Foraging Locations of Double-crested Cormorants in the Beaver Archipelago of Northern Lake Michigan: Potential for Impacts on Smallmouth Bass

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Abstract.—The breeding population of Double-crested Cormorants (*Phalacrocorax auritus*) increased in the Beaver Archipelago of northern Lake Michigan, while simultaneously, a Smallmouth Bass (*Micropterus dolomieui*) population in the region declined. However, the role that cormorants played in this decline has remained uncertain. During summer 2003, VHF radiotelemetry and rafting locations were used to determine whether birds foraged primarily in bass habitat. The foraging activities of ten breeding cormorants were monitored by radiotelemetry from both land and water on a daily basis, weather permitting, throughout the breeding season. In addition, cormorant foraging raft locations were documented by boat survey throughout the breeding season. Radiotelemetry indicated that cormorants typically foraged 2.5 km away from their colonies, at the northeastern end of Beaver Island. This area overlaps with the area determined from rafting locations; however the latter were centered further south. These data allow for better estimation of foraging patch use by archipelago cormorants and indicate that birds are not typically concentrating their foraging in Smallmouth Bass habitat. Cormorants forage in open water in areas with dramatic changes in depth, and these locations agree with diet data that indicates that Alewife (*Alosa pseudoharengus*) are important prey. Data gathered has led to a better understanding of cormorant foraging patterns in the study area, and indicate that if cormorant foraging areas remain spatially separate from bass habitat, the probability of birds directly impacting these fish is low. *Received 1 March 2006, accepted 2 July 2006.*

Key words.—cormorant, *Phalacrocorax auritus*, bass, *Micropterus dolomieui*, Beaver Archipelago, Lake Michigan, foraging ecology, radiotelemetry, rafts.

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Over the past several decades, the population of Double-crested Cormorants (*Phalacrocorax auritus*), or DCCOs, has increased substantially in size throughout the Great Lakes Basin (Ludwig 1984; Cuthbert *et al.* 1997; Ludwig and Summer 1997; Wires *et al.* 2001), including the Beaver Archipelago of northern Lake Michigan (Seefelt and Gillingham 2005). Cormorants are opportunistic fish predators that often feed in shallow waters (Lewis 1929; Birt *et al.* 1987), and the relatively high density of birds has led to their implication in declines of both commercial and recreational fisheries throughout the Great Lakes region (Ludwig *et al.* 1989; Neuman *et al.* 1997; Lantry *et al.* 1999). Cormorants may have only small and localized effects on fish populations during migration (Kirsch 1995), but in the breeding season they can deplete some species of prey fish around their colonies (Birt *et al.* 1987).

The Beaver Archipelago, and particularly the habitat around Garden and Hog Islands, has been considered in the past to have excellent Smallmouth Bass (*Micropterus dolomieui*) fishing, and this reputation has been published in the national media (Smith 1975; Robinson 1995). However, compared to data gathered by researchers nearly 20 years ago, the bass population has declined by perhaps as much as 75-80% in some archipelago habitats (Seider 2003). Cormorants have been documented to feed on Smallmouth Bass (Blackwell *et al.* 1997; Neuman *et al.* 1997; Schiavone 2001, 2003) with records of bass predation in the Beaver Islands (Ludwig *et al.* 1989), but bass have not recently been documented as important prey in the diet of archipelago birds (Seefelt 2005). Thus, the role that cormorants may have played in the bass decline has remained uncertain.

Researchers have followed feeding flights of DCCOs by airplane to learn distances birds travel from breeding colonies to forage, and to attempt to determine potential home ranges of these birds (Ainley and Boekelheide 1990; Custer and Bunck 1992). How-

ever, in the main basin of Lake Michigan, there is little information on the localization of foraging sites within such large potential areas. With these data lacking, it is not easy to ascertain the ecological impacts that large numbers of foraging birds may have on aquatic communities, including fish populations that may be localized within particular habitats, such as the littoral and pelagic zones. Wanless *et al.* (1995), Gremillet (1997) and Gremillet *et al.* (1998, 1999) have successfully used radiotelemetry to monitor shags and cormorants, and to estimate foraging patch use and seasonal variation. Studies of this nature can lead to a better understanding of cormorant behavior patterns and help determine potential impacts on local prey sources.

The objectives of this study were to: 1) determine important foraging areas for breeding DCCOs in the Beaver Archipelago of northern Lake Michigan in 2003, by utilizing VHF radiotelemetry and by observing rafting areas throughout the breeding season; and 2) to compare DCCO foraging areas with previously documented high quality Smallmouth Bass habitat to determine the potential for direct impact on the bass fishery.

METHODS

Study Site

The study was conducted in the Beaver Archipelago of northern Lake Michigan. This archipelago consists of about ten main islands and numerous small islands (Fig. 1). The number of smaller islands depends on fluctuating lake levels. Two of the larger islands (Gull and Hat) and two small islands (Pismire and Southeast Garden) provided sites for nesting DCCOs in 2003. Pismire colony (lat 45°45.8'N, long 85°26.6'W) and the Southeast (SE) Garden colony (lat 45°45.8'N, long 85°27.0'W) are relatively close together (approximately 1.5 km or 0.92 miles apart) and are the focal colonies of this work. In 2003, 1164 breeding pairs were established at Pismire colony and 615 pairs were documented at SE Garden colony during June. By late July, the number of nests had declined to 807 and 355, respectively (Seefelt and Gillingham 2004). These two colonies were chosen due to their central location within the archipelago and their close proximity to important habitat areas for Smallmouth Bass, as indicated by Seider (2003). In the Beaver Archipelago, Smallmouth Bass are associated with inshore areas at several locations around Beaver, Garden, and Hog Islands. These fish prefer habitats with rock, gravel or sand substrates, as well as underwater structure (large rocks, submerged trees, aquatic vegetation), and typically are found in waters ranging from 2-6 m during the summer months (Becker 1983; Seider 2003).

Telemetry

VHF radiotransmitters (Model RI-2C Backpack, Holohil Systems Ltd., Carp, Ontario; 6.4 g with whip antennae; frequency range 150.026-150.204 MHz) were attached to harnesses that were constructed in the lab (prior to trapping birds) using standard methods outlined by Dunstan (1972). Harnesses were composed primarily of 8 mm Teflon ribbon. At junctions, seams were fastened by stitches (needle and thread), fast-setting marine adhesive, and Teflon-coated fiberglass tape. One connection was left free to allow for quick attachment to the birds in the field. The combined mass of each transmitter and harness was approximately 20 g, which is between 1-2% of the body weight of adult birds.

On 4 June 2003, eight birds were trapped using soft-catch leg hold traps (model SN35798, Forestry Suppliers, Jackson, Mississippi) on Pismire Island. To insure the capture of experienced adult birds, these traps were placed on and between nests at a well-established, central location in the colony, using standard methods (King *et al.* 1998). A central colony location was chosen, because in past years birds nesting in the center of the colony were successful at fledging chicks, while some nests at the periphery were not successful (Seefelt 2005). To better estimate foraging areas, it was important to select cormorants that would remain at the colony and within the Beaver Archipelago for the entire breeding season. When birds were captured, they were promptly removed from the traps and placed in wet pillowcases. Birds were carried to another area on Pismire Island, away from cormorant nests and out of sight of nesting birds, to be processed. Each bird was weighed and the harness (with radiotransmitter) was attached. Seam construction followed the same method used in the laboratory. As soon as the harness was attached, birds were released. Handling time was kept at a minimum (less than 10 minutes). To minimize colony disturbance at Pismire Island, on 5 June 2003, two birds were trapped and harnessed at SE Garden colony using the above methods for a total of ten transmittered birds.

Birds were monitored via radiotelemetry from a boat on a daily basis, weather permitting, throughout the breeding season (4 June-31 July) and during post-breeding (1 August-13 September) using a receiver (model LA 12-Q, AVM Instrument Co. Ltd., Colfax, California; frequency coverage 150.000-151.999 MHz) and 8-element yagi aerial. The time of day when radiotelemetry locations were obtained varied each day, depending on weather and wave conditions. It was difficult to sight birds, so triangulation was used to document bird locations, as follows. Once a bird's signal was heard, the GPS location of the boat was obtained (using a Garmin Handheld GPS Unit) and a compass bearing (Brunton® Outback Electronic Compass) based on the strongest signal strength was taken. This process was repeated twice at different locations within 10 minutes. In addition, date and time (beginning and ending) were noted. In some cases, signals were detected coming from the colonies and birds were assumed to be at or near the colonies. To avoid disturbing birds, documenting a more accurate location was not attempted. On several occasions, birds were actually sighted foraging in open water, but most bird locations were determined remotely to avoid disturbing the birds and to insure the safety of the researchers.

When weather did not permit boat travel, birds were monitored from land on the northeast portion of Bea-

ver Island, referred to as Sucker Point or Gull Harbor (lat 45°44.9'N long 85°29.9' W) (Fig. 1). From this station, it was noted whether birds were present at the colony (or near colony) or whether they were away. In addition, birds were monitored from the southeastern portion of Garden Island (lat 45°46.5'N long 85°27'W) on several occasions to determine presence at the colony (Fig. 2). From these data, the general daily activity periods of birds at the colonies could be determined. The activity pattern for each bird was defined by their first departure from the colony in the morning to their last arrival at the colony in the evening.

Rafting Locations

Beginning 18 May 2003 and ending 13 September 2003, cormorant rafting locations were marked by boat survey. Rafts (groups of birds on the water surface) can indicate foraging locations or staging areas (Hatch and Weseloh 1999). In this study, diving activity was used as an indication that rafting birds were, in fact, foraging. In general, daily surveys for foraging rafts were conducted on the northern and eastern waters around Beaver Island, weather permitting. The timing of these surveys varied from day to day based on weather and wave conditions. Also, in-shore areas of Garden Island that are considered to be primary Smallmouth Bass habitat, including Garden Island Harbor, Northcut Bay and Sturgeon Bay (Seider 2003), were surveyed (Fig. 2). Garden Island Harbor is 2.25 km (1.4 miles) from Pismire Island, Northcut Bay is 1 km (0.62 miles) from Pismire Island, and Sturgeon Bay is 0.5 km (0.3 miles) from Pismire Island. In addition, the Paradise Bay-St. James Harbor area of Beaver Island (3 km or 1.86 miles from Pismire Island) was also surveyed, as were the waters between Garden and Hog Island (north of Pismire Island) (Fig. 1). These inshore areas are also considered to be good habitat for bass, as opposed to open water habitats (Seider 2003). On several occasions, surveys were conducted around the entire periphery of Beaver Island. To

Figure 1. The Beaver Archipelago with inset map indicating the location of the island group in northern Lake Michigan.

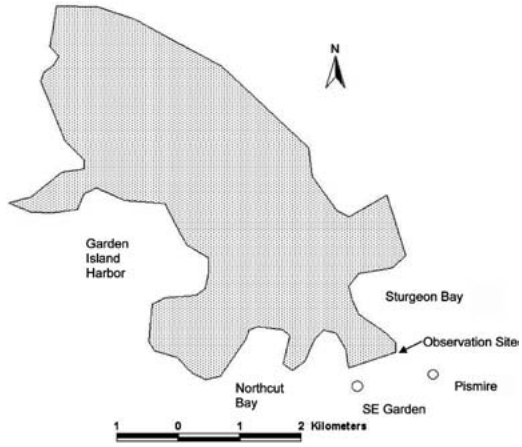

Figure 2. The bays of Garden Island that are documented Smallmouth Bass habitat and their proximity to Pismire and Southeast Garden colonies.

assure independence of all foraging sites documented, individual bird locations determined by radiotelemetry were not included as rafting sites.

Groups of rafting birds, ranging from three to approximately 300 birds, were located on these surveys. In some cases, when rafts were large (exceeding 50 birds), it was necessary to estimate bird numbers as opposed to actually counting all individuals; a portion of the flock was counted and this number was used to estimate the remaining number of cormorants based on the area covered by birds. The central location (area of greatest bird density) for each rafting site was marked using a Garmin hand-held GPS unit and an approximate water depth was noted (as read on a Humminbird Fish-finder Depth Sensor). The date and time were also recorded.

Analysis

Locations for each bird were determined using Locate II triangulation software (Nams 2001). Locate II uses a Maximum Likelihood Estimator (developed by R.V. Lenth) to plot locations that are 95% confidence areas of ellipses based on error angle (bearing standard deviation) (Nams 2001). These data were imported into ArcView GIS 3.3 and locations for all birds were plotted together. Kernel Estimator: Extension Animal Movement (Hooge and Eichenlaub 1997) set with standard parameters was used to determine primary foraging areas, based on the density of locations triangulated. This estimator provided 20% density contours based on the number of actual locations and determined the area where birds were most likely found when away from the colony; these areas were then compared to known bass habitat (Seider 2003). The area within each density contour was compared to water depth contours (NOAA 1989).

Rafting locations, as well as the number of birds per raft and date, were imported into ArcView GIS 3.3. These were plotted and 20% density contours were determined, that weighted each raft location by the number of birds observed per raft (Hooge and Eichenlaub 1997). Because both large and small rafts were typically marked in the same day, weighting the points by the number of birds present was a more effective way to de-

termine foraging patch use by archipelago birds. Greater numbers of birds using a location could reflect the number of prey available, and therefore provide a better estimation of foraging site quality both temporally and spatially. Rafting areas were compared to known bass habitats (Seider 2003), and the area within each density contour was compared to water depth contours (NOAA 1989).

RESULTS

A total of 131 foraging locations were plotted for the ten birds with radiotransmitters from 09 June 2003 through to 07 September 2003. All birds remained in the Beaver Archipelago until at least 31 August 2003, with eight DCCOs remaining in the area through 13 September 2003. A total of 223 at (or near) colony locations were documented by boat and an additional 185 were documented from Beaver Island. The Sucker Point-Gull Harbor and Garden Island observations indicated that the birds typically began leaving their colonies at 05:00 EST, and all birds returned to roost by 19:00 EST during the breeding season. Birds spent a considerable amount of time at or near the colonies during the day.

Figure 3 shows the 20% density contours for all foraging locations marked using radiotelemetry. Locate II reported a mean error angle (bearing standard deviation) for triangulated locations as 0.138. Overall, the harnessed birds tended to concentrate their foraging efforts in an area at the northeastern end of Beaver Island. This area is centered approximately 2.5 km (1.55 miles) from the colonies and is close to Luney Point and the Paradise Bay-St. James Harbor mouth. It is also an area with dramatic depth contours, with areas of only 1-3 meters dropping rather abruptly to areas greater than 18 meters (NOAA 1989). In addition, there are several shoals and a channel used by ferry service to Beaver Island (NOAA 1989). The density contours indicate that although birds typically forage over a large area, most foraging locations were concentrated near the ferry channel. Overall, cormorants did not show any seasonal changes in foraging locations, except for one bird that foraged very close to Pismire Island during June and part of July. These points are not included in the density contours in Figure 3, because it was difficult to discern when this bird was at the colony or foraging in the water near the colony. However, this bird did forage in the area shown in Figure 3 during the latter half of the field season.

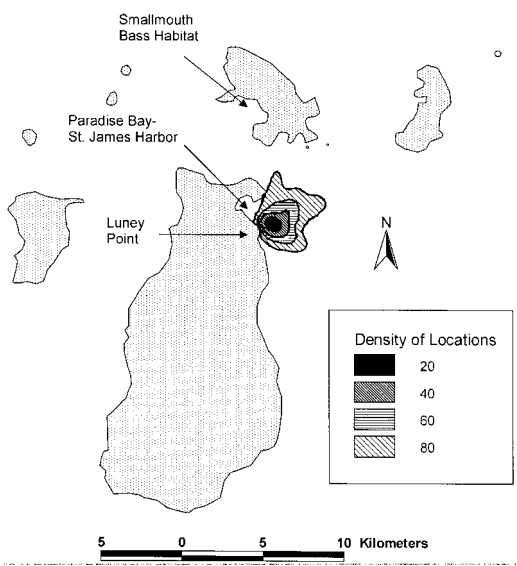

Figure 3. Density contours for foraging areas of Double-crested Cormorants determined by VHF radiotelemetry during the 2003 breeding season.

A total of 271 rafting locations, with an average of 33 birds per raft, were documented in 2003. Figure 4 shows the 20% density contours weighted by the number of birds per raft. This area overlaps the foraging areas for birds with radiotransmitters and encompasses the sites that were visited most frequently by harnessed birds, including the ferry channel. However, the highest density of weighted rafting locations is further south and is centered near Conn's Point and the north end of Sand Bay, Beaver Island. Like the area defined by telemetry, the major rafting areas have rather dramatic depth contours, with areas of 1-3 meters dropping off to areas of 18 meters or more (NOAA 1989). The density contours indicate that rafting birds use a relatively large area for foraging, but again concentrate their efforts where there are rapid changes in depth. The areas highlighted to the southeast and west of Beaver Island are due to a few large rafts (200+ birds) observed at sites in July. Very few rafts

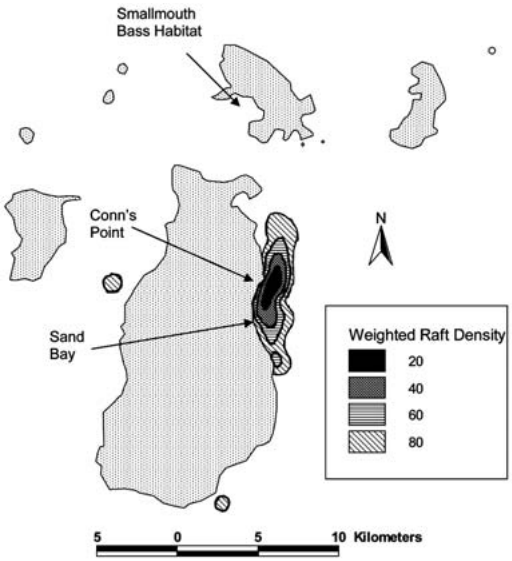

Figure 4. Weighted density contours for foraging areas determined by Double-crested Cormorant rafting locations using boat surveys during the 2003 breeding season.

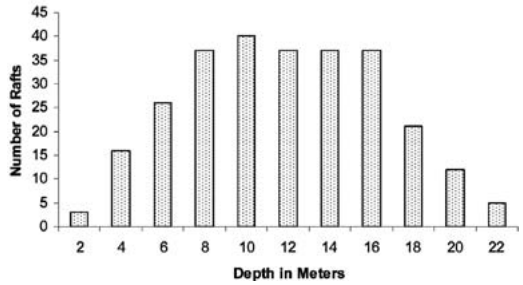

Figure 5. Water depth (in 2 meter intervals) documented at Double-crested Cormorant foraging raft locations during the 2003 breeding season.

were documented in in-shore areas of Garden Island, St. James Harbor-Paradise Bay, and between Garden and Hog Islands.

Overall, cormorant foraging rafts were located in areas that ranged in depth between 2 and 22 meters, with an average depth of 11.63 meters (SD = 4.66) (Fig. 5). The centers of most rafts were documented to be between 8 and 16 meters in depth, however these areas were often situated where depth was changing rather abruptly (NOAA 1989).

DISCUSSION

Both radiotelemetry and rafting site maps produced similar foraging area patterns in 2003. The primary foraging areas for many cormorants in the Beaver Archipelago are centered near the northeastern portion of Beaver Island, especially near dramatic depth contours. Cormorants nesting on Pismire and SE Garden islands appear to remain close (within a few kilometers) to the colonies when foraging. Both methods indicate that important habitat areas for Smallmouth Bass are not used extensively by DCCOs in the study area, including those areas relatively close to the colonies. Cormorants do forage in areas that share the same range of depths frequented by Smallmouth Bass during the summer (Becker 1983; Seider 2003), however birds tend to forage in deeper water, as well as in open water areas spatially separated from the inshore habitats preferred by bass (Seider 2003). The ferry channel, which may attract schooling forage fishes due to rapid changes in depth, appears to be an important area for foraging cormorants. The foraging distances documented in this study tend to agree with other studies; similar results have been reported in DCCOs breeding in the Wisconsin waters of Green Bay, Lake Michigan (Custer and Bunck 1992), and in Great Cormorants (*Phalacrocorax carbo carbo*) breeding at the Chausey Islands, France (Gremillet 1997).

The differences between the radiotelemetry and rafting locations may be due to individual differences in bird foraging behavior. More likely, the rafting locations documented represent not only Pismire and SE Garden birds, but other birds present in the archipelago, including non-breeders. The 20% density contours do indicate a great deal of overlap between radiotelemetry and rafting locations. However, fewer rafts were documented in the area used most intensely by harnessed birds, which tended to remain much closer to their colonies. Yet, the overlap does indicate that both known breeders and other unknown birds forage in the same general area, and may be focusing on the same basic habitat indicators (rapid changes in depth) when foraging. These areas seem

to correlate with preferred habitats for important prey (see below). Interestingly, not all areas that are relatively close to Pismire and SE Garden colonies that show sharp changes in depth appear to be important foraging sites for cormorants in 2003. The channel between Beaver and Garden Islands is such an area where drastic depth contours occur. However, very few individual locations or rafting sites were documented here, which could be due to the strong currents that may make this area less suitable for foraging cormorants and/or their prey.

Cormorant foraging locations in the Beaver Archipelago also seem to correspond with areas that are frequented by Alewife (*Alosa pseudoharengus*). Alewife are a major planktivorous species in the Lake Michigan community and an important energy link to upper consumer levels (Madenjian *et al.* 2004). In addition, Alewife are an important link between inshore and deep lake communities (Eck *et al.* 1987; Madenjian *et al.* 2004). Because of their life history and their abundance, Alewife are considered to be a key species in Lake Michigan and their population trends appear to be a driving force in fish community dynamics (Eck *et al.* 1987; Madenjian *et al.* 2002, 2004). In the study area, Alewife have also been documented to be an important prey for cormorants and typically comprise an estimated 72% of the prey biomass consumed by breeding DCCOs and their chicks each year (Seefelt and Gillingham 2005). Because cormorant diets include species that are of little commercial value but important in community trophic dynamics (Craven and Lev 1987), birds could have a secondary effect on sport fisheries by competing with desired species for forage fish and other prey such as crayfish (*Orconectes* spp.). Although the effects on forage fish numbers may be limited and may only occur in localized areas (Madenjian and Gabrey 1995), this combined with direct sport fish depredation may have some impact on sport fish populations. Data gathered in 2003 suggest that birds are not foraging extensively in Smallmouth Bass habitat; however, whether cormorants are competing with these bass for local prey items remains uncertain.

Cormorants nesting at some locations in the Beaver Archipelago, including Hat and Gull Islands, were not studied in this work. These colonies typically support more nesting pairs than either Pismire or SE Garden colonies, with Hat Island consistently being the largest colony (Seefelt and Gillingham 2005). Hat Island is relatively near some areas of bass habitat around Hog Island (Seider 2003); however, open-water areas, specifically areas of dramatic depth contours, are much closer to this colony (NOAA 1989). Furthermore, there has been no evidence of bass in the diet of these birds (Seefelt 2005). The Gull Island colonies are separated from the main island group by a stretch of open water to the west of Beaver Island. From aerial surveys (unpublished data), it was concluded that the cormorants breeding at Gull Island remain close to these colonies and do not regularly travel to the Main Archipelago. In addition, DCCO diet data from Gull Island documents that these birds are dependent on Alewife (Seefelt 2005).

In conclusion, the primary foraging locations of DCCOs documented using radiotelemetry and rafting locations are concentrated in areas close to their colonies, but removed from Smallmouth Bass habitat. Cormorant foraging areas, as determined by radiotelemetry and rafting sites, do support bird diet data gathered in a larger study that demonstrates birds primarily feed on Alewife and other prey that are not valuable to sport or commercial fisheries. Multiple years of cormorant foraging location data can be combined with data on prey population dynamics to further investigate the complex relationships between cormorants and their prey. Ascertaining foraging locations alone, in the absence of a cormorant diet study, can aid in determining potential impacts. If cormorant foraging areas remain spatially separated from the habitats of valuable fish species, the likelihood of direct impact is low.

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