	2	1.04	2.62	3	0.55	1.70	0	0	0	6	0.54	4.28
White Bass *Morone chrysops*	0	0	0	0	0	0	0	0	0	1	0.09	0.34
Walleye *Sander vitreus*	0	0	0	0	0	0	0	0	0	2	0.18	0.58
Rainbow smelt *Osmerus mordax*	0	0	0	0	0	0	0	0	0	2	0.18	0.38
Channel Catfish *Ictalurus punctatus*	0	0	0	0	0	0	0	0	0	6	0.54	2.67
Total	192			541			438			1117		

Table 3. Prey species by date in Double-crested Cormorants from the Upper Niagara River, 2004-2007. Number of birds represents the number of cormorants containing identifiable prey.

Date	No. birds	Total prey	Round Goby	Shiners[a]	Gizzard Shad	Smallmouth Bass	Yellow Perch	Rock Bass	Other[b]
12-May-04	16	71	15	51	0	0	1	1	3
14-May-04	6	14	5	7	0	0	0	0	2
17-May-04	3	18	4	14	0	0	0	0	0
19-May-04[c]	4	6	3	0	0	2	0	1	0
25-May-04	15	27	19	1	0	1	1	0	5
27-May-04	4	5	4	0	0	0	1	0	0
04-Jun-04	12	23	22	0	0	0	0	0	1
10-Jun-04	1	3	3	0	0	0	0	0	0
25-Jun-04	11	25	23	1	0	0	0	0	1
18-May-05	10	49	10	37	0	0	0	0	2
19-May-05	5	17	6	11	0	0	0	0	0
23-May-05	25	125	28	96	0	0	0	0	1
25-May-05	27	125	27	95	0	1	0	0	2
26-May-05	32	126	35	87	0	0	0	2	2
01-Jun-05	18	90	16	73	0	0	0	0	1
09-Jun-05	9	9	6	1	0	0	1	0	1
09-May-06	82	208	34	27	133	5	0	3	6
31-May-06	12	25	10	2	9	2	0	2	0
07-Jun-06	11	25	13	7	0	2	1	0	2
15-Jun-06	40	70	33	10	0	3	1	17	6
20-Jun-06	19	37	18	9	0	1	1	5	3
03-Jul-06	16	35	17	3	0	6	0	1	8
07-Jul-06	5	10	10	0	0	0	0	0	0
20-Jul-06	5	8	7	0	0	0	0	1	0
03-Aug-06	6	14	4	10	0	0	0	0	0
30-Aug-06	3	6	0	4	0	2	0	0	0

[a]Shiners include Emerald Shiner, Common Shiner and Spottail Shiner.
[b]Other category includes Logperch, Pumpkinseed, pike/pickerel, Channel Catfish, bullhead, White Bass, White Sucker, White Perch, Johnny Darter, Freshwater Drum, Walleye, Sea Lamprey, Rainbow Smelt and Common Mudpuppy.
[c]Data for 19-May-2004 represents data pooled from 18-20 May due to low sample sizes.

Table 3. (Continued) Prey species by date in Double-crested Cormorants from the Upper Niagara River, 2004-2007. Number of birds represents the number of cormorants containing identifiable prey.

Date	No. birds	Total prey	Round Goby	Shiners[a]	Gizzard Shad	Smallmouth Bass	Yellow Perch	Rock Bass	Other[b]
07-May-07	91	591	28	529	0	1	0	3	30
14-May-07	5	54	4	49	0	0	0	0	1
23-May-07	28	171	22	137	1	1	1	0	9
08-Jun-07	23	81	23	55	0	0	0	0	3
26-Jun-07	26	58	43	0	0	0	0	14	1
06-Jul-07	2	5	3	0	0	0	0	1	1
28-Aug-07	28	157	22	75	34	15	4	3	4
Totals:	600	2288	517	1391	177	42	12	54	95

[a]Shiners include Emerald Shiner, Common Shiner and Spotail Shiner.
[b]Other category includes Logperch, Pumpkinseed, pike/pickerel, Channel Catfish, bullhead, White Bass, White Sucker, White Perch, Johnny Darter, Freshwater Drum, Walleye, Sea Lamprey, Rainbow Smelt and Common Mudpuppy.
[c]Data for 19-May-2004 represents data pooled from 18-20 May due to low sample sizes.

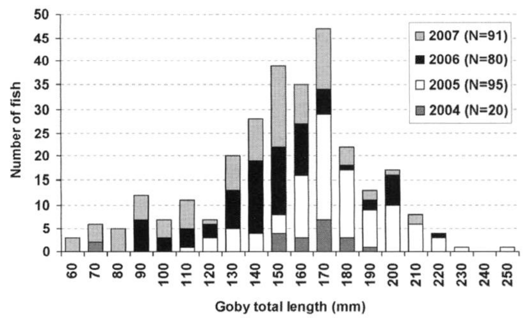

Figure 1. Length frequency distribution of Round Goby from measurements of intact fish (N = 286), recovered in Double-crested Cormorant stomach samples from the Niagara River, 2004-2007. Lengths are grouped by 10-mm block. No Round Goby <60 mm was recovered.

measurable Emerald Shiners recovered over all dates was 81.7 mm (range = 44-149 mm, SE = 0.52, N = 501).

DISCUSSION

Round Goby comprised a considerable proportion of the diet of cormorants in the Niagara River in each year of this study, particularly in 2004 and 2005 when samples were collected in May and June only. Their presence in Niagara River diet samples was not unexpected given their rapid population growth in eastern Lake Erie since 1999 (NYSDEC 2007), and the fact that Round Goby had been found in cormorant diets at Hamilton Harbor, Lake Ontario, in 2002 (Somers *et al.* 2003), and at sites in eastern Lake Ontario in 2003 (Ross *et al.* 2004). However, the overall contribution of Round Goby to cormorant diet was greater at the Niagara River sites than those previously reported. In contrast, species prevalent at the other sites, like Alewife (*Alosa pseudoharengus*) and Threespine Stickleback (*Gasterosteus aculeatus*), were not found in our samples. Gizzard Shad were most abundant in cormorant diet samples collected 9 May 2006, when a large number of cormorants with identifiable prey (N = 82) was collected (Table 3). The conspicuous boost in shad consumption was relatively short-lived and was likely the result of the temporary availability of schooling juvenile Gizzard Shad near the two islands. The relatively large number of

Table 4. Mean length of intact round gobies recovered in Double-crested Cormorant stomach samples from the Upper Niagara River, 2004-2007.

Year	Month	Mean length (mm)	SD	N
2004	May	157.9	37.5	14
	June	169.8	8.6	6
	Total	161.5	31.9	20
2005	May	178.3	27.4	81
	June	176.1	15.7	14
	Total	178.0	26.0	95
2006	May	152.7	19.5	33
	June	150.8	30.7	21
	July	137.5	38.3	26
	Total	147.3	30.0	80
2007	May	146.5	29.8	35
	June	146.6	32.5	33
	July	130.7	53.3	3
	August	119.1	45.5	20
	Total	140.0	36.7	91
All	May	164.5	30.7	163
	June	155.2	30.2	74
	July	136.8	38.9	29
	August	119.1	45.5	20
	Total	156.1	35.1	286

samples collected in early May, 42% of the total for the season, ensured that Gizzard Shad featured prominently in cumulative diet totals for 2006. Diet samples from May 2007 also revealed a notable quantity of non-goby prey, with Emerald Shiner comprising an estimated 34% of the diet by weight, and 84% by number for all samples collected

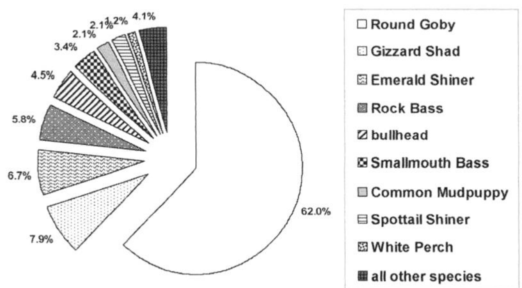

Figure 2. Prey species composition by wet weight in all Double-crested Cormorant diets (N = 600 birds) sampled over four seasons (2004-2007) at Motor Island and Strawberry Island in the Upper Niagara River. Annual proportions were averaged across the four years for each species, so years are independent. Only species contributing >1% of the diet are depicted individually; all others are summed. Bullhead were not identified to species. Scientific names for prey species are shown in Table 2.

that month. The prominent surge in Emerald Shiner consumption in spring 2007 followed a year (2006) of record-high Emerald Shiner densities reported for eastern Lake Erie (NYSDEC 2007), and is indicative of the opportunistic tendencies of cormorant foraging behavior, and thus the variable nature of prey exploitation. Notably absent from the diet samples were any salmonid species, and the number of warm water sport fish recovered was lower than expected, particularly for Walleye (*Sander vitreus*) and Muskellunge (*Esox masquinongy*).

The size distribution of Round Goby in the Niagara River cormorant diets suggests a bias in the age, and likely the sex, of gobies consumed. Reliable population data are lacking for Round Goby in the Niagara River, which precludes a robust analysis of selectivity. However, assuming the number of younger smaller fish in the river exceeds the number of older fish, as found in the central basin of Lake Erie (Johnson *et al.* 2005), we would expect to see greater representation of smaller (i.e. <120 mm) gobies in the diet samples if cormorants were taking them strictly in proportion to their abundance. We did not sex or age the recovered fish, but assuming that annual growth in the Niagara River is similar to that observed in central Lake Erie (Johnson *et al.* 2005), the observed lengths indicate that most of the gobies were at least two to three years old, and therefore sexually mature (MacInnis and Corkum 2000). Moreover, it is likely that the majority of gobies consumed were male, since females exceeding 157 mm (Johnson *et al.* 2005) have not been reported in North America. Round Goby males aggressively protect spawning territories and nests/ eggs, potentially making them more vulnerable to predation. Such behavior may account for the skewed length distribution in our samples. Furthermore, it is notable that a substantial number (11%) of the gobies we recovered were 200+ mm, since gobies of this size have not previously been reported in this quantity in North American studies (MacInnis and Corkum 2000; Johnson *et al.* 2005; Dietrich *et al.* 2006). The high proportion of larger gobies may represent size selection by cormorants, which differs from catchability of fisheries sampling gears, or it may represent an unusually high growth rate in an aging founder population in the Niagara River, with potential implications to our assumptions of age and sex above. The latter hypothesis is supported by the decreasing trend in mean body length observed in the diet samples in the last two years of the study (Table 4). It may also be possible that selective pressure on larger fish from cormorant predation was enough to account for the decreasing sizes of Round Goby observed, but this hypothesis requires additional research to substantiate.

Cormorants are extremely effective fish predators, with a breeding range that currently overlaps with the extent of Round Goby distribution in North America. While the energetic quality of Round Goby as a prey item (3.2 kJ/g) is not as high as other species typically consumed in the Laurentian Great Lakes (Johnson *et al.* 2005), their high densities and aggressive behavior likely make them an ideal forage base for piscivores, with the potential to impact predator populations. In Poland's Gulf of Gdańsk, Jakubas (2004) reported a higher caloric value for Round Goby (6.3 kJ/g) and documented an increase in breeding success rates and population growth in Grey Herons (*Ardea cinerea*) associated with a diet consisting mainly (up to 95%) of Round Goby. Similarly, King *et al.* (2006) reported increased growth rates and body size in the Lake Erie Water Snake (*Nerodia sipedon insularum*) following a shift in diet to one consisting predominantly (>92%) of Round Goby, and they speculated that these changes were also likely to result in population growth. While similar relationships were not examined here, it is clear that cormorants can and will consume gobies in great quantities where they are available. The potential for population-level impacts to cormorants similar to those documented for other species warrants further investigation. It is also important to note that gobies have also been increasingly consumed by predatory fish species in this region, but with no appreciable impact on annual growth rates (Forage Task Group 2005, 2006, 2007).

Diet samples collected in 2004 and 2005 were limited temporally to May and June, but demonstrated the high degree (up to 85% by mass) to which gobies can be exploited by cormorants. Diets from 2006 and 2007 indicate that gobies are consumed throughout the summer months (May-August), but the species variation observed in May samples from both years raises additional questions about prey selection. Gizzard Shad and Emerald Shiner consumption was substantially higher in May of 2006 and 2007, respectively, presumably due to increased availability of these schooling, forage species. However, gobies were likely just as prevalent in May of these years as they were in 2004 and 2005, although perhaps not with the same frequency of large individuals, as indicated by declining total lengths in the diet. Thus, the factors potentially influencing selection of shad and shiners over gobies include: effort of pursuing schooling vs. more sedentary demersal fish; caloric density of prey, which is higher in Gizzard Shad (5.1 kJ/g; Miranda and Muncy 1989) and Emerald Shiners (5.0

kJ/g; Kelso 1972); and differences in spatial interaction and/or visibility between the different prey species.

The Round Goby and the Double-crested Cormorant have both demonstrated a remarkable ability to rapidly pervade the entire Great Lakes system, which has been a source of concern for biologists, anglers and fisheries/wildlife managers. Management programs are currently in place to control cormorants throughout the Great Lakes (NYSDEC 2004; USDA/APHIS 2004, 2005; MDNR 2005; OMNR 2006), but there are far fewer options available for managing the impacts of Round Gobies on aquatic systems, especially considering that the extent of their impacts is virtually unknown. Round Gobies compete with native species for food resources, but have also become a major source of prey for predacious fish, including many prominent sport fish (Johnson *et al.* 2005; NYSDEC 2007). Moreover, while our results suggest that cormorant predation may help to keep goby populations in check near colony sites, their presence at these locations also buffers native species, including those of economic or recreational value, from the effects of cormorant predation. While one can debate the relative value of these contributions, the implication that gobies have facilitated the spread of type-E botulism in the Lower Great Lakes, and the bioamplification of environmental contaminants (Corkum *et al.* 2004; Ruffing 2004; Yule *et al.* 2006; Hogan *et al.* 2007), is serious enough to warrant further examination. Therefore, an awareness of trophic and spatial interactions between gobies and avian predators is critical to understanding the mechanisms behind botulism outbreaks and contaminant cycling.

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