December 1997

A Geographic Information System To Monitor Nest Distributions of Double-Crested Cormorants and Black-Crowned Night-Herons at Shared Colony Sites Near Toronto, Canada

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Abstract: In the early 1990's, it became apparent that the rapid colonization of Tommy Thompson Park on Lake Ontario near Toronto by double-crested cormorants *(Phalacrocorax auritus)* would eventually affect the existing colonies of black-crowned night-herons *(Nycticorax nycticorax)* owing to competition for nest sites and destruction of nest trees. As a result, monitoring of these two species was expanded in 1992 by individually marking all nest trees (using permanent metal tree tags) and by recording the numbers of heron and cormorant nests for all nest trees. In 1996, professional surveyors determined the exact locations of nest trees. We have developed a geographic information system (GIS) to plot the changes in the nesting distributions of cormorants and night-herons during 1992–97 on three peninsulas at Tommy Thompson Park. The GIS clearly illustrates the relationship between the expanding nesting areas of the cormorants and the receding nesting areas of the night-herons at the two shared colony sites. The GIS products will be helpful in any discussions of local cormorant management.

Keywords: double-crested cormorant, *Phalacrocorax auritus,* black-crowned night-heron, *Nycticorax nycticorax,* geographic information system, competition, distribution, Lake Ontario

The rapid and dramatic increase in double-crested cormorants (DCCO's) in North America and specifically within the Great Lakes over the past 2 decades has been well documented (Weseloh et al. 1995 and 1977, Scharf and Shugart 1981, Milton and Austin–Smith 1983, Hatch 1984, Ludwig 1984, Vermeer and Rankin 1984, Craven and Lev 1987, and Chapdelaine and Bédard 1995). Along with documenting this resurgence, research has been directed at examining and understanding the impacts of increased cormorant numbers within both the breeding and wintering areas of their range (Craven and Lev 1987, Brugger 1995, Glahn and Stickley 1995, and Weseloh et al. 1995).

One of the more publicly visible impacts that has emerged is the defoliation and destruction of trees within nesting colonies. Damage occurs through the birds' habitual stripping of leaves from the trees (to use as nest material), broken branches resulting from the weight of the birds and their nests, and their guano, which can be deposited extensively onto the leaves and ground (Weseloh and Ewins 1994, Weseloh and Collier 1995). At the largest cormorant colony on Lake Ontario, on Little Galloo Island, most of the trees have died, primarily as a result of defoliation and guano deposition (Weseloh and Ewins 1994).

Bédard et al. (1995) described the complete or partial loss of trees on islands situated in the St. Lawrence estuary and the resulting damage to unique habitats and decreased plant and wildlife diversity. In Lake Erie, nesting cormorants have damaged significant Carolinian habitat, specifically stands of Kentucky coffeetree *(Gymnocladus dioicus)* on East Sister Island (Weseloh and Collier 1995, Ontario Ministry of Natural Resources 1997 unpubl.). Increasing cormorant numbers in Hamilton Harbour in western Lake Ontario have destroyed stands of eastern cottonwood *(Populus deltoides)* at one nesting site and while doing so have excluded a previously established colony of black-crowned night-herons (BCNH's) (Moore et al. 1995).

At Tommy Thompson Park (TTP) on the Toronto waterfront, a similar impact has been observed since 1990, when cormorants nested for the first time. This colony has increased to 1,241 nests in 1997, and it is now apparent that this rapid colonization by DCCO's is affecting an existing colony of BCNH's because of competition for nest sites and progressive destruction of nest trees.

In Ontario, the BCNH has been proposed for designation as a rare species because there are relatively few nesting areas, and they are at the northern edge of the species' North American range (Austen et al. 1994). The colony at TTP is one of the largest known colonies of this species in Ontario (Goodwin 1987).

Here we present the results of an 8-year monitoring program that has documented the establishment and subsequent expansion of DCCO colonies at TTP, and the resulting competition and impact on existing colonies of BCNH's. A geographic information system (GIS) data base has been developed to illustrate the annual changes in number and distribution of both species at this location clearly. These data, combined with the high-quality graphics inherent in GIS analysis, will provide important information on which to base decisions if control or population management is required in the future. The background data will also form the basis for future work at TTP to evaluate the impact on tree condition by nesting cormorants and herons.

Study Area and Background

Tommy Thompson Park, also referred to as the Leslie Street Spit, is a manmade peninsula that extends 5 km into Lake Ontario from the Toronto waterfront (fig. 1). The site has been constructed through the deposition of dredged silt and sand and with imported fill and rubble from excavations and demolitions associated with urban development. Construction of this area was initiated in 1959 and continues today. About 400 species of plants have colonized the site (Higgins et al. 1992), and more than 296 bird species have been documented (Fraser 1983; The Toronto and Region Conservation Authority, unpubl. data).

A mosaic of differing habitats, each with its own associated plant communities and wildlife species, has developed at TTP. As a result of this rich diversity, the presence of regionally, provincially, and nationally significant plant species, and TTP's function as an important migration stopover, the park was designated an environmentally significant area in 1982 (Metropolitan Toronto and Region Conservation Authority 1982).

Over the years, deciduous woodlands, primarily eastern cottonwoods, have become established in the park. As the trees matured, they provided nesting habitat for the BCNH's that first nested at TTP in 1979 with six nests (Fraser 1983). During 1980–85, the number of BCNH nests varied between 27 and 42. Virtually all were located on Peninsula B (fig. 1). In 1986, there were 100 nests divided equally between Peninsulas B and C. The nesting population increased quickly from 1987 to 1989, and the greatest concentration (83 percent of the 918 nests) occurred on Peninsula C by 1989. For the first time, BCNH's also nested on Peninsula A in 1989 (with 19 nests).

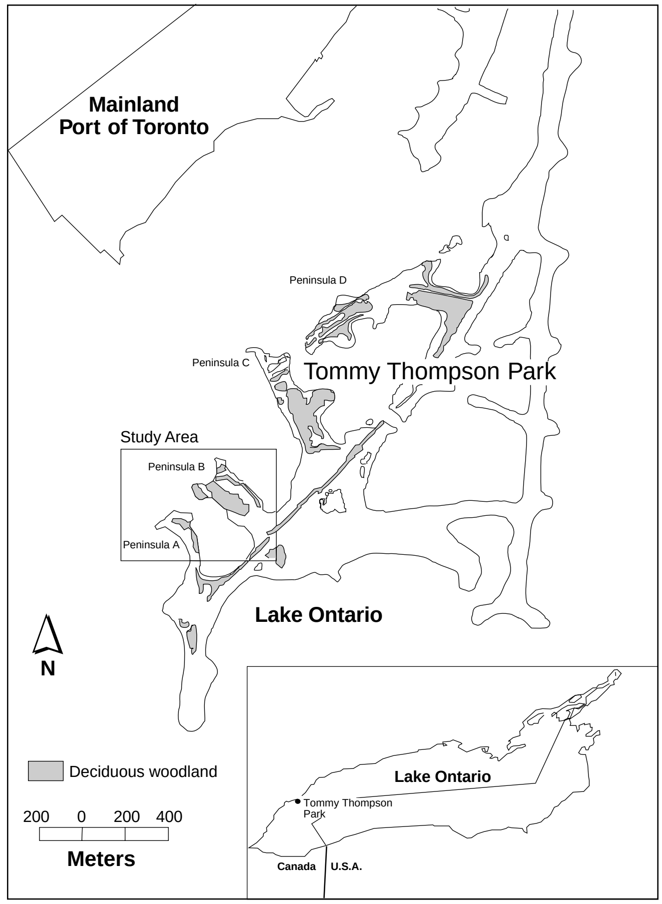


Figure 1—The Tommy Thompson Park study area showing the extent of deciduous woodland in 1997.

Methods

Nest Counts

From 1984 to 1991, staff of The Toronto and Region Conservation Authority (TRCA) and the Canadian Wildlife Service conducted an annual census of active BCNH nests at TTP to determine the number of breeding pairs and their general distribution. Active nests were counted between mid-May and early June during daylight hours by a team of one to six observers who moved systematically through each peninsula. Observers marked with colored flagging tape trees containing active nests and recorded the number of active nests for each area. In 1991, DCCO's were included in this inventory using the same methods.

In 1992, we began using small, aluminum, numbered tree tags (National Tag and Band #14) to mark individual trees with cormorant nests. Starting in 1993, we began using the same method for marking the nest trees of BCNH's. The tags were affixed to the northwest side of the tree trunk at breast height with two 2.5-cm galvanized roofing nails. In addition, a 5-cm strip of yellow plastic was nailed to the trunk adjacent to the tag to increase the visibility of marked trees.

In 1997, circular 2.5-cm metal tags (National Band and Tag #85, 0.050 mm thick) were used to tag new nesting trees and replace old damaged tags. These new tags were attached to the tree with a single 5-cm galvanized roofing nail. The longer nail was used so that the tag could be left out about 2.5 cm from the tree trunk to allow growth of the tree without damaging the tag.

Once the trees had been identified with tags, we carried out modified data collection on an annual basis as above but included references to specific tag numbers. In areas of potential species overlap, we determined the identification of nesting species through actual observation of birds on the nest or from the nest structure itself. Compared with BCNH nests, DCCO nests often were larger, used larger twigs and branches, occasionally used plastic debris, and showed more copious whitewash (coauthor Blokpoel, unpubl. data).

Nesting Tree Coordinates

Spatial data in the form of 6° Universal Transverse Mercator (UTM) coordinates and elevations were obtained through a professional survey of all previously tagged trees during January 1997. Tree diameter at breast height (d.b.h.) was recorded to the nearest half centimeter at the same time using a standard metric forestry caliper. We conducted the survey during the winter to take advantage of the better visibility afforded by the absence of tree foliage and ground cover.

During the 1997 nest inventory, we obtained UTM coordinates for new (or previously unsurveyed) trees by measuring the linear distance and compass bearing to a previously surveyed tree. The UTM coordinates were then determined using the measuring function within ArcView GIS ver. 3.0 software (Environmental Systems Research Institute Inc., Redlands, CA).

Ground truthing was carried out in March 1997 to search for tagged trees that were not found during the survey and also to confirm UTM coordinates.

GIS Development

We entered spatial data (tree coordinates) and attribute data (annual nest numbers, species, d.b.h., etc.) into a Lotus 1–2–3 ver. 5.0 (Lotus Development Corp., Cambridge, MA) spreadsheet and then converted them into Dbase format for integration into the ArcView GIS. The resulting points and associated attributes were then integrated with a shoreline layer (1:50,000 National Topographic Series mapping) and digital georeferenced color aerial photographs of the area (Triathalon Mapping Corporation, 1:20,000, fall 1995).

Initial review of the shoreline layer indicated that it was out of date owing largely to ongoing erosion in the area of interest and accelerated by recent high water levels. An update of the shoreline form and position was undertaken using a combination of onscreen digitizing from the color aerial photography and measurements of the linear distances from surveyed trees to the shoreline within the study area.

Results

Tagged Trees

Between 1992 and 1996, we tagged 1,754 trees at TTP: 224 on Peninsula A, 608 on Peninsula B, and 922 on Peninsula C. During the winter of 1996–97, we obtained UTM coordinates for 1,667 of these trees. Of the remaining 87 trees for which coordinates were not obtained, 35 had fallen, 51 were listed as "unknown," and 1 was identified as "tag destroyed."

Trees were identified as unknown if they could not be found during either of the 1995 or 1996 surveys or during the ground truthing in March 1997. These trees could have fallen (or have been lost as the result of erosion and wave scouring at the water's edge) with their fate not confirmed, or the tag number could have been changed as a result of a damaged or missing tag and not recorded as such. In the case of the latter, coordinates for these trees may have been obtained during the survey but not linked to the previously collected data.

During the 1997 nest census, an additional 123 trees were tagged (11 on Peninsula A, 78 on Peninsula B, and 34 on Peninsula C), bringing the total number of tagged trees at TTP to 1,877.

Nesting Distribution and Density

The numbers and distribution of cormorant and night-heron nests at TTP from 1987 to 1997 is presented in table 1. The annual changes in distribution and nest density of DCCO's and BCNH's were mapped for Peninsulas A and B from 1990 to 1997 and are shown in figures 2–7. Because marking the individual nest trees of night-herons started in 1993, their distribution is illustrated with polygons in 1990 and 1992. Although the majority of BCNH's have annually nested on Peninsula C, that area was not included in the mapping because there was no competition with DCCO's for nest trees there.

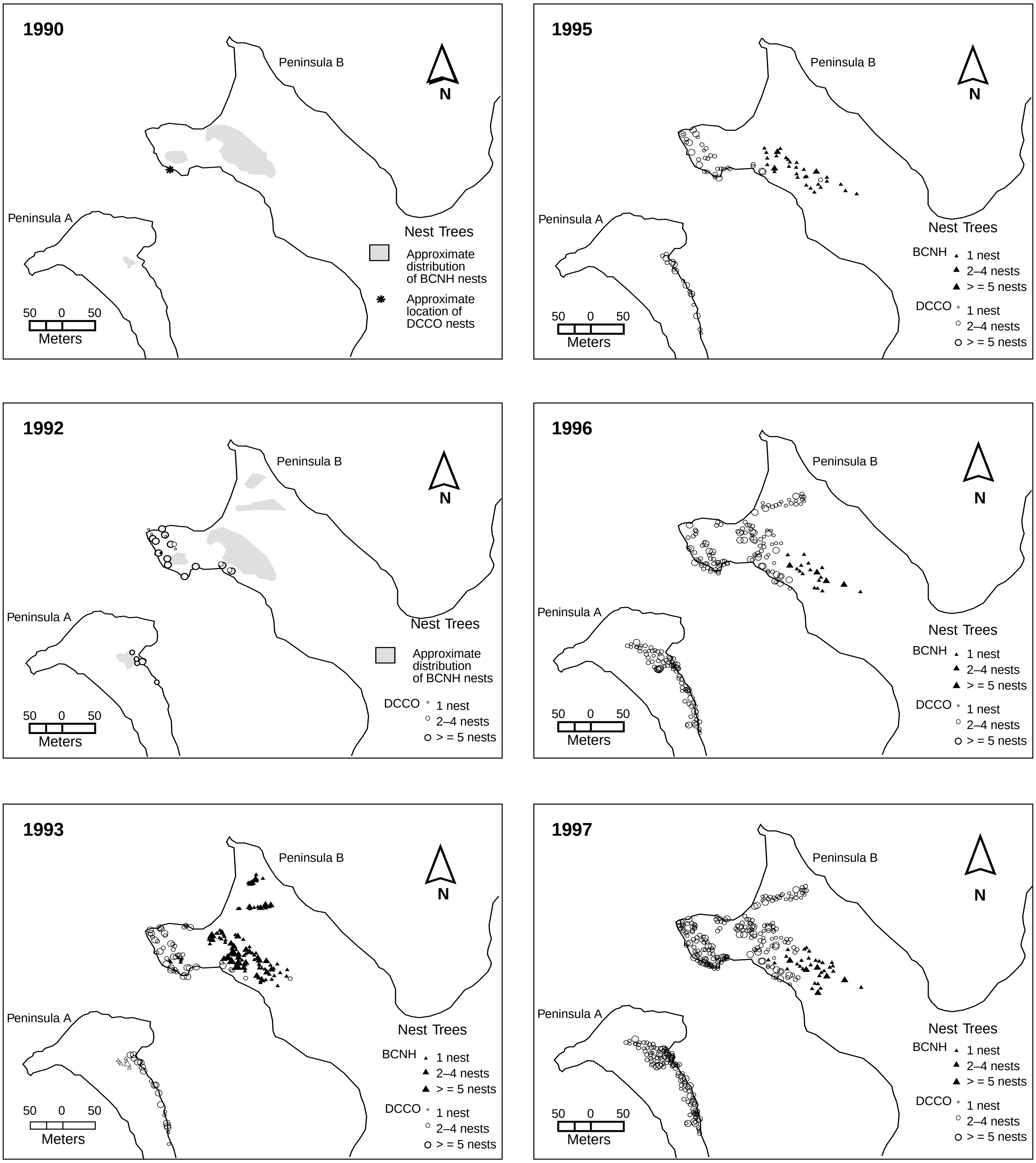
In 1990, cormorants began nesting at TTP with six pairs occupying four trees on the southwest tip of Peninsula B (fig. 2). Nests were located in branches overhanging water. BCNH's were nesting on Peninsulas A and B, but their nest numbers and distribution were not recorded relative to tagged trees in 1990. The BCNH nesting consisted of a small colony on Peninsula A, a larger primary colony on Peninsula B, and one small subcolony on the southwest tip of Peninsula B.

In 1991, cormorant numbers had increased tenfold, and nesting had expanded to trees on Penin-

Table 1. Number of nests and nesting trees occupied by double-crested cormorants and black-crowned night-herons on three peninsulas at Tommy Thompson Park from 1987 to 1997

	Double-crested cormorants								Black-crowned night-herons							
	Peninsula A		Peninsula B		Peninsula C		Totals		Peninsula A		Peninsula B		Peninsula C		Totals	
Year	Nests	Trees	Nests	Trees	Nests	Trees	Nests	Trees	Nests	Trees	Nests	Trees	Nests	Trees	Nests	Trees
1987	0	0	0	0	0	0	0	0	0	0	75	NA[1]	516	NA	591	NA
1988	0	0	0	0	0	0	0	0	0	0	40	NA	570	NA	610	NA
1989	0	0	0	0	0	0	0	0	19	NA	135	NA	764	NA	918	NA
1990	0	0	6	4	0	0	6	4	2	NA	182	NA	805	NA	989	NA
1991	20	NA	42	NA	0	0	62	NA	14	NA	111	NA	667	NA	792	NA
1992	12	11	73	47	0	0	85	58	10	7	NA	NA	NA	NA	860	NA
1993	61	36	127	75	0	0	188	111	10	9	207	149	694	NA	911	NA
1994	248	106	276	138	0	0	524	244	0	0	134	110	402	289	536	399
1995	166	69	248	128	0	0	414	197	0	0	54	50	736	506	790	556
1996	339	136	592	249	0	0	931	385	0	0	72	61	1,123	603	1,195	664
1997	349	150	892	336	0	0	1,241	486	0	0	63	56	766	476	829	532

[1] NA denotes that data were not available.



Figures 2–7—Distribution of DCCO's and BCHN's nesting on Peninsulas A and B at Tommy Thompson Park, by year (1990–97).

sulas A and B. The selected nesting trees were still located along the shore at the water's edge; however, the majority of the DCCO's nesting at TTP were on Peninsula B.

By 1992, the distribution of DCCO's was beginning to expand within the southwest tip of Peninsula B, and there were already several nests in trees situated away from the water's edge (fig. 3). On Peninsula B, the BCNH colony consisted of one large primary colony located within the center of the largest stand of cottonwoods and three subcolonies located near the southwest and northwest tips of the peninsula. A substantial colony of BCNH's (860 pairs) was present on Peninsula C; however, their nest numbers and distribution were not recorded relative to tagged trees in 1992.

Through 1993 and 1994, the DCCO nesting population continued to increase steadily. In addition to an expanded distribution, there was also an increase in nest density: 18 trees on Peninsula A and 30 trees on Peninsula B contained between 2 and 4 nests each. Further, there was one tree on Peninsula A and there were two trees on Peninsula B that contained more than five nests in 1993. Cormorants nesting on Peninsula A continued to spread south along the shoreline, nesting in trees located at the water's edge. The small subcolony of BCNH's on Peninsula A was present in 1993. Cormorant nesting density continued to increase on the southwest tip of Peninsula B as the birds began to occupy more trees away from the water's edge. In 1993, the small subcolony of BCNH's located on the southwest tip of Peninsula B was almost completely surrounded by nesting cormorants (fig. 4). In 1994, cormorants nested in 10 trees that had been occupied by BCNHs in 1993.

By 1995, the BCNH's had completely abandoned their nest trees on Peninsula A and the subcolony on the southwest tip of Peninsula B (fig. 5). In addition, nest numbers and density had decreased in the primary BCNH colony on Peninsula B and the two subcolonies on the northwestern tip. In 1995, cormorants nested in 11 trees that had been occupied by BCNH's in 1994.

The 1996 map (fig. 6) illustrates the substantial increase in nest density of cormorants on Peninsulas A and B as well as the increased occupation of nesting trees well away from the shoreline areas on both peninsulas. The BCNH's on Peninsula B had completely abandoned the two subcolonies located on the northwest tip of the peninsula, and their distribution within the primary colony was considerably reduced. The continued increase in distribution and density is reflected in the 1997 map, which illustrates DCCO occupation of most trees on Peninsula A and a further shift in nest distribution toward the interior of Peninsula B (fig. 7). In 1997, cormorants nested in nine trees that had been occupied by BCNH's in 1996.

There were only two instances where both species were found nesting in the same tree during the same year. The first was on Peninsula B in 1992 with a tree containing one nest each of BCNH and DCCO. The second case, also on Peninsula B, involved a tree on the southwestern tip that contained one BCNH nest and three DCCO nests. The locations of these nests were not indicated on the 1992 and 1996 maps because they were not visible owing to the density of nest symbols in the surrounding area.

It is also noteworthy that, although the subcolony of BCNH's on the northwestern tip of Peninsula B had become abandoned by 1996, it was not occupied by DCCO's until 1997. Thus, the apparent impact of the cormorants on the night-herons is not well understood.

Discussion and Management Implications

The GIS mapping for Peninsulas A and B clearly shows that the nesting areas of the cormorants are expanding, whereas those of the herons are receding. Although there is probably a cause-and-effect relationship between these two phenomena, we do not know the exact mechanism whereby the cormorants are encroaching on and/or overtaking the herons' nesting areas. The takeover may be caused by cormorants actually usurping active heron nests in the course of a breeding season or occupying nesting trees early in the season before the herons have begun to nest.

Although we made no frequent observations over the course of a season (which would be required to document any actual eviction), we happened to witness a potential case. On May 7, 1993, in the woodlot at the northwestern end of Peninsula B, a cormorant sitting on a night-heron nest was jabbing at the two night-herons who were trying to regain their nest. Later that same day, the herons had reoccupied their nest. To identify the mechanism for cormorant takeover more clearly, a clearer understanding of the breeding phenology of these two species at TTP will be required. Although these data are not available at present, they may be the focus of future work at this site.

During the initial stages of colonization, we speculated that the primary competition between the DCCO's and the BCNH's would be for trees immediately at the water's edge and that further competition inland from the water's edge would be minimal owing to the distance from the water. Clearly this is not the case, for cormorants quickly occupied trees in the centers of both peninsulas.

From the patterns shown by the GIS, we can predict that DCCO's will completely overtake the woodland in Peninsula B in the next few years (as they have already done on Peninsula A), and that BCNH's will abandon these areas and restrict themselves to Peninsula C. Shifting of BCNH's to Peninsula C as a result of competition with DCCO's on Peninsulas A and B may have occurred already; however, we do not have any data to confirm this. Further, it is very likely that DCCO's will eventually begin to nest on Peninsula C (and possibly Peninsula D at a later date), where this process of colonization and competition will be repeated.

Shifts in the distribution and number of nesting DCCO's will increase further as they continue to kill their nest trees. The premature destruction of the woodlands at TTP will reduce or eliminate the colonies of BCNH's and provide opportunities for ground nesting DCCO's. There are several reports of cormorants shifting nests to the ground as a result of the destruction of nest trees. In Hamilton Harbour, cormorants were observed nesting on the ground following the destruction of nest trees or the saturation of available nesting trees (Moore et al. 1995). Similar shifts were observed at Little Galloo Island (Weseloh and Ewins 1994), including a distinct increase in nesting activities toward the center of the island well away from the shoreline. A transition to ground nesting may lead to reduction in productivity because of a greater threat of predation and human disturbance (Lewis 1929, Vermeer 1973). To date, no ground nesting has been observed at TTP, presumably because of the availability of suitable nesting trees.

On the basis of the results of this monitoring and the pattern that has emerged, some form of cormorant management or control seems needed and justified for TTP. Any control or management of cormorants at this location will likely be very controversial and will require strong rationale and justification as well as the support of various interest groups and government agencies associated with this site. The high-quality GIS mapping will be helpful in discussions with the various stakeholders regarding the need for, and feasibility of, cormorant management or control at TTP.

Acknowledgments

We appreciate reviews of early drafts of this manuscript by R. Pratt, M. E. Tobin, D. V. Weseloh, and an anonymous reviewer. We are grateful for the assistance provided by D. Clayton, C. Gerstenkorn, and D. Parkinson in the development of the GIS and by G. Sadowski and G. D. Tessier during the many years of data collection.

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