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James F. Farquhar
NYS Department of Environmental Conservation, jffarquh@gw.dec.state.ny.us

Irene M. Mazzocchi
NYS Department of Environmental Conservation

Russell D. McCullough
NYS Department of Environmental Conservation

Richard B. Chipman
USDA, APHIS, Wildlife Services

Travis L. DeVault
USDA/APHIS/WS National Wildlife Research Center, Travis.L.DeVault@aphis.usda.gov

Mitigation of Double-crested Cormorant Impacts on Lake Ontario: From Planning and Practice to Product Delivery

James F. Farquhar[1,*], Irene M. Mazzocchi[1], Russell D. McCullough[1], Richard B. Chipman[2] and Travis L. DeVault[3]

[1]NYS Department of Environmental Conservation, 317 Washington Street, Watertown, NY, 13601, USA

[2]USDA, APHIS, Wildlife Services, 1930 Route 9, Castleton, NY, 12033, USA

[3]USDA Wildlife Services, National Wildlife Research Center, 5757 Sneller Road, Brewerton, NY, 13029, USA

*Corresponding author; E-mail: jffarquh@gw.dec.state.ny.us

Abstract.—The New York State Department of Environmental Conservation initiated a Double-crested Cormorant (*Phalacrocorax auritus*) control program in the eastern basin of Lake Ontario to mitigate cormorant impacts in 1999. Key objectives included improving the quality of Smallmouth Bass (*Micropterus dolomieu*) and other fisheries, restoring the structure and function of the warmwater fish community and reducing cormorant impacts to nesting habitats of other colonial waterbird species. In eight years of intensive control, cormorant numbers declined, with a corresponding reduction in estimated fish consumption. Diversity and numbers of co-occurring waterbirds either increased or have not been shown to be negatively impacted by management. Woody vegetation favorable to Black-crowned Night-Herons (*Nycticorax nycticorax*) has been maintained. A ca. 2.5-fold increase in the abundance of Smallmouth Bass abundance in assessment nets over the last seven years is a sign of improved recruitment to the fishery. Since the target population level of 4,500 to 6,000 cormorants has essentially been achieved, the eastern Lake Ontario cormorant program is expected to shift in 2007 from a population reduction focus towards a less intensive program intended to prevent population resurgence. *Received 5 September 2007, accepted 20 December 2009.*

Key words.—Double-crested Cormorant, Lake Ontario, management, *Micropterus dolomieu,* monitoring, New York, *Phalacrocorax auritus*, Smallmouth Bass, wildlife damage.

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Double-crested Cormorants (*Phalacrocorax auritus*; hereafter cormorants) on the Great Lakes have undergone a major population increase in the past 30 years (Hatch 1995). The Great Lakes population declined throughout the 1960s and early 1970s, from a peak of approximately 900 nests in 1950 to 114 in 1973 (Weseloh and Collier 1995; Weseloh *et al.* 1995). The decline, along with that of other fish-eating birds, was associated with high levels of toxic contaminants, particularly DDE and PCBs, found in the ecosystem (Miller 1998). Due to control programs, contaminant levels were reduced and cormorant numbers recovered in the Great Lakes and elsewhere (Price and Weseloh 1986).

Increases in cormorant numbers within the eastern basin of Lake Ontario throughout the 1980s and 1990s resulted in angler and resource manager concerns about real and perceived impacts to recreational fisheries, waterbird diversity, and island habitat (Farquhar *et al.* 2003b). Research by the New York State Department of Environmental Conservation (NYSDEC) and the U.S. Fish and Wildlife Service (USFWS) to determine the impacts of cormorants on such natural resources began in 1992. In 1998, NYSDEC and U.S. Geological Survey (USGS) research identified a correlation between increasing cormorant numbers and increased mortality of young Smallmouth Bass (*Micropterus dolomieu*; Adams *et al.* 1999; Lantry *et al.* 1999).

Implementation of a cormorant management plan for U.S. waters of the eastern basin of Lake Ontario began in 1999. A revised management approach was implemented in 2004. The goal of the management, in both cases, was to improve the benefits derived from the Lake Ontario eastern basin ecosystem by:

1) restoring the structure and function of the warmwater fish community;
2) reducing the negative impacts of cormorants on nesting habitats and other colonial waterbird species;
3) improving the quality of Smallmouth Bass and other fisheries;
4) fostering a greater appreciation for Great Lakes colonial waterbird resources.

To achieve the desired results, cormorant control efforts were directed at reducing the Little Galloo Island population to levels associated with 1,500 nesting pairs (pre-Smallmouth Bass impacts), preventing expansion of cormorant nesting to other islands in the eastern basin (to limit competition with other waterbirds), and suppressing cormorant impacts to vegetation (NYSDEC 2000).

The paper describes the first eight years of a research, management and monitoring program for cormorants in the eastern basin of Lake Ontario and focuses on the integration of methods and the adaptive management approach to meeting long-term goals.

METHODS

Study Area

The eastern basin of Lake Ontario is located in the northeast portion of the lake (Fig. 1). The basin is a relatively shallow (<70 m) area of roughly 2,000 km^2 east of a line between Stony Point, New York, and Prince Edward Point, Ontario. Approximately 50% of the basin is within U.S. boundaries. Cormorant management sites include Gull (0.8 ha) and Little Galloo (17 ha) Islands, which are owned by NYSDEC, and Bass (2.1 ha) and Calf (12 ha) Islands, which are privately owned. The islands contain several colonial waterbird colonies. Gull and Bass Islands are ringed by woody species, primarily Box-elder (*Acer negundo*), Black Willow (*Salix nigra*), Eastern Cottonwood (*Populus deltoides*) and Silky Dogwood (*Cornus amomum*), with herbaceous vegetation dominating the center. Black-crowned Night-Herons (*Nycticorax nycticorax*) nest in the shrub layer and lower canopy. Three gull species nest in the open portions of these islands. Management of cormorants nesting on state-owned Little Galloo Island (LGI) and Gull Island supports both eastern basin fish community and waterbird diversity objectives (NYSDEC 2000). Management efforts on Calf and Bass Islands include maintenance of vegetation on private property, in addition to support of eastern basin fish, waterbird and habitat objectives.

Figure 1. Double-crested Cormorant management study area in eastern Lake Ontario.

Management and Research

Nest-removal activities on Gull and Bass Islands have been conducted annually since 1994. In 1997, Calf Island was included in nest-removal activities following an attempt by cormorants to establish a colony. Prior to 1999, management on Bass and Gull Islands was directed only at preventing new colony establishment to protect habitat for other waterbirds. All cormorant nests were removed in May and June. Ground nests were removed by hand and tree nests were either knocked down with a telescoping pole or disrupted using a shotgun to break eggs present in the nest. Each nest removed was scattered as much as possible to discourage rebuilding. Since 2004, cormorants that nested in trees too high for nest removal, or that persisted in rebuilding destroyed nests, were shot (culled) using .22-caliber rimfire rifles.

Annual treatment of accessible cormorant nests on LGI with food-grade corn oil began in spring 1999 (Farquhar *et al.* 2003a, b). Oil was applied from a backpack sprayer unit in sufficient volume to cover the exposed surface of each egg, approximately six ml/egg. The oiling process was conducted every two weeks, four or five times per season. The outside of each nest or group of nests treated was marked with spray-paint by one of the oiling team members to ensure treatment of all nests accessible from the ground. Biweekly application of oil ensured that each nest was treated at least twice during the incubation period. Also, oiling teams recorded the number of nests treated (Table 1), the number of eggs in each nest, the number of chicks observed, and the number of tree nests or control nests not treated.

A limited cull of cormorants on LGI was conducted in 2004 to determine the efficacy of the technique, assess non-target species disturbance, and add to the effect of non-lethal removal efforts. In 2005-2006, culling was used as a management technique. Culling was conducted by shooting with .22- or .17-caliber rimfire rifles. On LGI, culling took place during late incubation on one or two dates between late May and mid-June. At Bass and Calf Islands, culling was conducted as needed to discourage nesting from early May through the end of July. Culling teams consisted of at least two people. Carcasses were disposed of by burial.

Breeding waterbird numbers were derived from direct counts of nests on the four managed islands. Cormorant, Black-crowned Night-Heron and Caspian Tern (*Hydroprogne caspia*, formerly *Sterna caspia*) nests were counted annually in June or early July. Cormorant nest numbers were also tallied during each management session. Gull species were monitored less frequently to detect long-term trends. Ring-billed Gulls (*Larus delawarensis*) were abundant on LGI and Bass Island and were surveyed only during decadal Great Lakes cen-

Table 1. Number of Double-crested Cormorant (DCCO) nests removed or oiled and birds shot (nests with no intact eggs were not oiled) during management activity on New York's eastern Lake Ontario islands. Nests removed are cumulative. Number in parentheses is peak one day number.

Location	Technique	1999	2000	2001	2002	2003	2004	2005	2006
Little Galloo Island	Peak nests oiled	5,627	4,301	3,865	3,707	3,389	3,359	2,896	2,275
	Nests removed	0	0	0	0	0	0	0	0
	DCCO culled	—	—	—	—	—	18	686	620
Bass Island	Peak nests oiled	0	0	0	0	0	0	0	0
	Nests removed	37 (37)	793 (757)	0 (0)	986 (279)	260 (117)	959 (348)	935 (600)	477 (174)
	DCCO culled	—	—	—	—	—	167	281	200
Gull Island	Peak nests oiled	0	0	0	0	0	0	0	0
	Nests removed	146 (111)	574 (478)	21 (21)	157 (77)	1427 (486)	485 (188)	0 (0)	113 (110)
	DCCO culled	—	—	—	—	—	3	0	0
Calf Island	Peak nests oiled	0	0	0	0	0	—	—	—
	Nests removed	0	0	0	0	0	415 (539)	0	0
	DCCO culled	—	—	—	—	—	37	0	0

suses. Less abundant Herring Gulls (*L. argentatus*) and Great Black-backed Gulls (*L. marinus*) were surveyed in May at two- to three-year intervals.

From 1999 to 2001, productivity estimates for LGI Ring-billed Gulls and Caspian Terns were conducted to assess cormorant management impacts. Productivity was estimated through sub-sample counts of nests with adults tending pre-fledged young (Farquhar *et al.* 2003a). In addition to monitoring breeding waterbird numbers, each cormorant taken by culling, nests oiled and eggs oiled were recorded (Table 1) on each date that management activities occurred.

Site fidelity of eastern basin cormorants was evaluated through a combination of satellite and VHF telemetry studies in 2000, 2001 and 2002. A primary objective of the satellite telemetry was to evaluate effects of repeated egg-oiling treatments on within-breeding-season movement of cormorants captured on LGI (Dorr *et al.* this issue). Objectives of VHF telemetry were to determine foraging movements and nest site fidelity of cormorants on unmanaged islands, and cormorant response to ongoing management at LGI (Mazzocchi 2002). In early May of each year, adult cormorants were trapped on nests at LGI and on two control islands (2000, 2001) using modified padded leghold traps (King *et al.* 2000; Mazzocchi 2002; Dorr *et al.* this issue). Captured cormorants were then weighed and measured (culmen, tarsus, and wing chord) for sex determination (Glahn and McCoy 1995). A transmitter affixed to a backpack harness (Dunstan 1972; King *et al.* 2000) was attached to each bird prior to on site release. A total of 121 VHF and 52 satellite transmitters were deployed on cormorants during the course of the study (Mazzocchi 2002; Dorr *et al.* 2002, this issue).

Woody vegetation on the four eastern basin islands was assessed annually in early July for cormorant damage by visual observation, and quantitatively categorized as unaffected, stressed, or dead. Unaffected trees or shrubs showed either no leaf loss or minimal loss attributable to cormorant use. A stressed plant typically contained several cormorant nests with visible evidence of leaf loss through branch stripping or guano deposition (Hebert *et al.* 2005). Trees and shrubs experiencing annual stress over several years were deemed susceptible to eventual loss.

Fisheries Assessments

Annual cormorant diet studies at have been conducted at LGI since 1992. Regurgitated pellet samples were collected biweekly from the nesting colony from mid-April through mid-October. All samples were analyzed by the U.S. Geological Service Great Lakes and Leetown Science Centers (Johnson *et al.* 2006; Ross *et al.* 2006). Additionally, stomach contents were analyzed in 1998 and 2005 (Schneider and Adams 1999; Johnson *et al.* 2006). To estimate cormorant feeding days and fish consumption by chicks from the LGI colony, a model developed by Weseloh and Casselman (unpublished report) was used where each adult bird contributed 158 feeding days per season, subadults contributed 112 feeding days, and chicks contributed 92 feeding days.

Warmwater fish stocks have been assessed annually in New York waters of Lake Ontario's eastern basin since 1976. Sampling was conducted during early August at stratified random sites. Nets are 61 m long by 2.4 m deep and contain nine 15.2-m panels. Stretch measure mesh sizes range from 51 to 152 mm. Up to 29 nets were set overnight, on bottom, in three depth strata covering the range 3.7 to 30.5 m. Fish were identified, weighed and measured (total length) and examined for sex and maturity. Scales and otoliths were removed for age determination (Lantry 2007).

During the period of cormorant abundance at LGI, two creel surveys that focused on New York waters of Lake Ontario were conducted in 1998 and 2003. Each creel survey consisted of two independent samples. Angler interviews were conducted by direct contact at representative access sites to provide data such as catch and harvest rates and angler characteristics. Effort data were collected by instantaneous aerial counts of fishing boats. The surveys extended from the opening of Walleye season (first Saturday in May) through 30 September. Surveys involved 33 to 39 flights and 1,010 to 1,065 interviews.

RESULTS

Management and Research

On LGI, annual egg oiling has effectively prevented hatching of treated eggs, thereby reducing the number of cormorants present during the breeding cycle. Nest removal efforts on Gull, Calf and Bass Islands has varied annually (range 21-1,859 nests removed) in response to the number of initial nests and persistence of re-nesting efforts. The addition of culling since 2004 has contributed to lowering cormorant numbers on LGI, and in removing cormorants that persistently nest in high trees from Bass Island. Numbers of nest oiled, nests removed and birds culled are summarized in Table 1.

Since the onset of management, cormorant numbers on LGI have declined from 5,681 breeding pairs in 1999 to 2,730 pairs in 2006 (Table 2). Chick productivity has averaged 0.07 chicks per nest (1999-2006) annually compared to an estimated productivity of 2.00 chicks per nest (1992-1998) prior to management (Johnson *et al.* 2007). Most cormorant nest productivity occurred in untreated tree nests or in small control sub-colonies. Co-occurring waterbird numbers have generally remained stable or have increased during the period 1999 to 2006 (Table 2). Caspian Terns, which first nested on LGI in 1986, increased from 1,445 nests in 1999 to 1,589 nests in 2006. Weseloh (unpublished report) assessed the effects of cormorant management on Caspian Tern numbers and did not detect a correlation. Ring-billed Gulls were not surveyed during the control program, but did decline to 38,000 pairs on LGI based on a 2008 census. The observed decline in numbers between decadal counts is not believed to be related to cormorant management. Ring-billed Gull and Caspian Tern productivity was assessed annually from 1999 to 2001. Average estimates for numbers of chicks fledged per nest were 0.80 and 1.26, respectively (range 0.64-0.88 and 0.94-1.48, respectively). Herring Gull nest numbers have increased slightly over the course of three surveys during the management program (Table 2), and likely were not affected negatively by the cormorant control program.

Great Black-backed Gulls are a recent pioneer within the eastern basin without a long presence. Mortality of Great Black-backed Gulls has been associated with Type E botulism outbreaks in portions of the eastern basin in 2005 and 2006, and has resulted in observations of near total loss of the species locally. Black-crowned Night-Herons have shown an increasing trend since cormorant management was implemented. Numbers of Black-crowned Night-Herons in the eastern basin have increased from 56 pairs in 1999 to 109 in 2006 (unpublished field data). Most of these nests were on Gull and Bass Islands, where cormorant nest removal has maintained nesting space and shrubby vegetation favored by night-herons.

Satellite (Dorr *et al.* this issue) and VHF telemetry (Mazzocchi 2002) on cormorants concluded that within a breeding season, site fidelity through the eight-week egg-oiling period was 60 to 71% for marked cormorants on LGI. Most of the movement away from the colony occurred during later periods of control activity coinciding with the nestling and early fledging dates of initial nests on LGI (Dorr *et al.* this issue). Breeding-season fidelity of cormorants on the unmanaged islands was 43 to 66% of marked birds (Maz-

Table 2. Estimated number of breeding pairs of colonial waterbirds on New York's eastern Lake Ontario islands. Cormorant numbers for Bass, Gull and Calf Islands indicate active nests after removals.

Species	Island	1999	2000	2001	2002	2003	2004	2005	2006
Double-crested Cormorant	Little Galloo	5,681	5,119	5,440	4,780	4,251	3,967	3,401	2,730
	Gull Island	0	0	0	0	0	1	0	0
	Bass Island	0	0	0	0	35	12	5	5
	Calf Island	0	0	0	0	0	0	0	0
Ring-billed Gull	Little Galloo	53,000	—	—	—	60,000	—	—	—
	Gull Island	0	0	0	0	0	0	0	0
	Bass Island	2,300	—	—	—	2,500	—	—	—
Herring Gull	Little Galloo	275	—	—	—	313	—	—	367
	Gull Island	45	—	—	—	42	—	—	40
	Bass Island	10	—	—	—	11	—	—	10
Great Black-backed Gull	Little Galloo	8	—	19	15	12	—	—	4
	Gull Island	0	0	0	1	0	0	0	0
	Bass Island	0	0	0	0	0	0	0	0
Caspian Tern	Little Galloo	1,440	1,350	1,590	1,585	1,658	1,560	1,788	1,589
	Gull Island	0	0	0	0	0	0	0	0
	Bass Island	0	0	0	0	0	0	0	0
Black-crowned Night-Heron	Little Galloo	1	1	1	1	3	3	4	0
	Gull Island	46	20	50	24	35	78	81	77
	Bass Island	9	36	13	36	44	17	46	32

zocchi 2002, 2003). Both studies detected short-term (less than three months) breeding season movements from LGI and earlier late-summer departure from the nesting colony for unmanaged birds. Control efforts did not result in large-scale abandonment of LGI; however, some (12%) cormorants relocated to other active colonies for long enough periods (over three months) to potentially raise young (Dorr *et al.* this issue).

Throughout the period from 1999 to 2006, no individual trees or shrubs used by cormorants were killed. On LGI, all mature trees were dead from prior cormorant nesting and continue to deteriorate. A small area of Silky Dogwood supports large numbers of cormorant nests and exhibits annual stress, but no discernable loss. On Gull and Bass Islands, about 50% of the trees were used annually by cormorants and exhibited visible stress. Nest removal activities on these sites limited the duration and intensity of seasonal use by cormorants to a shorter period (approximately 50 days) than would be typical of an unmanaged colony. Cormorants sporadically (1997, 1998 and 2004) nested on Calf Island, and with prompt nest removal (within 14 days), resulted in limited tree stress visible only in those years.

Fisheries Assessments

Smallmouth Bass abundance has been low since the mid-1990s, compared to historical estimates, and remained so through 2004 (Lantry 2007). Low abundance was attributed to increased mortality of young Smallmouth Bass due to cormorant predation (Lantry *et al.* 1999, 2002). Smallmouth Bass abundance increased by a factor of 2.5 in 2005 and 2006 relative to the 2000-2004 period (Lantry 2007). Because young-of-the-year bass take approximately three years to recruit to the assessment sampling gear, increased abundance may be attributable to reduced predation pressure three years earlier (Fig. 2). Johnson *et al.* (2007) estimated that cormorant feeding days declined 67% and actual fish consumption declined 57%

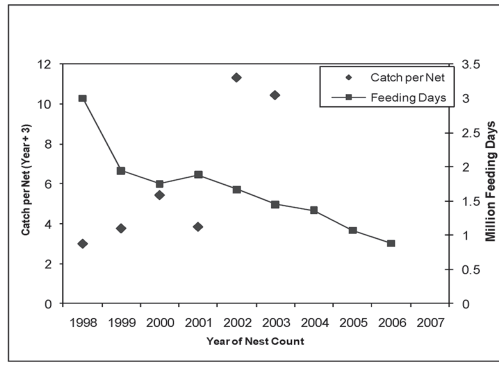

Figure 2. Trend in cormorant feeding days (millions) at the Little Galloo Island colony (target 785,000 feeding days) and Smallmouth Bass assessment catch.

from 1999 to 2006. Rapid expansion of the invasive Round Goby (*Neogobius melanostomus*) has resulted in a shift of the cormorant diet towards this abundant new prey species, which has relieved predation pressure on other species, such as Smallmouth Bass (Johnson *et al.* 2007).

From 1985 through 1990, Smallmouth Bass harvest rates at the Henderson survey site of the NY Lake Ontario fishing boat census equaled or exceeded lakewide rates. After 1990, harvest rates at Henderson were below lakewide rates in all years (Eckert 2002). The 1998 creel survey in New York waters of the eastern basin reported Smallmouth Bass harvest rates 34 to 45% of those reported by surveys in the 1960s, '70s and '80s (McCullough and Einhouse 1999). Low bass harvest rates coincided with the increase in relative mortality of young Smallmouth Bass and rapid increase in cormorant numbers at LGI (Lantry *et al.* 2002). Using creel survey data through 2003, McCullough and Einhouse (2004) did not find any improvement in angler catch of bass (estimated catch: 35,376 fish in 1998 and 18,984 fish in 2003). Anecdotal reports from anglers indicate that Smallmouth Bass fishing has improved since 2004. Response of the fishery to reduced cormorant predation pressure will not be quantified at least until the next creel survey, scheduled for 2012. Substantive improvements in catch rate cannot be expected until a strong year class is produced (a weather-dependent process), the young fish survive predation and three to four years of growth bring the year class to, or near, legal size (305 mm).

DISCUSSION

Cormorant numbers on LGI have responded to management as predicted, but there is some indication that immigration to the eastern basin has exceeded emigration from the basin throughout the management period of 1999 to 2006. The number of cormorants attempting to nest on Gull, Calf and Bass Islands has ranged from 200 to 600 pairs annually despite near zero reproductive success on these sites. Since 2004, the number of cormorant nests on LGI has declined at a slower rate than during the period of 2001 to 2003. Although a small change could be related to improved survival or a density-dependent effect, the rate of decline was expected to increase after the addition of culling in 2005. Management elsewhere in the Great Lakes system has likely resulted in a larger number of birds prospecting for new undisturbed colonies in which to breed. As LGI is relatively remote from the mainland of New York, and visits are made at two-week intervals, LGI may appear undisturbed to cormorants displaced from colonies elsewhere. LGI may serve as an ecological "trap" that diverts breeding cormorants away from more productive habitats (Gates and Gysel 1978). As such, cormorant management on LGI also may influence breeding numbers at other colonies in the region.

Although most (71%) of the marked cormorants in telemetry studies demonstrated within-season fidelity to LGI during the control period, approximately 50% of those cormorants moved away from LGI temporarily, most notably following control efforts occurring after late June (Dorr *et al.* this issue). Control activities likely resulted in temporary relocation to other colony sites within the breeding season. Some (12%) cormorants moved to other sites during the breeding season long enough to raise young. Although it is possible that these birds successfully fledged young, the fact that most birds moved to other active colonies late in the breeding season likely would have reduced chick survival (Dorr *et al.* this issue). Overall, telemetry results and concurrent nest count data support the conclusion that the control program is not moving large numbers of cormorants to other sites.

With respect to co-occurring waterbirds, trend data collected during the course of the management program indicate that the abundance of most species has remained stable or increased. In particular, Black-crowned Night-Heron numbers have doubled since cormorant management began (56 and 57 nests in 1999 and 2000, respectively, versus 131 and 109 nests in 2005 and 2006, respectively), probably due to management efforts that protected nesting space and shrubby vegetation. Gull species appear to be stable during the eight-year period based on periodic nest counts and estimates. Caspian Terns exhibited an increasing trend not believed to be influenced by cormorant management (C. Weseloh, unpublished data). Collectively, the cormorant management program in the eastern basin appears not to have resulted in negative impacts to co-occurring waterbird species, at least in terms of abundance. For Black-crowned Night-Herons, cormorant management appears to have had a positive effect on abundance.

Managing cormorant numbers has allowed woody vegetation on eastern basin islands to be maintained without loss due to cormorant guano or branch stripping. Over time, annual stress to some trees in which cormorants continue to attempt to nest will likely result in die-back, but low shrubs and most trees will likely continue to survive. Maintaining woody vegetation contributes to waterbird diversity objectives, because favorable nesting habitat remains for shrub- and tree-nesting species. The reduction of cormorant numbers on LGI took place after the loss of woody vegetation. Future efforts may include re-establishment of shrub species on LGI to determine whether both a cormorant colony and limited woody habitat can coexist.

The response of fish species to cormorant management has been encouraging, but Smallmouth Bass assessment catch rates remain at about 50% of their pre-1994 average levels (Lantry 2007). Current levels of predation pressure by cormorants are likely to allow detectable improvement in fish stocks and associated fisheries. Great Lakes Smallmouth Bass population levels are typically driven by the production of occasional strong year classes. Since the mid-1990s, predation by cormorants has apparently prevented young Smallmouth Bass, although abundant at the young-of-the-year and yearling stages, from surviving to recruit to the adult stage. With predation pressure now eased, it is expected that future abundant year classes, produced when weather conditions permit, will survive to recruitment at an increased rate. Continued stock assessment and creel surveys will be necessary to confirm such a development.

Cormorant management in the eastern basin of Lake Ontario has largely resulted in predicted outcomes or measured progress towards stated objectives. As a case study in management of an abundant waterbird species to produce outcomes beneficial to the public, some valuable lessons have been learned which may be applicable elsewhere. In particular, efforts to understand pre-management conditions and persistent monitoring throughout the control program have been important. By tracking results, the program could be adapted to match conditions and keep focus on desired outcomes. DeVault *et al.* (this issue) similarly emphasize the value of pre- and post-monitoring in an adaptive management process. While their central New York program had different goals, progress towards those goals has been measurable through integration of monitoring with management.

Cormorant management implemented to protect natural resources is contentious but can be accomplished in a manner that considers conflicting stakeholder interests. Management success should not be measured by the number of birds, nests or eggs taken, but rather by improvement to resources that are defined in terms of clear, measurable goals and milestones. The eastern basin program is an example of a carefully planned, implemented and monitored program that has produced desired outcomes with minimal negative consequences.

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