Double-Crested Cormorant Studies at Little Galloo Island, Lake Ontario in 2011: Diet Composition, Fish Consumption and the Efficacy of Management Activities in Reducing Fish Predation

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For almost two decades Little Galloo Island (LGI) has supported the largest colony of double-crested cormorants (*Phalacrocorax auritus*) in the eastern basin of Lake Ontario. Cormorant nest counts on the island since the early 1990's have averaged 4,495 per year, reaching a high of 8,400 in 1996. Johnson et al. (2011) estimated that cormorants from LGI alone have consumed 444 million fish since 1992. The proliferation of cormorants in the eastern basin of Lake Ontario coincided with declines in two important recreational fish species, smallmouth bass and yellow perch. Lantry et al. (2002) and Burnett et al. (2002) provide convincing evidence linking cormorant population increases to declining eastern basin smallmouth bass and yellow perch stocks. Decline of these fish stocks was evident only in the eastern basin, suggesting a localized problem, which is consistent with the halo effect where large piscivorous waterbird colonies may deplete local fish stocks (Birt et al. 1987).

The year 2011 marked the twentieth consecutive year of study of the food habits and fish consumption of LGI cormorants and the twelfth consecutive year evaluating the efficacy of management activities to control the reproductive success of cormorants nesting at LGI. The program consists mainly of spraying cormorant eggs with oil as well as the culling of adult and immature birds. This paper reports the findings of work carried out in 2011 at LGI.

Methods

Diet Examination

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants on LGI in 2011. A total of 265 pellets were collected during the pre-chick feeding period (5/9/11), chick feeding period (6/22/11 and 7/6/11) and post-chick feeding period (9/21/11). In the laboratory, diagnostic bones, all otoliths, and representative scales were removed from the pellets and identified under magnification. Eye lenses were also enumerated and, 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 hydroxide solution. Species were identified to the lowest practical taxonomic level.

Fish Consumption Estimation

To estimate number of fish consumed by cormorants from the LGI colony, we used a model similar to that of Weseloh and Casselman (1992). 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, and a fecal pathway correction factor for fish not detected in pellets (Johnson and Ross 1996). To estimate the number of cormorants feeding we used annual nest counts (all nests counted) provided by the NYSDEC 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 YOY cormorants is the product of the fledgling productivity estimate for the year and the number of active nests. Residence times at LGI may actually be shorter because of annual management activities at the colony. Mazzocchi et al. (2003) found that the departure date of cormorants was 16 days later for a sub-colony of cormorants at LGI where no management activities occurred, compared to a sub-colony in the managed area. 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 on Lake Ontario). 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). Although immature cormorants are essentially fully grown, they are 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 composition and daily fish consumption (i.e. the number of fish per pellet). Pre-chick feeding was from late April to early June, the chick feeding period from mid June to late July, and the post-chick feeding period from early August to early October. To examine cormorant fish consumption by feeding period (i.e. pre-chick, chick, and post-chick) we further broke down the number of cormorant 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 have 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 LGI 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 (approximately 1 pound) of 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 key species including (total length) yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*) and pumpkinseed (*Lepomis gibbosus*) consumed during each cormorant feeding period by measuring otoliths from each species/period to the nearest 0.1 mm with calipers (Burnett et al. 2001, Ross et al. 2005). Broken or chipped otoliths were not considered for measurement. To estimate the weight of these species consumed by cormorants we used length-weight regressions for eastern Lake Ontario populations (unpublished data).

Control Measures

NYSDEC staff began treating accessible double-crested cormorant nests on LGI with corn oil beginning on May 9 and ending June 27, 2011. The oiling process was conducted four times over the season on each nest with eggs. Oil was applied from a backpack sprayer unit in sufficient volume to cover the exposed surface of each egg (approximately 6 ml/egg or 0.2 oz/egg). The number of eggs treated per nest was recorded and each nest or group of nests was marked with spray paint to facilitate efficient movement throughout the colony as well as complete nest coverage. Also recorded were the number of nests not treated and the number of chicks present per visit. We adjusted the number of cormorant feeding days and total number of fish consumed to account for 566 cormorants culled at LGI on June 3 (436) and July 6 (130).

We estimated reductions in cormorant feeding days and fish consumption annually from egg oiling. For chicks, these estimates were determined from 1999-2011; for immature cormorants, from 2000-2011; and for adult cormorants, from 2002-2010. These time periods assume that the effects on chicks began immediately (1999), the effects on immature birds began one year post initial treatment (2000), and effects on adult cormorants began when they reach maturity at age 3 (2002). To derive projected estimates, a standard of 5,681 nests from 1999 when egg oiling was first started was used. For each subsequent year, that nest count was subtracted from 5,681 (example: 2005 was 5,681-3,401=2,280 fewer nests). That nest count figure was then used to derive adult, immature, and YOY reductions in both feeding days and fish consumption using the standard Weseloh and Casselman model. This estimate plus the annual estimated reduction in feeding days from chicks alone and the actual number of feeding days for each year for the entire colony were summed to provide the projected estimate. Projected feeding day estimates were multiplied by the annual number of fish per pellet (i.e. daily fish consumption) to provide the projected estimate for fish consumption.

Results

Diet Composition

Round goby (92.9%) were the major prey of LGI cormorants in 2011 and dominated the diet during all feeding periods (Table 1). Alewife (2.5%), yellow perch (2.2%), and rock bass (1.1%) were the next most abundant species in the diet. For the entire season forage species (i.e. round goby, alewife, cyprinids, slimy sculpin, etc.) contributed 96.3% of the diet of LGI cormorants, while panfish (i.e. yellow perch, pumpkinseed, rock bass, ictalurids, etc.) and gamefish (smallmouth bass), composed 3.6% and 0.1%, respectively.

Fish Consumption

The number of fish per pellet (adjusted for fecal loss) was highest during the post-chick feeding period (64.3) and averaged 40.0 for the season (Table 1). The number of fish per pellet was the highest observed in the twenty years of investigations at the LGI and was the result of cormorants consuming small round gobies. A peak count of 2,884 cormorant nests was observed on LGI in 2011 and chick productivity was estimated at about 0.33 chicks per nest. To account for birds that were shot on June 3 and July 6 in the fish consumption model the adult bird estimate was reduced by 18,312 and 29,432 feeding days, respectively for the chick and post-chick feeding periods. Using the Weseloh and Casselman model we estimate about 1.01 million cormorant feeding days for the LGI colony in 2011 and about 1.01 million pounds of fish consumed (Figure 1). Numbers of fish consumed by feeding period in 2011 included 8.54 million during the pre-chick feeding period, 6.27 million during the chick feeding period, and 22.33 million during the post-chick feeding period.

In 2011, LGI cormorants consumed 35.82 million forage fish including 34.64 million round goby and 0.85 million alewife (Figure 2). About 1.35 million panfish were eaten, including 0.83 million yellow perch, 0.43 million rock bass, and 0.07 million pumpkinseed. Cormorants consumed about 0.03 million game fish, mostly smallmouth bass (Figure 2).

Size of Fish Consumed

A total of 373 otoliths recovered from cormorant pellets were measured in 2011. There was no apparent seasonal trend in the size of any species consumed by LGI cormorants in 2011. The average weight of yellow perch, rock bass, and pumpkinseed (computed from length-weight regression) for each feeding period is provided in Table 2. For the entire feeding season on LGI cormorants consumed an estimated 32,000 pounds of yellow perch, 30,000 pounds of rock bass, and 1,500 pounds of pumpkinseed.

Effects of Control Measures

The removal of 566, mostly adult, cormorants from the LGI population reduced the number of cormorant feeding days by about 47,744 and reduced total fish consumption by an estimated 2.30 million. Consequently, these feeding days and number of fish were not considered in estimating the effects of egg oiling. Chicks accounted for 86,480 cormorant feeding days from early June to mid October (Table 3). The total number of cormorant feeding days by the LGI colony in 2011 was estimated at 1.01 million (Table 3). We estimated that 5,192 chicks would have been produced on LGI from 2,884 nests in 2011 in the absence of reproductive suppression (i.e. egg oiling) by using the chick productivity estimate of 1.8 chicks per nest. Egg oiling limited cormorant chick production to 940 chicks, which is an 82% reduction. The number of chick feeding days by the LGI colony was reduced by 82%. For the entire LGI colony in 2011, reproductive suppression reduced the total number of cormorant feeding days from 1.41 million to 1.02 million (27.8%) and the number of fish consumed from 57.0 million to 37.2 million (34.8%) (Table 3). The relative magnitude of the reduction in fish consumption caused by reproductive suppression at LGI in 2011 was consistent with what was achieved in the previous six years (Figure 3).

We estimate that the 940 cormorant chicks produced on LGI in 2011 consumed about 3.88 million fish (Table 4). If egg oiling was not carried out and 5,192 cormorant chicks were produced on LGI in 2011, we estimate that these chicks would have consumed 21.5 million fish (Table 4). Consequently, egg oiling reduced fish consumption by 17.6 million fish in 2011. Using diet composition information for the chick and post-chick feeding periods, the reduced fish consumption represented 16.53 million round goby, 0.40 million yellow perch, 0.35 million alewife, and 0.02 million rock bass (Table 4).

Discussion

Since the egg oiling program was initiated in 1999 the number of cormorant nests at LGI has been lower than the pre-control level (5,681). Results achieved by the double-crested cormorant reproductive suppression program on LGI since 1999 have been remarkably consistent. Chick productivity has been reduced from an average of about 2.00 chicks per nest (1992-1998) to 0.16 chicks per nest (1999-2011), a 92% reduction. Since initiated in 1999, egg oiling has resulted in: (1) a 92.0% (annual range 76.0% to 98.0%) reduction in cormorant chick production, (2) a 29.0% (annual range 23.9% to 32.7%) reduction in cormorant feeding days, and (3) a 27.4% (annual range 19.1% to 34.8%) reduction in total fish consumption (Johnson et al. 2006, 2007, 2008, 2009,2010). A double-crested cormorant milestone was reached in 2010 when, for the first time, the number of feeding days (650,000) was below the management target of 780,000 that has been set for the LGI colony (McCullough et al. 2011).

We estimate that the cormorant reproductive suppression program on LGI has cumulatively reduced fish consumption by chicks at the colony by 85.8 million fish since it was initiated in 1999. Included in this estimate are approximately 9.7 million yellow perch and 2.6 million smallmouth bass that were not consumed by cormorants. These two species are especially important since declines in their abundance in the eastern basin of

Lake Ontario have been associated with cormorant population increases (Burnett et al. 2002, Lantry et al. 2002).

Cumulative Effects of Egg Oiling

The annual reduction in chick productivity at LGI provides only partial insight into the overall cumulative effects in terms of the reduction in both cormorant feeding days and fish consumption at the colony. Full consideration of the effects of egg oiling on these parameters should include projections for the immature and adult birds that would have been produced annually at the colony in the absence of egg oiling. Since egg oiling was initiated at LGI in 1999 about 5,390 chicks have been fledged compared to an estimated 77,533 if egg oiling had not occurred. If these 72,143 chicks had survived we estimate that fish consumption by chicks alone would increase by 123.8 million (Figure 4). In addition, the number of cormorant feeding days declined by 63% (11% attributed to cull; 2.71 million to 1.01 million from 1999 to 2011) (Figure 5) and actual annual fish consumption increased by 58%; (23.6 million to 37.2 million) during the same period (Figure 6). This increase was due to dominance of small round gobies consumed by cormorants at LGI in 2011.

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Table 1: Seasonal and total percent diet composition of double-crested cormorants from Little Galloo Island, 2011. Sample dates for the pre-chick, chick, and post-chick feeding periods were 5/9/11, 6/22/11, and 7/6/11, and 9/21/11, respectively.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	95	77	93	265
Fish/pellet (adjusted x 1.042)	22.5	21.8	64.3	40.0
Round goby	90.1	87.6	96.0	92.9
Alewife	3.4	8.8	<0.1	2.3
Rock bass	2.3	1.9	0.5	1.1
Yellow perch	2.1	1.3	2.5	2.2
Pumpkinseed	0.8	---	<0.1	0.2
Ictalurids	0.3	0.1	---	0.1
Catosomids	0.6	---	<0.1	0.1
Cyprinids	0.3	0.1	0.9	0.7
Escoids	<0.1	---	<0.1	<0.1
White perch	<0.1	---	---	<0.1
Smallmouth bass	---	0.2	---	<0.1
Total	100.0	100.0	100.0	100.0

Table 2. Estimated total length (TL, inches), mean weight (Wt., pounds), and number examined (No.), of yellow perch, rock bass, and pumpkinseed consumed by double-crested cormorants during each feeding period on Little Galloo Island in 2011. (SD = standard deviation).

	Feeding Period								
	Pre-chick			Chick			Post-chick		
	TL(SD)	Wt.	No.	TL(SD)	Wt.	No.	TL(SD)	Wt.	No.
Yellow perch	4.6 (1.2)	0.04	62	4.4 (1.0)	0.03	34	4.5 (1.2)	0.04	100
Rock bass	4.4 (1.7)	0.06	54	4.4 (1.0)	0.06	53	5.3 (1.0)	0.10	41
Pumpkinseed	4.3 (0.5)	0.02	29	----	----	----	----	----	----

Table 3. Estimated number of chicks produced, chick feeding days, total cormorant feeding days, and the number of fish eaten based on chick productivities of 0.33 (control = egg oiling) and 1.8 chicks per nest (no control) on Little Galloo Island in 2011.

Action	No. of chicks	No. of chick feeding days	Total cormorant feeding days	No. of fish eaten
No control	5,192	477,664	1,406,000	57,010,000
Control (egg oiling)	940	86,480	1,015,000	37,155,000
Difference	4,252	391,184	391,000	19,855,000

Table 4. Fish consumption estimates for double-crested cormorant chicks based on chick productivities of 0.33 (control = egg oiling) and 1.8 chicks per nest (no control) on Little Galloo Island in 2011.

	Number of fish consumed		
Species	Control	No control	Difference
Round goby	3,655,000	20,188,000	16,533,000
Yellow perch	86,000	475,000	389,000
Alewife	77,000	425,000	348,000
Rock bass	32,000	177,000	145,000
Cyprinid	27,000	149,000	122,000
Smallmouth bass	3,000	17,000	14,000
Ictalurid	2,000	11,000	9,000
Pumpkinseed	1,000	6,000	5,000
	3,883,000	21,448,000	17,565,000

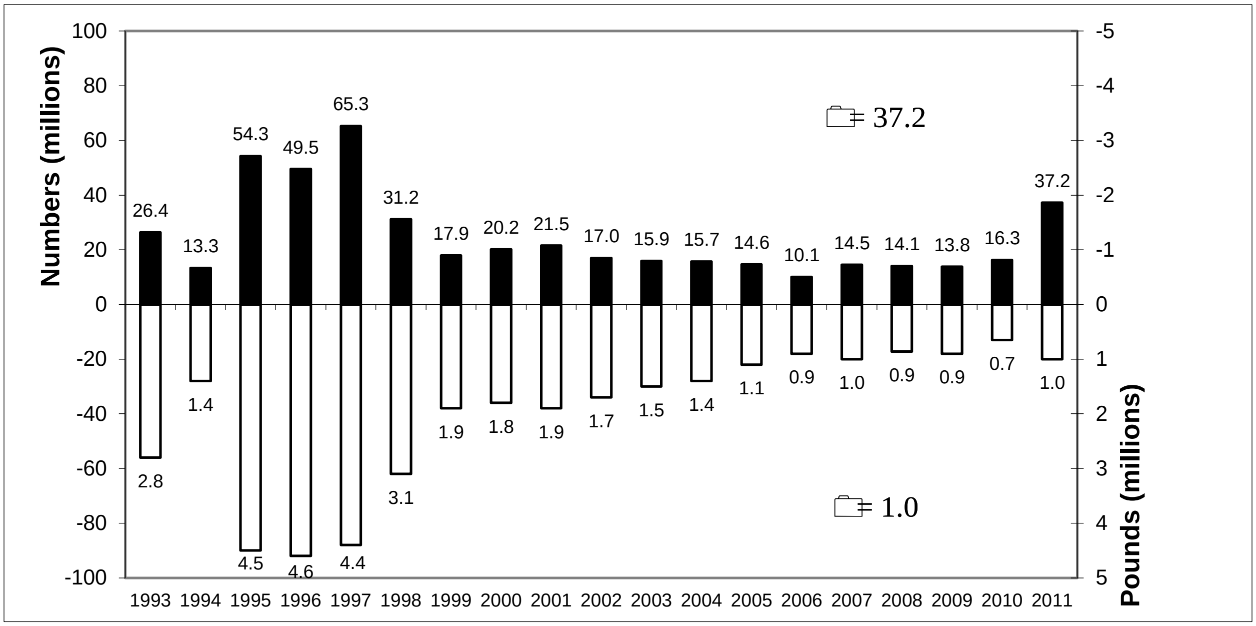

Figure 1. Estimated annual fish consumption in terms of numbers (top) and pounds (bottom) by the Little Galloo Island double-crested cormorant colony, 1992-2011.

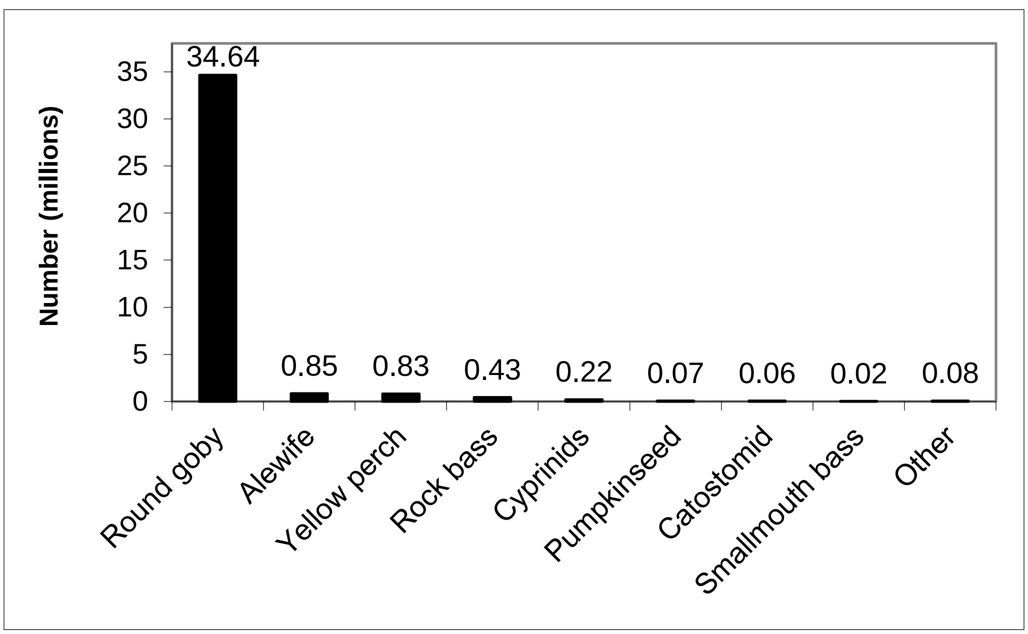

Figure 2. Estimated species-specific fish consumption by double-crested cormorants at the Little Galloo colony, 2011.

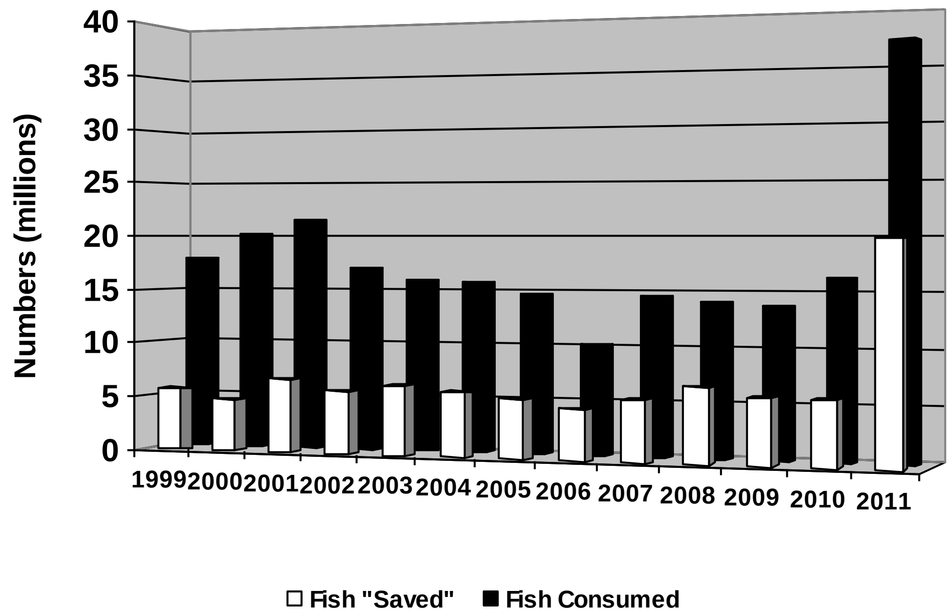

Figure 3. Estimated numbers of fish consumed by double-crested cormorant chicks and estimated number of fish "saved" by cormorant reproductive suppression since 1999 on Little Galloo Island.

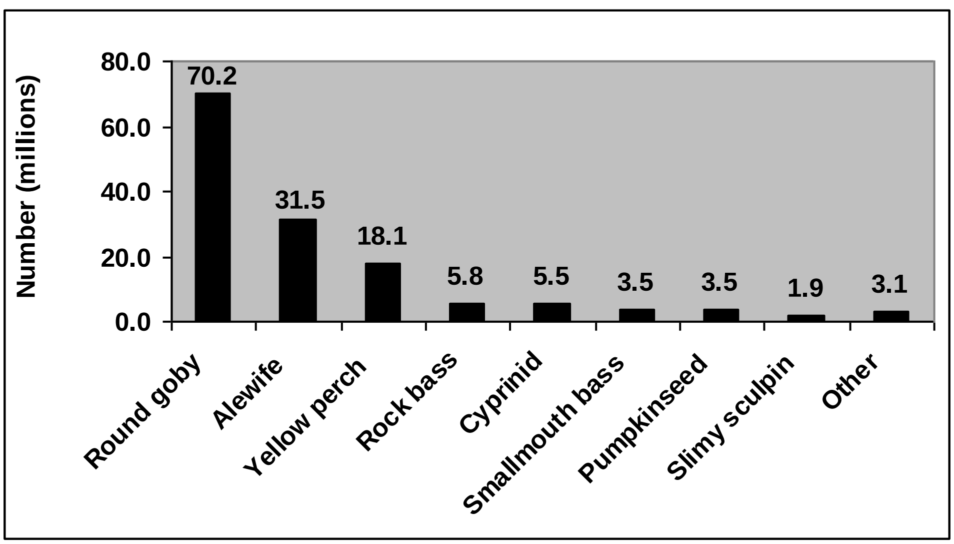

Figure 4. Total Number (millions) of fish "saved" by egg oiling program at Little Galloo Island, 1999-2011.

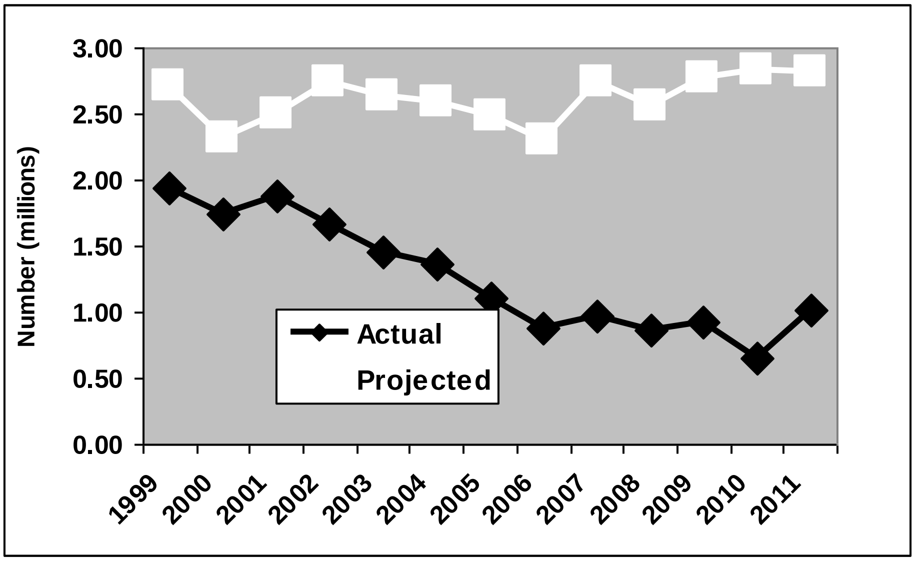

Figure 5. Actual (control-egg oiling) and projected (no control) double-crested cormorant feeding days at Little Galloo Island, Lake Ontario, 1999-2011.

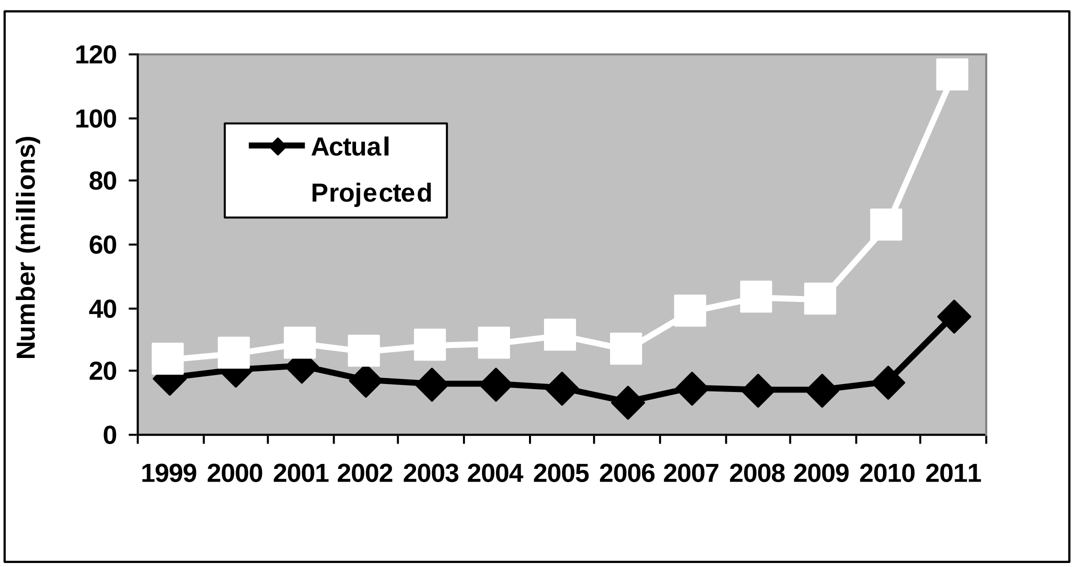

Figure 6. Actual (control-egg oiling) and projected (no control) estimates of double-crested cormorant fish consumption at Little Galloo Island, Lake Ontario, 1999-2011.