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Distribution, relative abundance, and prey demand by double-crested cormorants on Manitoulin Island lakes vs. Lake Huron Coast

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ABSTRACT

An aerial distance sampling survey of double-crested cormorants (*Phalacrocorax auritus*) was conducted in the northern region of Lake Huron (North Channel; four largest lakes of Manitoulin Island; South Shore of Manitoulin Is. facing the main body of the lake) to assess the relative distribution, abundance and prey demand by cormorants on inland lake vs. coastal habitat. On a per area basis, the density (approx. 1–2 cormorants$\cdot$km^{-2}) and prey demand (approx. 1.2 kg ha^{-1}) of cormorants in the four inland lakes matched that of the North Channel. The South Shore had approximately half the density and prey demand as the other two areas. Cormorants on the inland lakes of Manitoulin Island represented 13% early in the season and a high of 33% of the total population for this region of Lake Huron later in the summer. Estimating regional distributions of cormorants within the Great Lakes basin is important because mapped nest colonies and nest counts are not representative of the actual distribution of foraging cormorants during and after the nesting season. There are two general conclusions to emerge from this survey. First, aquatic productivity from both Great Lakes coast and inland lakes contributes to trends in population and distribution of cormorants in the northern region of Lake Huron and perhaps elsewhere. Second, inland aquatic ecosystems are important throughout a season for foraging cormorants from the Great Lakes and may become more important as Great Lake productivity trends downward.

Introduction

Population trends of double-crested cormorant (*Phalacrocorax auritus*) on the Laurentian Great Lakes are well described by colony locations and nest counts at whole lake or regional scales within a lake (i.e., archipelagos; connecting channels; coastal zones). Colony location can influence where cormorants choose to forage to some extent (Ashmole, 1963; Birt et al., 1987), but colony locations alone cannot fully account for regional distributions of foraging cormorants. Colony locations may be irrelevant in determining foraging distributions after the nesting season when adults and juveniles disperse. The spatial extent of foraging cormorants is less understood than colony locations but acknowledged to be a regional question given the scale of study in the Great Lakes (Dorr et al., 2010a; Fielder, 2008, 2010; Johnson et al., 2010; Lantry et al., 2002; Madenjian and Gabrey, 1995; Seefelt and Gillingham, 2006). Certainly, the public perception of cormorants is situated at regional scales within Great Lakes ecosystems (Muter et al., 2009). Individual movements and population monitoring are two direct methods for determining the regional distribution of foraging cormorants.

Tracking movements of individual cormorants reveals spatially distributed foraging locations for a colony. Foraging areas occurred at scales of $10 \geq 100$'s km^2 in large aquatic ecosystems (Columbia R., Anderson et al., 2004; Oneida Lake, Coleman et al., 2005; Les Cheneaux Is., Dorr et al., 2010b). Regional movements of individuals in other species of cormorants matched this spatial scale (Frere et al., 2008). Mean home range size of satellite collared cormorants in the Laurentian Great Lakes basin was 1937 km^2 (Guillaumet et al., 2011). There were no clear colony effects on home range size demonstrating the limits of colony-scale variables on regional distributions of foraging cormorants in the Great Lakes. The only pattern was consistent differences among individuals in home range size (Guillaumet et al., 2011). In most studies, movements included areas inland from the main body of water presumably to other aquatic ecosystems. Movements of individuals can provide information on the maximum extent and specific locations of foraging individuals but not a regional distribution of a population of foraging cormorants.

Seasonal monitoring programs also reveal large scale movements at regional levels. On Oneida Lake, fall migration results in an influx of double-crested cormorants constituting the peak abundance for the year (Rudstam et al., 2004). Other cormorant species show movement among aquatic ecosystems within season or months frequently doubling abundance from one survey to the next as flocks move among sites (Dorfman and Kingsford, 2001). Although this approach

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lacks the resolution of individual movement studies, estimating a regional distribution of cormorants provides the best available method for assessing their distribution among aquatic ecosystems. It also provides information on relative demand for regional aquatic ecosystems and therefore comes closest to addressing a number of management issues. Specifically, where do foraging cormorants occur within a region and what is the prey demand associated with their distribution? An approach that captures the spatial distribution of foraging cormorants at regional scales would be an improvement over past methods.

Lake Huron's watershed includes numerous lakes inland from Lake Huron itself and a coastal zone defined by a complex of embayments and island archipelagos (Dorr et al., 2010a; Ridgway, 2010c). Nesting colonies on Lake Huron are abundant, distributed throughout the coastal zone, and in close proximity to inland lakes for numbers of colonies (Dorr et al., 2010b; Ridgway et al., 2006). If Great Lake colonies are near inland lake or river ecosystems then foraging cormorants could easily integrate these aquatic ecosystems into their foraging distribution at regional scales (e.g., Guillaumet et al., 2011). This has important implications for understanding the carrying capacity of the Great Lakes cormorant population. Population trends described by nest counts may be partially or perhaps largely supported by productivity from aquatic ecosystems inland and not strictly from Great Lake food webs.

The purpose of this study is to determine the distribution, abundance and prey demand of double-crested cormorants at a regional scale in the northern zone of Lake Huron. The focus is the Manitoulin Island region incorporating areas of the North Channel (Ridgway, 2010c), the four largest lakes on Manitoulin Island, and the South Shore facing the main body of Lake Huron. Many nests occur in colonies in the North Channel (2005: N = 7364 nests) and along the South Shore (2005: N = 1241 nests) but only a hundred or so nests occur on Manitoulin Island (Ridgway and Fielder, 2011; Weseloh et al., 2002; OMNR data). As in most locations, North Channel colonies are near the coast and in close proximity to the inland lakes with large recreational fisheries. Public interest in the cormorant issue on Manitoulin Island is regional in focus and links increasing numbers of cormorants as perpetrators of declines in fish abundance (Muter et al., 2009). The survey is based on aerial line transect methods beginning in the nesting period through to late summer, and as a result provides a consistent methodology across all aquatic ecosystems surveyed during and after the nesting period (Ridgway, 2010b,c). It provides the first regional scale estimate of population distribution and prey demand over a set of inland lakes and Great Lakes coast utilized by cormorants.

Methods

Study area

The aerial survey covered sections of the North Channel between Manitoulin Island and the mainland, four large lakes on Manitoulin Island (>2000 ha surface area; hereafter referred to as inland lakes; Table 1), and the South Shore of Manitoulin Island adjacent to the main body of Lake Huron (hereafter referred to as South Shore) (Fig. 1). The North Channel is characterized by a short flushing time, large drainage basin relative to surface area (i.e., relatively high phosphorus loadings), and a shallow bathymetry indicating a lack of significant depositional areas (Sly and Munawar, 1988; Thomas, 1988; Weiler, 1988). Manitoulin Island is the largest freshwater island in the world (Chapman and Putnam, 1973), with numerous lakes ranging in size from <200 ha to >10,000 ha (Jackson and Harvey, 1989), each with relatively high pH (>8.0) stemming from a bedrock of dolomitic limestone (Harvey and Coombs, 1971). The four lakes surveyed are the largest lakes on Manitoulin Island, representing 72% of the total surface area of lakes on the island (Table 1). The South Shore is fully exposed to the main basin of Lake Huron and receives significant fetch from prevailing winds (Fig. 1).

Table 1
Features of the four surveyed lakes on Manitoulin Island. Wolsey Lake is an embayment connected to the North Channel.

Lake name	Latitude	Longitude	Area (km^2)	Mean depth (m)
Manitou	45.7775	81.9836	106.1	15.2
Kagawong	45.8292	82.3056	56.4	11.2
Mindemoya	45.7611	82.2039	38.2	7.4
Wolsey	45.8228	82.5247	23.2	12.4

Flight surveys

Flights took place from mid-June through the end of August in 2005. Sampling periods were labeled mid-June (June 14–17), early July (July 6–8), late July (July 25–27), mid-August (Aug. 15–17) and late August (Aug. 29–31). The mid-June and early July flights occurred during the early chick and late chick stages of nesting, respectively. From late July onwards flights occurred in the post-fledging period. All flights occurred between 09:00 and 14:00 hours.

In each of the three areas, distance sampling with aerial line transects was used to estimate density of double-crested cormorants based on detections of birds flying, sitting on the water or loafing on shore. Procedures and details of the aerial cormorant survey are described in Ridgway (2010b,c). Distance sampling is a method of estimating animal density based on an observer's ability to detect animals as a function of distance from the line in conventional distance sampling (Buckland et al., 2001). Because aerial surveys always have detection probabilities <1.0, the probability of detecting double-crested cormorants on the flight line was based on earlier double-observer estimates of the detection process ($g(0) = 0.724$; Ridgway, 2010b).

Different flight path designs were used to sample three areas in the Manitoulin Island region. In the North Channel, four sample frames were monitored as part of a larger study on potential interactions between cormorant and fish abundance. Frames were 20 km × 20 km each and were spaced along the north shore of the North Channel to ensure approximately similar total nest counts among frames and 20 km spacing between frames (Fig. 1). Ten 20 km flight lines in each frame were set perpendicular to shore. Flight line positions are illustrated in the western most frame of Fig. 1. Flight lines were divided into eight sections each at 2.5 km intervals. Any cormorants detected inland from the North Channel were not included since the survey provided only limited coverage of the north shore along the mainland. Only line length over Lake Huron water or the immediate shoreline was used in density estimates. A total of 281 sample lines were covered in the North Channel.

Aerial transects were set perpendicular to shore and divided into approximately 2 km lengths across the surface of each lake in the large lake set of Manitoulin Island (Fig. 1). A total of 47 sample lines were flown on the combined lake set of Manitoulin Island.

A zigzag sampling design, without equal angles, was employed along the South Shore because the flight schedule began at the western end of Manitoulin Island and proceeded east on return to the flight center (Fig. 1). A gap between each leg of the zigzag route minimized sampling issues of adjacent lines in close proximity (Strindberg and Buckland, 2004). The zigzag route extended 5 km offshore with a total of 28 sample lines along the South Shore.

Data analysis

Data were analyzed using DISTANCE 5.0 (Thomas et al., 2010) based on a common detection function for all areas and post-stratification by sub-regions (i.e., North Channel, Manitoulin Is. inland lakes, South Shore). Conventional distance sampling was used with size-biased regression of cluster size on distance from the plane to