Effects of Egg-Oiling on Double-crested Cormorant Movements in Eastern Lake Ontario

Brian Dorr, Jimmy D. Taylor II, Scott J. Werner, D. Tommy King, James F. Farquhar, Irene M. Mazzocchi, and Russell D. McCullough

Abstract Knowledge of double-crested cormorant (*Phalacrocorax auritus*, hereafter cormorant) response to population control activities is important for implementation of a science-based management regime. To better understand adult cormorant response to egg-oiling, we initiated a two-year satellite telemetry study in May 2000 to evaluate cormorant movements (n = 26/year), reproductive success, and nest-site fidelity at Little Galloo Island (LGI) in eastern New York. Egg-oiling effectively reduced reproductive success on LGI to < 6% in 2000 and 2001. Mean distance of core use areas (50% kernal home ranges) from LGI differed (P = 0.004) between control and egg-oiling treatments (n = 31). The distance of core use areas from LGI for the final 2-week treatment period was significantly ($P \leq 0.05$) greater than all other periods . Core use areas of 12 (39%) of 31 cormorants did not contain LGI during $\geq$1 treatment periods (2 May - 9 July). However, 97% of these bird's core use areas contained LGI through the 3rd treatment period and 71% still contained LGI by the end of the final (4th) treatment period. Of all the cormorants that moved during or after control activities, only 2 (8%) remained in the vicinity of active breeding colonies for >3 months. Mean departure date for southerly migration was 10 September (SE = 8 days), though re-nesting efforts may have caused select individuals to delay migration until late October. Our data indicate control efforts do not result in complete abandonment of LGI for most cormorants during the nesting period. However, it may influence temporary relocation to other colony sites. More importantly, few cormorants relocated to other active colonies for long enough periods to successfully raise young. This study indicates that given long-term commitment, local and or regional egg-oiling efforts in the Great Lakes can be successful in reducing recruitment of cormorants within breeding seasons.

The double-crested cormorant (*Phalacrocorax auritus*) is the most numerous and widely distributed of the 6 North American cormorants (Hatch and Weseloh 1999). Human persecution in the nineteenth and early twentieth centuries (Hatch 1995; Hatch and Weseloh 1999), coupled with environmental contamination through the early 1970s (Hatch 1995; Hatch and Weseloh 1999), severely reduced population levels of double-crested cormorants (hereafter, cormorant) throughout North America (Ludwig 1984; Hatch and Weseloh 1999; Wires et al. 2001). Response to increased human environmental awareness (i.e., reduction of environmental contaminants and regulatory protection of the species) over the past 3 decades facilitated a population resurgence of cormorants in North America, particularly in the interior region (Hatch and Weseloh 1999; Glahn et al. 2000), with numbers in some areas doubling in < 5 years (Hatch and Weseloh 1999). Changes in fish communities on the breeding (Hatch and Weseloh 1999) and wintering grounds (Glahn et al. 2000) also may have contributed to an increase in cormorant numbers. Conservative estimates of the total population of cormorants in the United States and Canada are > 1 million individuals (Tyson et al. 1999), but a true population estimate is likely closer to 2 million (Hatch and Weseloh 1999).

While the overall rate of growth in the North American cormorant populations slowed during the early 1990s (Tyson et al. 1999), significant population increases occurred in some areas. In the Great Lakes, where cormorants reached a low of around 200 nesting pairs between 1968 and 1973 (Ludwig 1984), nesting pairs of cormorants increased from 38,000 in 1991 (Weseloh et al. 1995), 93,000 in 1997 (Tyson et al. 1999) to 115,000 pairs in the 2000 breeding season (D.V.C. Weseloh, unpublished data). Concomitantly, decreased abundance of select fish species was observed in Lake Ontario, causing particular concern among recreational anglers and fisheries managers in the region (Schneider et al. 1999). Following a series of studies conducted by New York State Department of Environmental Conservation (NYSDEC), Schneider et al. (1999) concluded that cormorants impacted recreational fisheries, particularly

smallmouth bass (*Micropterus dolimieu*), in the eastern basin of Lake Ontario.

Due to declines in fish populations (Schneider et al. 1999) and a perceived threat to native biodiversity, the NYSDEC introduced control activities at cormorant breeding colonies in eastern Lake Ontario in 1994 (Schneider et al. 1999;NYSDEC 2002). Control activities began on Little Galloo Island (LGI) in May 1999. To supplement the NYSDEC efficacy assessment for these management actions, we began monitoring movements of cormorants following colony control activities at LGI on 2 May 2000.

Our objective was to determine the effect of repeated egg-oiling treatments (May-July 2000 and 2001) on the movement of cormorants captured and released from LGI. We assumed that cormorants marked on LGI were nesting there, that LGI would represent the center of their breeding season home ranges, and that egg-oiling would not cause cormorants to abandon LGI. Thus, we hypothesized that distance of cormorant home range centroids to LGI would not differ between control and egg-oiling treatments. Hatch and Weseloh (1999) indicated that cormorants need a minimum of ~3 months to successfully nest and raise young to independence from parental care. So, we hypothesized that cormorants which abandoned LGI would not have adequate time(>3 mo) to find alternate nest sites, re-nest, and fledge young before southward migration.

Methods

Egg-oiling and Colony Observations

We treated all accessible cormorant nests on LGI with pure food-grade vegetable oil at two-week intervals from 16 May to 28 June 2000, and from 15 May to 26 June 2001 (Farquhar et al. 2002). Oil was applied from a backpack sprayer at a rate of approximately 6 ml/egg (Farquhar et al. 2002). Concomitant with treatment applications, we recorded total number of nests, total nests oiled, total eggs oiled, number of nests with no eggs, number of unaccessible nests, and number of chicks observed.

Capture and Transmitter Attachment

We captured cormorants on LGI (26 on 2-3 May 2000; 26 on 7 May 2001) using modified leghold traps (King et al. 1998; 2000). Cormorants were each fitted with a satellite platform transmitter terminal (PTT) using a backpack harness (Dunstan 1972; King et al. 2000) and released at the capture site. In May 2000, we used a 45 g PTT-100 manufactured by Microwave Telemetry, Inc. (Columbia, MD). PTTs were programmed to transmit approximately 8 hours each 48 hours from May-September 2000, and 8 hours each 10 days from October 2000 to September 2001. In May 2001, we deployed an improved design PTT-100 transmitter (Microwave Telemetry, Inc., Columbia, MD) that allowed a 15 g weight reduction/transmitter (30 g) and increased efficiency using satellite in view (SiV) technology (Microwave Telemetry, Inc., Columbia, MD). In 2001 transmitters were programmed to transmit approximately 6 hours each 48 hours from May-September 2001 and 6 hours each 10 days from October 2001 to September 2002.

Birds were located using NOAA satellites with onboard tracking equipment operated by Service Argos Inc. (Landover, MD). The data temporarily stored on satellites were sent to ground telemetry stations and subsequently forwarded to us via electronic mail. Location error was reported by Service Argos as one of six location classes (LC): LC3 = <150 m, LC2 = 150-350 m, LC1 = 350–1000 m, LC0 >1000 m, LCA and LCB = no estimate of location accuracy.

Data Analyses

We used PC-SAS ARGOS Filter Version 2.4 (Douglas 2000) to remove erroneous data points. The program used two location filtering methods 1) a user defined distance to determine locational redundancy and 2) distance, rate and angle measurements designed to filter illogical locations. The user-specified information for the redundancy and rate filters included flight speed (40 kilometers/hour) and daily movement of 60 kilometers/day (Custer and Bunck 1992). Location data were analyzed, entered into databases, and plotted using ArcView GIS (Environmental Systems Research Institute Incorporated {ESRI}, Redlands, California).

We used the Animal Movement extension (Hooge and Eichenlaub 1997) in ArcView GIS (Environmental Systems Research Institute Inc., Redlands, California) to calculate 95% and 50% (core) kernal home range polygons for each cormorant at 2-week intervals throughout the breeding season. We used the Xtools

extension (DeLaune 2000) in ArcView GIS {ESRI} to calculate the centroid (the geometric center of the defined polygon) for each home range polygon for a 2-week period prior to egg-oiling (control) and for each of four 2-week periods following the initiation of egg-oiling (treatment). We evaluated effects of egg-oiling on resulting shifts in distance (km) of cormorant home range centroids from LGI using a 2-way ANOVA (PROC GLM, SAS Institute, Inc. 1996). Fixed effects tested were treatment period (2-week pre-oiling control and 4 two week egg-oiling periods), year, and the year*treatment interaction. Tukey's multiple range test was used to determine differences between group means (% = 0.05). We also overlayed 50% core use area polygons with known colony sites to qualify intercolony movement during treatment periods. We considered cormorants whose core area no longer included LGI to have abandoned LGI for breeding purposes.

We further used Animal Movement extension (Hooge and Eichenlaub 1997) to determine if select cormorants potentially re-nested and fledged young. To reduce bias we only included marked cormorants for which we collected data throughout the treatment periods and into fall migration. Departure date for migration was defined as the mean date between the last signal North of Lakes Ontario, Erie, Oneida and Onondaga and the first signal date in which birds remained south of these lakes (Martell et al. 2001). We plotted all breeding season locations and generated 50% kernal home range polygons for each individual's breeding season core use area. We qualitatively evaluated intercolony movements by whether cormorant activity moved away from LGI during egg-oiling or they had $\geq$3 months near an active breeding colony (Wires et al. 2001). Hatch and Weseloh (1999) indicated that cormorants need a minimum of ~3 months to successfully nest and raise young to independence from parental care. This view of site fidelity differs from the aforementioned in that we also considered abandonment of LGI following treatment periods. Thus, we considered it possible for a cormorant to remain in the vicinity of LGI throughout the treatment periods (9 July), re-nest at a subsequent site, fledge young, and migrate south in late October or November.

Results

We estimated 5,119 and 5,440 breeding pairs of cormorants on LGI in 2000 and 2001 respectively, based on the maximum number of nests detected annually (Farquhar et al. 2002). Egg-oiling of all ground nests reduced hatching rate of oiled eggs to <1%, though approximately 200 and 400 young were fledged from untreated tree nests on LGI in 2000 and 2001, respectively. Thus, reproductive success on LGI was reduced to 5.7% for breeding seasons 2000-2001 (Farquhar et al. 2002).

We collected 11,577 locations for 52 cormorants captured and released on LGI. For the 26 individuals telemetered on 2 May 2000, we recorded 5,150 locations from 2 May 2000 - 13 October 2001. Individuals telemetered on 7 May 2001 yielded 6,427 locations from 7 May 2001-April 19 2002. Mean ($\pm$ SD) number of transmitter days deployed/bird was 149 $\pm$ 172 (n = 26, min = 6, max = 529) and 179 $\pm$ 80 (n = 26, min = 23, max = 347) for birds telemetered in 2000 and 2001, respectively. Mean ($\pm$ SD) number of locations received for birds telemetered in 2000 and 2001 was 421 $\pm$ 196 (n = 26, min = 15, max = 633) and 276 $\pm$ 83 (n = 26, min = 57, max = 406), respectively. Twenty transmitters failed before the end of the fourth treatment, and one cormorant was removed from distance analyses because it moved > 550 km away from LGI during treatment periods and disproportionally affected results. Thus, we tested the effects of egg-oiling on changes in home range size and activity center shifts for the remaining 31 cormorants. Nine additional transmitters failed before fall migration; therefore, 22 cormorants were used to assess intercolony movement and the potential for individuals to fledge young from alternate nest sites.

Mean distance from 50% core use area home range centroids to Little Galloo Island differed with respect to treatment period ($F_{4, 145}$ = 4.42, P = 0.02). Tukey's multiple range test indicated that distance between core use centroids and LGI was greatest (P< 0.05) in treatment period 4 for both years combined (Table 1). Area (km^2) of 50% core use polygons was affected by an interaction with year and treatment ($F_{4,145}$ = 3.28, P = 0.01) thus we report individual means (SE) in Table 2. Area (km^2) of 95% core use polygons also was affected by an interaction with year and treatment [$F_{4,145}$ = 3.21, P = 0.01 (Table 2)]. Mean (SE) 50% core use area in km^2 for 2000-01 were 5.69 (5.53) and 10.27 (2.22) respectively. Mean (SE) 95% core use area in km^2 for 2000-01 were 42.14 (43.75) and 74.99 (13.42), respectively.

We plotted and qualitatively evaluated core use areas by treatment period for 31 cormorants (Figures1-5). Core use areas of 12 cormorants (39%) did not contain LGI during ≥1 treatment periods; however, 3 of the 12 cormorants returned to the vicinity of LGI before treatments ended (Table 3). Thus, 71% (22) of marked cormorants showed fidelity to their nesting colony on LGI during the entire 10-week monitoring period (2 May - 9 July). However, 8 of the 9 birds that left and did not return during control activities did not leave until the final (4th) treatment period (Table 3). Therefore, 30 (97%) of the 31 birds core use areas contained LGI prior to the final treatment period (Table 3). The percentage of cormorants whose core use areas did not contain LGI for each two week treatment period are given in Table 3.

Of the 31 cormorants used to describe intercolony movements with respect to treatment period, 23 continued to transmit locations up to or through fall migration. However, we describe movement of an additional bird which was removed from distance and home range analyses as an extreme outlier (n = 24). Core areas of 6 (25%) of these birds contained LGI until initiation of fall migration. The remaining 18 (75%) shifted core areas away from LGI during or following completion of all treatments, n = 7 (29%) and 11 (46%), respectively. Six began fall migration by the end of July (within 3 weeks of the completion of treatment period 4). The remaining 12 moved northwest up the St. Lawrence River (n = 4); remained in Lake Ontario but not on LGI (n = 2); moved south to Lakes Oneida and Onondaga (n = 3); moved southwest to Pymatuning Reservoir in western Pennsylvania (n = 1); and moved southwest to Lake Erie (n = 2). Of all the cormorants that moved during or after control activities, only 2 (8%) remained in the vicinity of single active breeding colonies for >3 months; 1 (Bird 4) on the St. Lawrence River near Montreal (Figure 6) and the other (Bird 28) on Middle Island in western Lake Erie (Figure 7).

Cormorants initiated southerly migration over a 16-week period ranging from 12 July to 29 October. Mean departure date from breeding sites was 10 September (n = 24, SE = 8 d). Seventy-five percent (n = 18) of cormorants telemetered from LGI traveled east of the Appalachian Mountains, primarily along the Atlantic and Gulf coasts. The remaining 25% traveled west of the Appalachian Mountains. Winter distribution of cormorants captured on LGI extended along the southern Atlantic coast as far south as the Florida Keys and west along the Gulf of Mexico to southeastern Louisiana.

Discussion

Egg-oiling during this study effectively reduced ground nesting cormorant productivity on LGI by approximately 94%, exceeding NYSDEC's 90% goal (NYSDEC 2002). However, success of these egg-oiling efforts cannot be measured by the number of unhatched eggs alone, but must include minimization of re-nesting attempts through extended incubation (Gross 1951, Blackwell et al. 2000) or relocation. Gross (1951) contended that cormorants would continue to incubate oiled clutches beyond the normal incubation period, though we found no studies which compared nest loss or abandonment to natural conditions in cormorants.

Abandonment of LGI, as measured through shifts in core use centroids and area, was minimal during the first 8 weeks of the study (control and treatments 1-3), suggesting negligible abandonment due to human presence (i.e., trapping and application of oil). Although significant shifts in distance between 50% core use home range centroids and LGI occurred only for treatment period 4, proximity of additional colony sites within daily foraging ranges allowed for potential intercolony movement by some individuals. While core areas of 71% of marked cormorants contained LGI at the end of the treatment periods, approximately half of those cormorants moved their core area away from LGI for ≥1 treatment period. Control efforts may not have resulted in complete abandonment of LGI by cormorants during the treatment period however, it likely influenced temporary relocation to other colony sites.

Several factors aside from human disturbance may have affected movement of cormorants away from LGI particularly in later treatment periods. Trends towards increasing distance from LGI, particularly by treatment period 4 coincide with expected hatching and fledging dates (Hatch and Weseloh 1999) of initial nests on LGI. This suggests cormorants may have moved away from LGI in response to unsuccessful nesting and possibly by cormorants searching for other nest sites. Due to year

effect, it is difficult to determine a pattern of change in home range and core use areal extent associated with treatment period. However, more colony sites away from LGI were included in core use areas by cormorants during period 3 than all other treatment periods, suggesting a search for other possible nesting sites due to unsuccessful nesting. Nevertheless, 97% of marked cormorants core use areas contained LGI up to the end of period 3. It is possible that NYSDEC control efforts on nearby active colony sites may have prevented cormorants from nesting at those sites and abandoning LGI. This suggests that proximity and availability of alternative nesting locations may effect abandonment of nesting areas due to control efforts.

Similar movements also may have occurred under natural conditions from unsuccessful nesting attempts or other factors. One such factor is described as "Ashmoles Halo" (Ashmole 1963), where local depletion of food resources surrounding a breeding colony necessitates increased foraging distances in order to obtain food resources. The availability of food resources may have caused the variation in areal extent of home ranges and core use areas between years with no effect on changes in activity centers of core use areas. If cormorants required greater foraging distances in a given year to obtain food resources, yet had high fidelity to a site, the increase in extent of core use areas would not necessitate a shift in centers of activity.

A central question regarding termination of nesting attempts at a control site is whether nesting is resumed at other active colony sites. The success of the egg-oiling efforts could be negated if cormorants successfully shift their nesting attempts to other locations. Our data suggest cormorant home ranges shift away from LGI, particularly in later stages of control activities, yet most cormorants do not leave the eastern basin of Lake Ontario during this time period. Although there are many active colony sites in the eastern basin of Lake Ontario, only 2 cormorants remained over 3 months at locations other than LGI. The spatial locations of these birds were widely disparate suggesting the movements away from LGI were not directed at the nearest available untreated colony site. Although it is possible these birds successfully raised young, the fact that 1 of these birds moved to an active colony approximately mid-July would likely have reduced chick survival. Although, cormorants may shift their core use areas to other colonies, few if any remained at any active colony site long enough to successfully raise young to independence from parental care.

Migration of cormorants from LGI has broad temporal and spatial variation as shown in this study and as reported by Hatch and Weseloh (1999). Departure dates of cormorants from their breeding grounds varied over a 16-week period. The mean departure date (10 September) recorded from this study corresponds with the range of peak departure dates for cormorants reported by Hatch and Weseloh (1999). Although, we do not have pre-control activity data specific to cormorants breeding on LGI, our data indicate that cormorants from LGI did not migrate earlier due to control activities relative to that reported for other cormorants in the Great Lakes region.

Most (75%) cormorants captured at LGI in May 2000-01 migrated east of the Appalachian Mountains along or near the Atlantic coast (Figure 8). Their winter range extended from southeastern LA, along the coast of the Gulf of Mexico to the southern portion of the Atlantic coast. The remaining cormorants generally migrated along the Mississippi Alluvial Valley, terminating their movement in coastal Louisiana. It would appear that cormorants marked at LGI generally follow a different migratory route than birds marked further west (Dolbeer 1991). This separation is supported by evidence of morphological differences in cormorants captured on Lakes Jackson and Eufaula, Alabama, versus cormorants captured >300 km west in the Mississippi Delta (Glahn et al. 1999).

Evaluation of inter-annual site fidelity to LGI was beyond the scope of this study. However, 1 transmitter survived for over 12 months and this bird exhibited almost identical breeding home range patterns in 2000 and 2001 (Dorr et al. 2002). Inter-annual site fidelity has important implications with regard to egg-oiling as a non-lethal control method. If birds shift breeding activity from LGI to other colony sites, a decline in numbers on LGI may not be attributable to the effectiveness of egg-oiling. Current data indicate the number of nesting pairs on LGI has been relatively stable during control activities, suggesting most birds are returning to the LGI colony site. This pattern of inter-annual site fidelity has been demonstrated in Europe for Great Cormorants (*P. Carbo sinensis*), which exhibited an 85-90% inter-annual fidelity to single sites (Frederiksen et al. 2002).

Evaluation of individual site fidelity to colony sites in the presence of egg-oiling based on color marking and subsequent observation of individuals would provide evidence of long term fidelity to LGI. This is important because for long-lived birds such as cormorants, non-lethal control methods such as egg-oiling will have little effect on numbers of adults for an extended time period in the absence of lethal control (Dolbeer 1998). Dolbeer (1998) contends that although reproductive control can be effective in reducing recruitment, it's immediate effects on population reduction are more apparent for shorter lived species than for longer lived species such as cormorants. Therefore a long-term commitment to egg-oiling and monitoring will be necessary to evaluate efficacy of the current management regimen for LGI.

Our data suggest that egg-oiling efforts in the Great Lakes can be successful in reducing local recruitment of Double-crested Cormorants at specific colony sites. This combined with movement data indicating the majority of cormorants are not successfully utilizing other colony sites to raise young indicates that local or regional colony reproductive control can be an effective management strategy in reducing local abundance of cormorants within breeding seasons.

Acknowledgements: This study was conducted under a cooperative research agreement between USDA's National Wildlife Research Center and the New York State Department of Environmental Conservation (Cooperative Service Agreement Number 00-7407-0399 [RA]). We sincerely appreciate the commitment and assistance of M.Carrara, R. Chipman P. Fioranelli, J. Gansowski, B. Harrel, A. Schiavone, and D. Weseloh as we planned and executed our fieldwork in eastern Lake Ontario in 2000 and 2001. D. Douglas provided valuable assistance with spatial data management and analyses. We thank S. Barras, and J.C. Jones for their comments on report drafts. Care and use of avian subjects was approved by the Wildlife Services, National Wildlife Research Center's Institutional Animal Care and Use Committee.

References

Ashmole, N. P. 1963. The regulation of numbers of tropical oceanic birds. Ibis 103:458-473.

Blackwell, B. F., M. A. Stapanian, and D. V. Chip Weseloh. 2000. Dynamics of the double-crested cormorant population on Lake Ontario. Wildlife Society Bulletin 30:345-353.

Custer, T. W., and C. Bunck. 1992. Feeding flights of breeding double-crested cormorants at two Wisconsin colonies. Journal of Field Ornithology 63:203-211.

DeLaune, M. G. 2000. XTools ArcView extension (Version 10/18/2000). Oregon Department of Forestry.

Dolbeer, R. A. 1991. Migration patterns of Double-crested Cormorants east of the Rocky Maintains. Journal of Field Ornithology 62:83-93.

Dolbeer, R. A. 1998. Population dynamics: The foundation of wildlife damage management for the 21st century. Proc. Of the 18th Vertebrate Pest Conference pp:2-11.

Dorr, B., D. T. King, and S. J. Werner. 2002. Intercolony and regional movements of double-crested cormorants breeding in eastern Lake Ontario- research report for calendar year 2001. New York Department of Environmental Conservation Special Report, March 2002.

Douglas, D. C. 2000. PC-SAS Argos Filter V2.4 Software Documentation. United States Geological Survey, Alaska Biological Science Center, Anchorage Alaska, USA.

Dunstan, T. C. 1972. A harness technique for radio-tagging raptorial birds. Inland Bird Banding News 44:4-8.

Farquhar, J. F., R. D. McCullough, and I. M. Mazzocchi. 2002. Cormorant management activities in lake Ontario's eastern basin. New York Department of Environmental Conservation Special Report, March 2002.

Frederiksen, M., T. Bregenballe, M. R. van Eerden, S. van Rijn, and J-D Leberton. 2002. Site fidelity of wintering cormorants *Phalacrocorax carbo sinensis* in Europe. Wildlife Biology 8:241-250.

Glahn, J. F., M. E. Tobin, and J.B. Harrel. 1999. Possible effects of catfish exploitation on overwinter body condition of Double-crested Cormorants. *In* M.E. Tobin Tech. Coord. Symposium on Double-crested Cormorants: Population Status and Management issues in the Midwest. USDA, Animal plant Health Inspection Service, Technical Bulletin No. 1879.

Glahn, J. F., M. E. Tobin, and B. F. Blackwell. 2000. A science-based initiative to manage double-crested cormorant damage to southern aquaculture. USDA, Wildlife Services, National Wildlife Research Center Technical Bulletin 11-55-010.

Gross, A. 1951. The herring gull-cormorant control project. Proceedings of the International Ornithological Congress 10:532-536.

Hatch, J. J. 1995. Changing populations of double-crested cormorants. Colonial Waterbirds 18 (Special Publication 1):8-24.

Hatch, J. J., and D. V. Weseloh. 1999. Double-crested cormorant (*Phalacrocorax auritus*) *in* A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA, and The American Ornithologists Union, Washington, D. C., USA.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extension to ArcView version 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, Alaska, USA.

King, D. T., J. D. Paulson, D. J. Leblanc, and K. Bruce. 1998. Two capture techniques for American white pelicans and great blue herons. Colonial Waterbirds 21:258-260.

King, D. T., M. E. Tobin, and M. Bur. 2000. Capture and telemetry techniques for double-crested cormorants (*Phalacrocorax auritus*). 19th Vertebrate Pest Conference. San Diego, California, USA.

Ludwig, J. P. 1984. Decline, resurgence and population dynamics of Michigan and Great Lakes double-crested cormorants. Jack-Pine Warbler 62:91-102.

Martell, M. S., C. J. Henny, P. E. Nye, and M. J. Solensky. 2001. Fall migration routes, timing, and wintering sites of North American Ospreys as determined by satellite telemetry.

New York State Department of Environmental Conservation. 2002. Double-crested Cormorant predation on smallmouth bass and other fishes of the eastern basin of Lake Ontario. NYSDEC, Special Report, March 2002.

SAS Institute, Inc. 1996. SAS/STAT software: changes and enhancements through release 6.11. SAS Institute, Incorporated. Cary, North Carolina, USA.

Schneider, C. P., A. Schiavone, Jr., T. H. Eckert, R. D. McCullough, B. F. Lantry, D. W. Einhouse, J. R. Chrisman, C. M. Adams, J. H. Johnson, and R. M. Ross. 1999. Double-crested Cormorant predation on smallmouth bass and other fishes of the eastern basin of Lake Ontario: overview and summary. NYSDEC Special Report, pages 1-6.

Tyson, L. A., J. L. Belant, F. J. Cuthbert, and D. V. Weseloh. 1999. Nesting populations of double-crested cormorants in the United States and Canada. Pages 17-26 *in* (M.E. Tobin, Technical Coordinator). Symposium on double-crested cormorants: Population status and management issues in the Midwest. 9 December 1997, Milwaukee, WI. Technical Bulletin 1879. Washington, D.C.: United States Department of Agriculture, Animal and Plant Health Inspection Service.

Werner, S. J., D. T. King, and B. S. Dorr. 2001. Intercolony and regional movements of Double-crested Cormorants breeding in eastern Lake Ontario-research report for calendar year 2000. New York Department of Environmental Conservation Special Report, March 2001.

Weseloh, D. V., P. J. Ewing, J. Struger, P. Mineau, C. A. Bishop, S. Postupalsky, and J. P. Ludwig. 1995. Double-crested cormorants of the Great Lakes: changes in population size, breeding distribution and reproductive

output between 1913 and 1991. Colonial Waterbirds 18 (Special Publication 1): 48-59.

Wires, L. R., F. J. Cuthbert, D. R. Trexel and A. R. Joshi. 2001. Status of the Double-crested Cormorant (*Phalacrocorax auritus*) in North America. Final Report to USFWS.

Figure Legends

Figure 1. Core use areas (50% kernal home range polygons) during control periods (2 May - 16 May, 2000-01) for 31 double-crested cormorants captured and released on Little Galloo Island (LGI), Lake Ontario, New York. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 2. Core use areas (50% kernal home range polygons) for 31 double-crested cormorants following first egg-oiling treatment (16 May - 29 May, 2000-01) on Little Galloo Island (LGI), Lake Ontario, New York. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 3. Core use areas (50% kernal home range polygons) for 31 double-crested cormorants following second egg-oiling treatment (30 May - 13 June, 2000-01) on Little Galloo Island (LGI), Lake Ontario, New York. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 4. Core use areas (50% kernal home range polygons) for 31 double-crested cormorants following third egg-oiling treatment (14 June - 27 June, 2000-01) on Little Galloo Island (LGI), Lake Ontario, New York. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 5. Core use areas (50% kernal home range polygons) for 31 double-crested cormorants following fourth egg-oiling treatment (28 June - 11 July, 2000-01) on Little Galloo Island (LGI), Lake Ontario, New York. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 6. Breeding season (May-Oct) core use areas (50% kernal home range polygons) for 3 double-crested cormorants captured and released on Little Galloo Island (LGI), Lake Ontario, New York, 2000-01. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 7. Core use area (50% kernal home range polygons) for 1 double-crested cormorant which abandoned Little Galloo Island (LGI), Lake Ontario, New York during egg-oiling treatments. Green stars represent known colony sites, red stars represent NYSDEC control sites.

Figure 8. Distribution of 52 double-crested cormorants captured and released on Little Galloo Island, Lake Ontario, New York, 2 May 2000 - 19 April 2002.

Table 1. Sample size (number of birds), mean, and standard error for distance in kilometers of 50% kernel home range centroids from Little Galloo Island, Lake Ontario, NY, for 2-week pre-treatment (control) periods and each of four 2-week treatment periods, 2 May-9 July 2000-01.

2-week treatment Period	N	Mean (km)	Standard Error (km)
0 (Control)	31	6.27	1.10
1	31	6.30	1.33
2	31	7.98	1.66
3	31	9.30	2.81
4	31	22.85 *	6.38

* Statistically different ($P < 0.05$) Tukey's Multiple Range Test

Table 2. Mean (SE) area (km^2) of 50% and 95% kernel home ranges for cormorants captured in 2000 (n = 8) and 2001 (n = 23) at Little Galoo Island, Lake Ontario, NY, for 2-week pre-treatment (control) periods and each of four 2-week treatment periods, 2 May-11 July 2000-01.

Year	Home Range Size (%)	2-Week Treatment Period				
		Control	1	2	3	4
2000	50	3.18 (0.7)	2.13 (0.4)	2.35 (0.8)	3.00 (1.1)	17.77 (11.9)
2001	50	8.74 (2.1)	13.39 (3.2)	9.92 (1.9)	12.23 (2.4)	7.05 (0.8)
2000	95	22.46 (4.0)	19.47 (3.3)	19.00 (4.4)	19.56 (4.7)	130.24 (96.0)
2001	95	67.49 (15.8)	90.69 (16.0)	74.64 (11.7)	85.42 (14.5)	56.70 (6.6)

Table 3. Number of known colony sites (other than Little Galloo Island) within 50% kernel home range polygons (core areas) for 31 cormorants captured and marked on Little Galloo Island (LGI), Lake Ontario, NY in May 2000 and 2001. The totals row contains the number and percent (%) of cormorants whose core use areas did not contain LGI by treatment period.

	Known colony sites in core area during treatment[a]				
Bird ID #	Control	1	2	3	4
01	1[b]	0	1	0	0
04	1	1[b]	0	0	2
07	1	1	0	0	1
08	0	0	0	0	0
09	0	0	0	0	0
15	0	0	0	0	1[b]
16	0	0	0	0	0
21	0	0	0	1	0
27	1	2	0	0	2
29	0	1	4	2	1[b]
30	0	0	0	1	1
31	0	2	0	0	0
32	0	0	1	1	0
33	1	0	1	0	1
35	0	6	1[b]	1	1[b]
36	0	0	0	3	0
37	3	2	2	0	0
38	0	1	2	1	0
39	0	1	1	1	1[b]
40	1	1	1[b]	1	1[b]
42	1	1[b]	1[b]	1	0
43	0	2	1	2	1
44	0	1	1	2	2[b]
45	0	2	1	1	1
46	0	0	2	3[b]	1[b]
47	0	2	3	2	2[b]
48	0	1	1[b]	3	1[b]
49	2	1	2	4	1
50	0	0	0	1	0
51	1	2	1	4	2
52	1	0	0	0	0
Total[b]	1 (3)	2 (6)	4 (13)	1 (3)	9 (32)

[a] Unless otherwise noted, core area contained LGI (i.e., 0 = LGI; 1 = LGI plus an additional known colony)
[b] Core area did not contain LGI

Table 4. Dorr, B., D. T. King, and S. J. Werner. 2002. Intercolony and regional movements of double-crested cormorants breeding in eastern Lake Ontario- research report for calendar year 2001. New York Department of Environmental Conservation Special Report, March 2002. Table 4. Migration initiation dates, routes, and winter areas for 24 cormorants captured and marked on Little Galloo Island, Lake Ontario, NY in May 2000 and 2001.

ID #	Migration start date	Migration Route	Winter Area
01	09/03/00	Atlantic	Atlantic Coast - FL
04	10/29/00	Atlantic	Gulf Coast - FL/AL
07	08/16/00	Atlantic	Gulf Coast - FL
08	10/20/00	Atlantic	Gulf Coast - FL
09	10/27/00	Interior	Inland - LA
15	09/25/00	Atlantic	Inland - FL
16	09/07/00	Atlantic	Inland - FL
21	10/18/00	Atlantic	FL Keys
28	10/06/01	Interior	Gulf Coast - LA
29	07/12/01	Atlantic	FL Keys
30	10/10/01	Atlantic	FL Keys
31	10/01/01	Interior	Inland - LA
32	08/07/01	Atlantic	Last trans. Chesapeake Bay
35	07/26/01	Atlantic	Gulf Coast - LA
36	07/24/01	Atlantic	Gulf Coast - LA
37	10/26/01	Atlantic	Gulf Coast - LA
38	08/11/01	Atlantic	Inland - LA
39	10/26/01	Atlantic	Last trans. NC Coast
40	07/29/01	Atlantic	Gulf Coast - FL
42	10/01/01	Interior	FL Keys
43	09/12/01	Interior	Inland - MS/AR/TN
44	09/29/01	Interior	Gulf Coast - LA
49	07/24/01	Atlantic	Atlantic Coast - NC
52	07/22/01	Atlantic	FL Keys