

From Yellow Perch to Round Goby: a Review of Double-Crested Cormorant Diet Composition
at Three St. Lawrence River Colonies, 1999-2013

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Abstract

The number of double-crested cormorants (*Phalacrocorax auritus*) in the upper St. Lawrence River has increased markedly since the early 1990's. In 1999, a binational study was initiated to examine the annual diet composition and fish consumption of cormorants at colonies in the upper river. Since 1999, 14,032 cormorant pellets, collected from May through September each year, have been examined from St. Lawrence River colonies to estimate fish consumption and determine temporal and spatial variation in diet. Temporal variation in diet composition within a colony was low. Prior to 2006 yellow perch was the primary fish consumed by cormorants in the upper St. Lawrence River. Round goby were first observed in cormorant diets in 2003 and by 2006 were the main fish consumed at two of the three colonies. The time interval it took from the first appearance of round goby in the diet at a colony to when goby were the dominant prey species varied by island, ranging from two to five years. Daily fish consumption at each cormorant colony increased significantly from the pre-round goby to post-round goby period. The mean annual biomass of yellow perch consumed decreased significantly during the post-round goby period at the three colonies. Reduced consumption of yellow perch by cormorants may alleviate suspected localized impacts on perch near some of the larger river colonies.

Introduction

The increase and expansion of double-crested cormorant (*Phalacrocorax auritus*) (hereafter referred to as cormorants) populations throughout the Great Lakes region is well documented (Weseloh et al. 1995; Weseloh et al. 2002). The primary factors that have been attributed to the proliferation of cormorants include reduced levels of environmental contaminants, increased food availability, and reduced human disturbance (Weseloh et al. 1995). The establishment of alewife (*Alosa pseudoharengus*), in the Great lakes, an **invasive** species with high caloric value (Van Guilder and Seefelt 2013) is thought to be an important factor in increased cormorant populations. Alewife have been shown to represent a large component of the diet of cormorants throughout the Great Lakes (Belyea et al. 1997; Johnson et al. 2002, 2010; Seefelt and Gellingham 2006) and post-fledgling survival is thought to be higher in years when the species is abundant (Weseloh et al. 1995).

More recently, profound changes have occurred within the fish community in the Great Lakes, with another invasive species, the round goby (*Neogobius melanostomus*), now a dominant component of the benthic community in many lakes (Van Guilder and Seefelt 2013). Besides having adverse affects on native benthic fish species (Dubs and Corkum 1996; Jansen and Jude 2001; Balshine et al. 2005), round goby have been shown to alter food web dynamics (Johnson et al. 2005; Dietrich et al. 2006). In the Great Lakes, round goby now contribute substantially to the diet of lake trout (*Salvelinus namaycush*) (Dietrich et al. 2006; Rush et al. 2012), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), northern pike (*Esox lucius*) (Taraborelli et al. 2010), brown trout (*Salmo trutta*), and walleye (*Stizostedion*

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vitreum) (B. Weidel, USGS, pers. comm.). Moreover, round goby has now become a major component of the diet of piscivorous birds including cormorants (Somers et al. 2003; Johnson et al. 2010; Van Guilder and Seefelt 2013).

Virtually all of the studies that have examined the diet of cormorants in the Great Lakes have been carried out in lentic ecosystems. No studies have been conducted in lotic habitats, in particular connecting corridors such as the St. Lawrence River. Cormorants 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. Three of the larger colonies in the upper river are at Griswold, McNair and Strachan Islands. Although the size of cormorant colonies in the upper St. Lawrence River is smaller than those in the eastern basin of Lake Ontario, the river colonies are generally in closer proximity to each other than the larger lake colonies. Because of increasing numbers of cormorants in the upper St. Lawrence River, and possible impacts on fish populations, a fifteen year study was carried out from 1999-2013 to quantify cormorant diet and fish consumption at the three largest colonies. The duration of the study period also provided a unique opportunity to examine the response of cormorants in a river ecosystem to an abundant and novel invasive prey species, the round goby.

Methods

Cormorant pellets were collected at three St. Lawrence River island colonies annually over a fifteen year period from 1999-2013. All three colonies are located in Ontario Provincial waters. The location of the islands, Griswold Island (0.13 ha: 44°47'N, 75°82'W), McNair Island (1.36 ha: 44°59'N, 75°66'W), and Strachan Island (0.66 ha: 45°02'N, 74°81'W) represented a 101 km stretch of the St. Lawrence River corridor. In 2010 and 2011 pellets were collected at Bergin Island (0.7 ha; 45°02'N, 74°86'W) instead of Strachan Island because of higher nest counts at the former. The islands are about 3.5 km apart. Pellets are a cost-effective, representative, and non-intrusive means of assessing the diet of adult cormorants (Newman et al. 1997; Johnson et al. 2010). Although there was some annual variation in the terms of the date of collections, double-crested cormorant pellets were collected on multiple occasions from April through September at all three colonies. Previous examination of the diet of cormorants at Lake Ontario island colonies demonstrated seasonal variation in both diet composition and daily fish consumption during pre-chick (prior to chick hatch, generally through early June), chick (chicks present and being fed by adults, mid-June to late July), and post-chick (no adult birds feeding chicks, generally after late July) feeding periods (Johnson et al. 2002; Johnson et al. 2010). A minimum target sample size of 85 pellets for each feeding period was set at each colony, although it was not always met. Illegal shooting of cormorants at Griswold Island in 2010 resulted in few birds nesting on the island such that diet and fish consumption could not be determined.

Pellets were frozen until examination in the laboratory. In the laboratory, diagnostic prey remains recovered from the pellets, were used to describe cormorant diets. Diagnostic prey

remains included bones, otoliths, and scales. 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 a concentrated sodium hydroxide solution. Species were identified to the lowest practical taxonomic level.

Annual fish consumption was estimated following the same procedure as Johnson et al. (2002) and Johnson et al. (2010). This method incorporated the life history based model developed by Weseloh and Casselman (1992). The model incorporates cormorant age-class population size and seasonal residence time to estimate the number of feeding days for each feeding period. Model input variables for population size (most counts x 2) and fledgling productivity (chicks per nest) were provided by the Canadian Wildlife Service. Fledgling productivity at all three colonies ranged from 1.5 to 1.8 and averaged 1.7. To estimate the number of fish consumed by cormorants during each feeding period the number of feeding days was multiplied by estimated mean daily fish consumption which was derived from the contents of the pellets, and to a much lesser extent, fecal material. Although the number of pellets produced by cormorants has been observed to vary over a specific time interval (Carss et al. 1997), several investigators consider that a single pellet is produced by adult cormorants each day (Craven and Lev, 1987; Orta 1992; Derby and Lovvorn, 1997). Consequently, we assumed that cormorants on these three St. Lawrence River islands produced one pellet each day and the contents of the pellet (multiplied by a fecal correction factor of 1.042 [Johnson and Ross, 1996]) represented daily fish consumption. The fecal correction factor accounts for diagnostic material that exits the bird in the feces concurrent with pellet production. Cormorant pellet production greater than one pellet per day would increase our estimate of fish consumption and pellet production less than one per day would decrease our estimate.

The seasonal variability in the diet composition of cormorants that had been observed at nearby Lake Ontario colonies (Johnson et al. 2002, 2010) did not occur at the three St. Lawrence River colonies. Consequently, cormorant diet information was examined on an annual basis and grouped based on the presence, absence, and contribution of round goby in the diet. For each island the diet was quantified for three time periods, (1) pre-round goby (before round goby were recorded in the diet), (2) transition (year of first appearance of round goby in the diet until the last year before goby became the primary prey), and (3) post-round goby (round goby were the primary fish species consumed).

We estimated the biomass of yellow perch, a species that has received special attention in terms of potential impacts due to cormorant predation (Lantry et al. 2002; Diana et al. 2006; Fielder 2010; DeBruyne et al. 2012), consumed by cormorants at each colony. Prey fish size was determined by measuring up to 100 otoliths recovered from the pellets during each feeding period. Otolith-length fish relationships (Burnett et al. 2002) were used to estimate the length and weight of yellow perch that were consumed. Total biomass of yellow perch consumed was

determined by multiplying the average weight of a yellow perch consumed for each feeding period by the total number of fish consumed. These numbers for each feeding period were then summed to provide an estimate of the total biomass consumed.

Percent diet composition data was transformed using an arcsin square root transformation to normalize the data prior to statistical analysis. The Shapiro Wilks normality test showed that diet composition and fish consumption (i.e. fish/pellet) were not normally distributed. The Kruskal-Wallis One Way Analysis of Variance was used to test for differences in mean consumption of individual fish species and fish consumption across the three time periods (i.e. pre-round goby, transition, post-round goby) as well as fish consumption by cormorant feeding period (i.e. pre-chick, chick, post-chick). When a significant difference was detected the Dunn's Multiple Comparison Test was used to determine which groups were different. A significance level of $P \leq 0.05$ was set for all comparisons.

Results

Cormorant nesting activity was highest at McNair Island, exhibiting a steady increase over the 15 year study period (Figure 1). Nesting activity at Griswold Island generally increased after 2006 whereas except of an increase in number of nests in 2010 and 2011, cormorant nesting activity was consistent at Strachan Island. A total of 14,032 double-crested cormorant pellets were examined over the 15 year study period including 6,334 from Griswold Island, 4,589 from McNair Island, and 3,109 from Strachan Island (Table 1).

Although cormorant diet composition did not vary by feeding period, the number of fish consumed did vary at some island colonies. The most pronounced seasonal variation in fish consumption occurred during the transition period at each colony when significant differences in fish consumption were observed at each colony (Table 2). During the transition period fish consumption was always higher during the pre-chick feeding period than the post-chick period. Of the three colonies, cormorants at Griswold Island exhibited the most seasonal variation in fish consumption with differences occurring during the pre-round goby, transition, and post-round goby time periods. Daily fish consumption (fish/pellet) at each cormorant colony increased significantly from the pre-round goby period to the post-round goby period (Table 3).

Yellow perch was the primary prey (41.9%-54.7%) consumed by cormorants at the Griswold Island and Strachan Island colonies during the pre-round goby and transition period and the second ranked prey (17.0%-21.4%) consumed at each colony during the post-round goby period (Table 4). Cormorants at McNair Island consumed mainly Rock Bass (*Ambloplites rupestris*) (34.2%) during the pre-round goby period, closely followed by yellow perch (32.5%). Yellow perch were slightly more abundant than rock bass in the diet of McNair Island cormorants (28.9% versus 28.6%) during the transition period. At each colony there was a significant decline in the contribution of yellow perch in the diet of cormorants between the pre-round goby and post-round goby time periods (Table 4). Several other prey species/groups also

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exhibited a significant decline in the diet of cormorants at all three colonies between pre-round goby and post-round goby time periods including cyprinids, darters, slimy sculpin (*Cottus cognatus*), and esocids (Table 2). Similar declines in consumption of smallmouth bass and rock bass were observed at two of the three colonies.

Round goby first appeared in the diet of St. Lawrence River cormorants at the McNair Island colony in 2003 when they composed 1.9% of the diet. Round goby were first observed in the diet of cormorants at Griswold Island (1.2%) and Strachan Islands (1.7%) in 2004. The duration of the transition period varied by island, with the shortest transition to round goby being the dominant prey occurring at Strachan Island (2 years) and the longest transition period being at Griswold Island (5 years). The contribution of round goby in cormorant diets during the post-round goby time period was similar (48.4%-49.5%) among the three islands.

Annual fish consumption at each of the three colonies increased beginning in 2007, although there was a decline at Strachan Island in 2012 and 2013 (Figure 2). Although fish consumption at the McNair Island colony was lowest from 1999-2003, beginning in 2005 fish consumption at McNair exceeded the other two colonies. For the 15 year period we estimate that cormorants from these three colonies consumed approximately 145 million fish including 60 million, 46 million, and 39 million, at the McNair, Strachan, and Griswold Island colonies respectively (Figure 3). Although round goby occurred in the diet only about 70% of the time period examined we estimated that approximately 63.7 million (44% of the diet over the 15 year period) were consumed by cormorants from these three colonies. In addition an estimated 39.7 million (27.4%) yellow perch, 16.2 million (11.2%) rock bass, and 11.5 million (7.9%) pumpkinseed (*Lepomis gibbosus*) were consumed by cormorants. The mean annual biomass of yellow perch consumed was significantly greater during the pre-round goby and transition period (10,400 kg) than during the post-round goby period (7,700 kg) at these three colonies.

Discussion

This study is the first to examine the diet of cormorants in a riverine ecosystem in the Great Lakes and one of the few that have been carried out in large rivers anywhere. Most cormorant diet studies in riverine systems in North America have focused on consumption of juvenile salmonids (Blackwell et al. 1997; Collis et al. 2002). In other parts of the world predation by another cormorant species (e.g. *Phalacrocorax carbo*) on juvenile salmonids in rivers has also received attention (Kennedy and Greer 1988; Suter 1995). Consequently, this study may have been the first conducted that examined cormorant diet and fish consumption in a large river ecosystem that focused on consumption of fish species other than salmonids. Studies examining diet of cormorants in lentic ecosystems of the Great Lakes have reported seasonal variation in the prey fish species consumed (Belyea et al. 1997; Newman et al. 1997). Seasonal differences in the diet of cormorants is thought to be related to prey availability, specifically when key species such as alewife and yellow perch are more readily available during spawning periods (Johnson et al. 2002). In many studies on the diet of cormorants in the Great Lakes

alewife moving inshore to spawn generally dominate the diet of cormorants during the chick feeding period (Belyea et al. 1997; Johnson et al. 2010). The lack of seasonal differences in the diet composition of cormorants at St. Lawrence River colonies may suggest that there is less variability in available fish prey compared to lentic ecosystems in the Great Lakes. Moreover, the key species that has been identified as causing seasonal variation in cormorant diets in the Great Lakes, alewife, although present in the St. Lawrence River, is only a minor component of the fish community.

Johnson et al. (2010) reported a significant increase in daily fish consumption by cormorants once round goby became the major prey in two Lake Ontario colonies. They speculated that round goby was likely of lower caloric value than the species it replaced in the diet, specifically alewife and yellow perch. Van Guilder and Seefelt (2013) also have associated increased food consumption by cormorants with the transition from alewife to round goby in their diet in northern Lake Michigan. At the St. Lawrence River colonies it is likely then that increased daily fish consumption during the post-round goby period was because round goby were of lower caloric value than the species they replaced, yellow perch. Whereas the low caloric value of round goby may have lead to increased fish consumption by cormorants, the presence of gobies in the diet appears to not have influenced seasonal trends in daily fish consumption. Johnson et al. (2002, 2010) found decreased daily fish consumption from the pre-chick feeding period to the post-chick feeding period. Daily fish consumption at two of the St. Lawrence River colonies (Griswold Island and McNair Island) exhibited this same seasonal trend. There was no clear trend in daily fish consumption by cormorants at Strachan Island. Johnson et al. (2010) suggested that increased fish consumption by cormorants early in the season was likely due to reproductive needs. Using energetics modeling Duerr et al. (2012) found that average daily energy demands of cormorants were lower during the post-fledgling period than the pre-fledgling period at two Lake Champlain colonies.

In instances where round goby have replaced other species in the diet of cormorants researchers have considered the potential effects on cormorant life history. Because of the lower caloric value of round goby compared to the fish they replaced in the diet Van Guilder and Seefelt (2013) speculated that, if cormorants did not increase their fish consumption, chick development time will increase or reproductive success will decrease. Johnson et al. (2010) suggested that the consumption of round goby, which were a more stable food source than seasonally available alewife, may influence the residency time of cormorants at Lake Ontario colonies with birds returning earlier and remaining later in the season. None of these potential outcomes on cormorant life history is likely to occur at St. Lawrence River colonies. At the river colonies, fish consumption has increased by cormorants during the post-round goby period so impacts on chick development time or reproductive success should be negligible. Moreover, seasonal trends in the diet of cormorants at the St. Lawrence River colonies, that had been documented at other colonies in the Great Lakes basin, were nonexistent. Consequently,

transition from a stable food source (i.e. yellow perch) to another (i.e. round goby) should not affect recovery time.

Similar to previous studies, our results illustrate how quickly cormorants adapt to an abundant new prey species (Somers et al. 2003; Van Guilder and Seefelt 2013). Johnson et al. (2010) suggested that both opportunistic and adaptive behaviors were involved when Lake Ontario cormorants switched their diet from predominantly pelagic (alewife) and demersal (yellow perch) prey to a benthic prey (round goby). De Bruyne et al. (2012) observed a similar rapid shift to alewife by cormorants after the species gained access to Lake Champlain. Prior to alewife proliferation in Lake Champlain yellow perch was the major prey species. Consequently, the switch in prey species represented a change from demersal feeding to pelagic feeding. Of particular interest in this study are the differences among the colonies in the time it took for round goby to dominate the diet from when they were first consumed. This transition period was different for each island, ranging from two years at Strachan Island to five years at Griswold Island. Because of the aforementioned opportunistic feeding behavior of cormorants it is likely that the observed differences in the duration of the transition period among the colonies is due to differences in round goby populations in the vicinity of each island.

The transition to round goby in the diet of cormorants had a significant impact on the consumption of other fish species. Specifically, the contribution of yellow perch and esocids in the diet of cormorants was significantly reduced at all three colonies as was the contribution of smallmouth bass and rock bass at two of the colonies by the post-round goby period. A similar decrease in the contribution of yellow perch and smallmouth bass in the diet of cormorants following the transition to a predominantly round goby diet has previously been observed at two Lake Ontario colonies (Johnson et al. 2010). In this study as well as the Lake Ontario study the reduction in the contribution of yellow perch in the diet of cormorants led to a significant decrease in the estimated annual biomass of perch consumed. Reduced consumption of yellow perch by cormorants at St. Lawrence River colonies may alleviate suspected localized impacts on perch (Klindt and Town 2003) at some of the colonies. More recently, the introduction of alewife into Lake Champlain and their dominance in cormorant diet has led to speculation that it could act as a buffer on yellow perch predation at some colonies (DeBruyne et al. 2012).

Besides gamefish and panfish the contribution of forage species also declined in the diet of St. Lawrence River cormorants from the pre-round goby to the post-round goby period. Two of these, slimy sculpin (*Cottus cognatus*) and darters, share similar benthic habitat with round goby. One might expect with a switch in foraging behavior to a primarily benthic mode by cormorants that there would be a concomitant increase in the diet of other benthic prey species. However, the opposite of this occurred; the contribution of other benthic prey species decreased. This raises the possibility that round goby had a detrimental effect on other benthic species through competitive interactions, and perhaps predation. The third prey species group that exhibited a significant decline in the diet of cormorants from the pre-round goby to the post-round goby period was cyprinids. Whether this reduction was a switch from a pelagic/demersal

pre-round goby foraging pattern to a benthic post-round goby pattern or if gobies may have had an impact on cyprinid populations is unknown.

Cormorant colonies in eastern Lake Ontario are larger than those in the St. Lawrence River, and consequently, annual fish consumption is higher. Over a nine year period Johnson et al. (2002) estimated that cormorants at the largest colony, Little Galloo Island, consumed 32.8 million fish annually. Annual fish consumption over a nine year period at two smaller eastern Lake Ontario colonies, Pigeon Island and Snake Island, was estimated at 18.2 million (Johnson et al. 2010). Cormorants at the three St. Lawrence River colonies consumed an average of 9.7 million fish annually. However, based on nest counts at all upper St. Lawrence River colonies, cormorants at the three colonies we examined represent about 51.1% of the birds in the upper river. Assuming that daily fish consumption at these three colonies is similar to other cormorant colonies in the upper St. Lawrence River total consumption at all river colonies would be about 19 million fish.

Similar to what has been observed at other cormorant colonies, this study documents the rapid response of cormorants to an abundant new prey. However, within about a 100 km stretch of river this study also shows how the transition period may vary. In the case of the three St. Lawrence River colonies this transition period varied from two to five years. Although cormorant consumption on round goby may be buffering predation on important game fish and prey fish species, including yellow perch, smallmouth bass and esocids, the effect on other fishes (i.e. slimy sculpin, darters, cyprinids) is less clear. Because of the switch to round goby in their diet, similar to management actions taken to protect unique plant and animal communities in the Lower St. Lawrence River, (Bedard et al. 1997), any future efforts to control cormorant populations in the upper river would likely not be due to perceived impacts on fish populations.

Acknowledgements

We thank a host of field and laboratory technicians who collected and processed pellets. Marc Chalupnicki and Ross Abbett assisted in data tabulation and analysis. This article is contribution XXXX of the USGS Great Lakes Science Center.

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Table 1. Number of double-crested cormorant pellets examined during pre-round goby, transition, and post-round goby periods at three St. Lawrence River colonies, 1999-2013.

| Colony | Pre-Round goby | Transition | Post-Round goby |
|-----------------|-------------------|-------------------|-------------------|
| Griswold Island | 3,100 (1999-2003) | 2,206 (2004-2008) | 1,028 (2009-2013) |
| McNair Island | 923 (1999-2002) | 1,631 (2003-2005) | 2,035 (2006-2013) |
| Strachan Island | 1,187 (1999-2003) | 518 (2004-2005) | 1,404 (2006-2013) |

Table 2. Mean number of fish consumed per pellet during each chick period within each time interval at three St. Lawrence River colonies, 1999 - 2013. Different letters across a row represent significantly different groups.

| | Pre-Chick | Chick | Post-Chick | P(F Stat) |
|-----------------|-----------|--------|------------|--------------|
| Griswold | | | | |
| Pre-Round Goby | 19.3 A | 15.0 B | 12.9 C | <0.01 (70.7) |
| Transition | 16.0 A | 14.9 A | 13.5 B | <0.01 (10.9) |
| Post-Round Goby | 16.0 A | 20.9 B | 13.1 A | <0.01 (26.1) |
| McNair | | | | |
| Pre-Round Goby | 12.8 A | 11.9 A | 11.4 A | 0.49 (50386) |
| Transition | 15.0 A | 12.7 A | 11.3 B | <0.01 (11.2) |
| Post-Round | 18 A | 16.3 A | 17.7 A | 0.13 (2.03) |

| Goby | | | | |
|----------------|--------|--------|--------|--------------|
| Strachan | | | | |
| Pre-Round Goby | 14.4 A | 13.2 A | 15.8 A | 0.13 (2.02) |
| Transition | 17.0 A | 12.8 B | 12.9 B | <0.01 (15.0) |
| Post-Round | | | | |
| Goby | 28.0 A | 17.0 B | 16.0 B | <0.01 (39.5) |

Table 3. Mean number of fish consumed per pellet during the Chick period within each time interval at three St. Lawrence River colonies, 1999 - 2013. Different letters down a column represent significantly different groups.

| | Griswold | McNair | Strachan |
|-----------------|--------------|--------------|--------------|
| Pre-Round Goby | 14.4 B | 11.9 B | 13.2 B |
| Transition | 14.3 B | 12.7 B | 12.8 B |
| Post-Round Goby | 20.1 A | 16.7 A | 17.0 A |
| P(F Stat) | <0.01 (8.33) | <0.01 (16.9) | <0.01 (4.62) |

Table 4. Percent numerical diet composition of double-crested cormorants during the pre-round goby, transition, and post-round goby periods at (A) Griswold Island, (B) McNair Island, and (C) Strachan Island, St. Lawrence River. Different letters following a numerical percent indicate a significant difference across a row.

(A) Griswold Island

| | Pre-Round Goby | Transition | Post-Round Goby | P(F Stat) |
|--------------------|-------------------|------------|--------------------|---------------|
| Yellow Perch | 50.9 A | 50.3 A | 18 B | 0.0023 (400) |
| Cyprinid | 11 A | 6.1 B | 1.2 C | 0.0037 (723) |
| Rock Bass | 17.4 A | 14.1 B | 14.6 B | <0.01 (39.9) |
| Pumpkinseed | 10.7 A | 11.8 A | 6.1 B | <0.01 (81) |
| Darter | 1 A | 0.7 A | 0.1 CB | <0.01 (31.1) |
| Ictalurid | 4.7 AB | 5.5 A | 4.3 B | 0.0288 (3.55) |
| Slimy Sculpin | 1.4 A | 1.3 A | 3.2 B | <0.01 (22.5) |
| Smallmouth Bass | 1.1 A | 1.3 A | 1.5 A | 0.1048 (2.26) |
| Esocid | 1.1 A | 0.6 B | 0.1 B | <0.01 (48.2) |
| Round Goby | 0 A | 7.3 B | 49.5 C | 0.0077 |

| | | | | |
|-------|-------|-----|-------|---------------|
| | | | | (2871) |
| Other | 0.7 A | 1 A | 1.4 A | 0.2992 (1.21) |
| | 100 | 100 | 100 | |

(B) McNair Island

| | Pre-Round Goby | Transition | Post-Round Goby | P(F Stat) |
|-----------------|----------------|------------|-----------------|---------------|
| Yellow Perch | 32.5 A | 28.9 A | 17 B | 0.0006 (103) |
| Cyprinid | 12.4 A | 7.1 B | 2.3 C | 0.0026 (513) |
| Rock Bass | 34.2 A | 28.6 B | 14.5 C | 0.0012 (196) |
| Pumpkinseed | 4 A | 8.8 B | 12.3 B | <0.01 (19.1) |
| Darter | 4.9 A | 2.4 B | 0.4 C | 0.0006 (139) |
| Ictalurid | 3.3 AB | 5 A | 2 B | <0.01 (16.7) |
| Slimy Sculpin | 4 A | 3.1 A | 0.1 B | 0.0012 (216) |
| Smallmouth Bass | 2.7 A | 1.6 B | 1.4 B | <0.01 (22.9) |
| Esocid | 0.5 A | 0.3 B | 0.2 B | 0.0048 (5.35) |
| Round Goby | 0 A | 12.6 B | 48.9 C | 0.0048 (1245) |
| Other | 1.5 A | 1.6 A | 0.9 B | <0.01 (17) |
| | 100 | 100 | 100 | |

(C) Strachan Island

| | Pre-Round Goby | Transition | Post-Round Goby | P(F Stat) |
|-----------------|----------------|------------|-----------------|---------------|
| Yellow Perch | 54.7 A | 41.9 B | 21.4 C | 0.0006 (176) |
| Cyprinid | 10.9 A | 6.8 B | 3.4 C | 0.0016 (283) |
| Rock Bass | 14.1 A | 15.1 A | 13.7 A | 0.8259 (0.19) |
| Pumpkinseed | 4.2 A | 4.8 A | 4.6 A | 0.8456 (0.17) |
| Darter | 2.6 A | 4 A | 0.9 B | <0.01 (27.3) |
| Ictalurid | 6.6 A | 8.5 A | 3.7 B | <0.01 (15.9) |
| Slimy Sculpin | 1 A | 2.1 A | 0 B | <0.01 (72.5) |
| Smallmouth Bass | 1.7 A | 0.7 B | 1 B | <0.01 (11.1) |
| Esocid | 0.5 A | 0.4 A | 0.1 B | <0.01 (19.2) |
| Round Goby | 0 A | 12.7 B | 48.4 C | 0.0034 (1102) |
| Other | 3.7 A | 3 B | 2.8 B | 0.0013 (6.69) |
| | 100 | 100 | 100 | |

Figure 1. Number of double-crested cormorant nests at three St. Lawrence River colonies, 1999-2003.

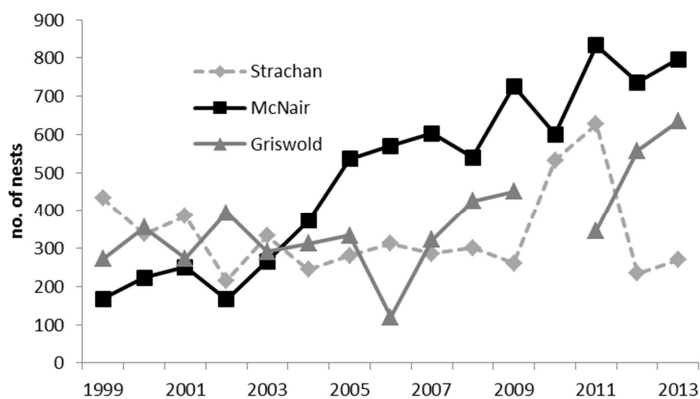


Figure 2. Annual estimated fish consumption by double-crested cormorants at three St. Lawrence River colonies, 1999-2003.

