J. Field Ornithol., 63(2):203-211

FEEDING FLIGHTS OF BREEDING DOUBLE-CRESTED CORMORANTS AT TWO WISCONSIN COLONIES

THOMAS W. CUSTER
U.S. Fish and Wildlife Service
Patuxent Wildlife Research Center
P.O. Box 2618
La Crosse, Wisconsin 54602-2618 USA

CHRISTINE BUNCK
U.S. Fish and Wildlife Service
Patuxent Wildlife Research Center
Laurel, Maryland 20708 USA

Abstract.—Unmarked Double-crested Cormorants (*Phalacrocorax auritus*) (n = 523) were followed by airplane from Cat Island and Spider Island, two nesting colonies in Wisconsin, to their first landing site. Cormorants flew an average of 2.0 km from Cat Island (maximum 40 km) and 2.4 km from Spider Island (maximum 12 km). The mean direction of landing sites differed seasonally for flights from Spider Island, but not from Cat Island. Cormorants generally landed in Green Bay or Lake Michigan (>99%) and rarely landed in inland lakes or ponds. The most frequent (>80%) water depth at landing sites for each colony was <9.1 m. Water depths ≥9.1 m were used less frequently than available within the maximum observed flight distance for each colony. The average flight speed for cormorants was 61 km/h.

VUELOS DE ALIMENTACIÓN DE INDIVIDUOS REPRODUCTIVOS DE *PHALACROCORAX AURITUS* DE DOS COLONIAS EN WISCONSIN

Sinopsis.—Individuos del cormorán *Phalacrocorax auritus*, que no habían sido marcados (n = 523), fueron seguidos con el uso de un aeroplano, desde sus colonias de anidamiento en las islas Cat y Spider, hasta el primer lugar en donde descendieron. Los cormoranes viajaron un promedio de 2.0 km (máximo 40 km) desde la Isla Cat y de 2.4 km (máximo de 12 km) desde la Isla Spider. La dirección promedio de los lugares en donde descendieron las aves varió estacionalmente en vuelos que se originaron en la Isla Spider, no así de vuelos desde la Isla Cat. Los cormoranes por lo general descendieron en Green Bay o el Lago Michigan (>99%) y raras veces en lagos internos o pozas. La profundidad más frecuente del agua (>80%) en los lugares de descenso, para cada colonia fue <9.1 m. Profundidades ≥a 9.1 m fueron utilizadas con menor frecuencia en relación a la disponibilidad de éstas a lo largo del máximo de las distancias de vuelo observadas para cada colonia. La velocidad promedio de vuelo resultó ser de 61 km/hr.

The U.S. Fish and Wildlife Service is investigating the effects of environmental contaminants on nesting Double-crested Cormorants (*Phalacrocorax auritus*) in Wisconsin. One of the assumptions is that contaminants accumulated by chicks are of local origin; however, the distance cormorants fly from the colony to feed is unknown. As the reduced wing span of cormorants requires more power output than most seabirds (Owre 1967, Pennycuick 1987), they probably forage close to the colony. Palmer (1962) suggested that a nesting requirement of this species is an adequate food supply within a short (8–16 km) foraging range; however, flights as far as 20 km have been suspected (Hobson et al. 1989). The objectives of this study were to measure the distance and direction of cormorant

feeding flights at two nesting colonies in Wisconsin and to determine whether colony or seasonal differences occur.

STUDY AREAS AND METHODS

Spider Island (45°12.5'N, 86°58'W) is a 7-ha limestone outcropping in Lake Michigan off the Door Peninsula (Fig. 1). In late June 1990, about 1500 cormorant pairs had active ground nests with eggs or chicks (K. Stromborg, U.S. Fish and Wildlife Service, pers. comm.). Most egg-laying and hatching occurred in the first week of May and the first week of June. Over 600 2-wk-old chicks were banded on 14 June; over 2500 chicks were banded over the summer.

Cat Island (44°34'N, 88°00'W) is a 1-ha island in Green Bay near the entrance of the Fox River (Fig. 2) and is about 70 km south and west of Spider Island. An estimated 914 cormorant nests were counted in eastern cottonwood (*Populus deltoides*) trees on 15 Jun. 1990 (T. Bahti, Wisconsin Department of Natural Resources, pers. comm.). As the trees were dead and the nests were high (>18 m), the trees were dangerous to climb and information on nesting chronology is limited. Based on advanced embryos in eggs collected from three nests on 24 May 1990, the timing of nesting events was similar to that on Spider Island.

During daylight hours (0730–1830 hours) from 18 May to 24 Jul. 1990, unmarked Double-crested Cormorants were followed by a Cessna 172 airplane from Cat Island and Spider Island to their landing sites. This technique has been used earlier (Custer and Osborn 1978) to determine flight distances of other colonially-nesting birds. About 80 h were expended in 11 flights to Spider Island and 18 flights to Cat Island.

The airplane with pilot and one or two observers circled counterclockwise about 100–300 m away from and 180–240 m above the colonies. The first cormorant(s) to leave the colony was followed to its landing site and the location was plotted on National Oceanic and Atmospheric Administration (NOAA) maps (Number 14918 scale 1:25,000; Number 14909 scale 1:80,000). Generally, sufficient landmarks identified the location; however, for less certain locations near Cat Island, Loran-C or VOR (Very High Frequency Omnidirectional Radio Range) coordinates were also taken. Time of day and time of the flight were recorded as well as the number and time that other cormorants joined the bird(s) being followed. Cormorants that joined flights included birds coming off the water and those leaving the colony before or after the one being followed. The number of cormorants or gulls at the landing site was also recorded. During each airplane flight, we attempted to follow about 20 birds in a 2-h time period; this schedule varied by the distance the birds flew and weather. After following an individual, we returned to the colony near the site of departure of the previous individual and repeated the procedure. We ignored any cormorants leaving in the previous direction until our airplane made one full circle around the colony.

In addition to inland ponds and lakes, four types of water locations were identified from NOAA maps: channel, water <1.8 m, 1.8–9.0 m

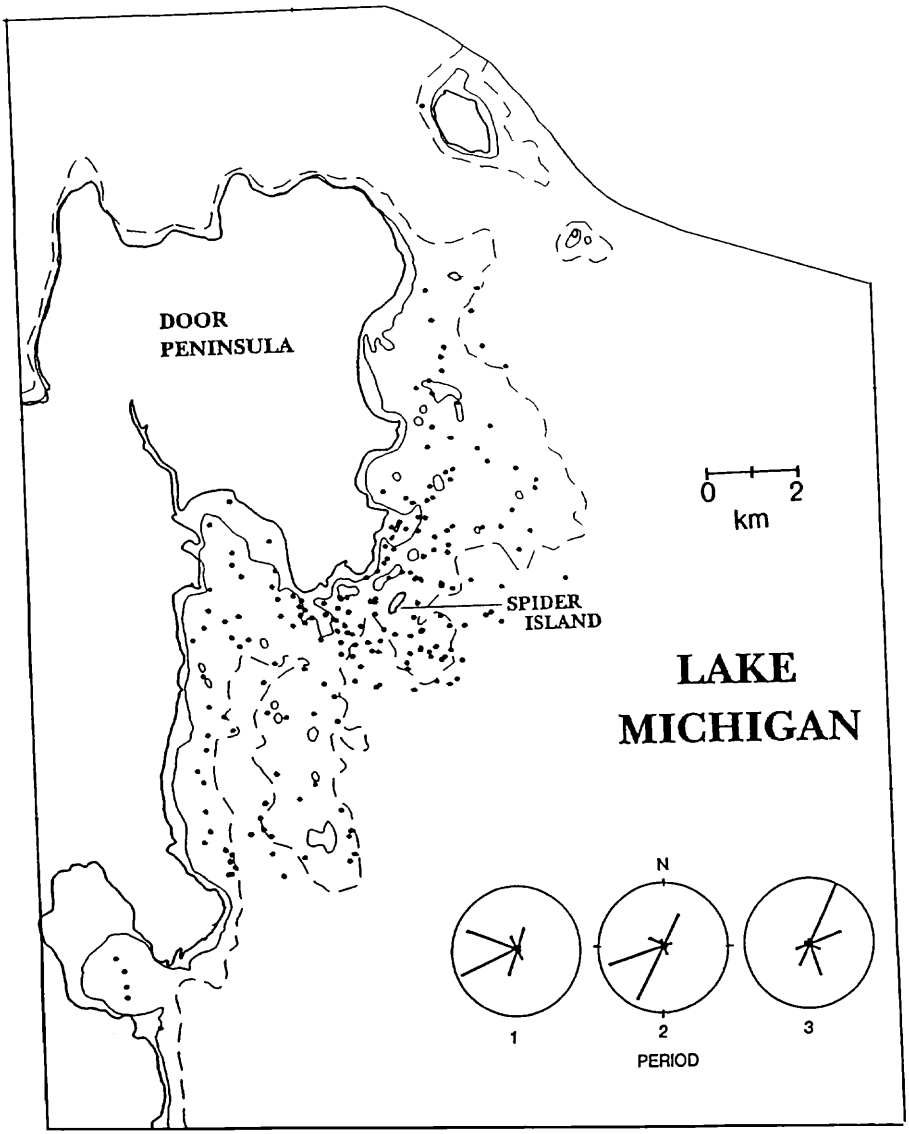

FIGURE 1. First landing locations (dots) of Double-crested Cormorant flights from Spider Island. The light solid line off Door Peninsula is the 1.8 m water depth contour; dashed line is the 9.1 m water depth contour. The inserted circles represent the percent of cormorant flights (n = 207) by direction over three periods. The radius of the circle represents 35%. Direction is in eight 45° increments arranged clockwise from north. The three periods are: 18 May–7 June, 8 June–7 July and 8–25 July.

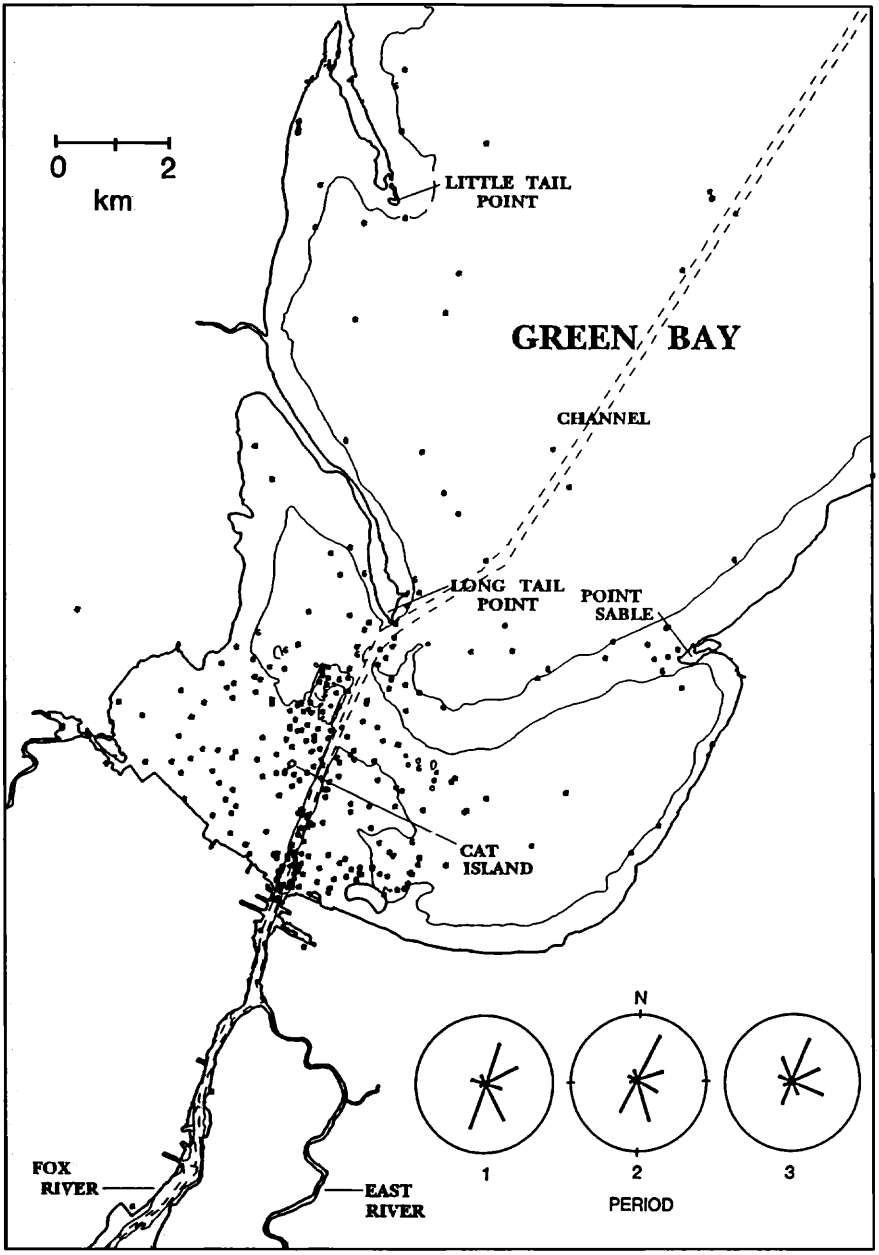

FIGURE 2. First landing locations (dots) of Double-crested Cormorant flights from Cat Island. The light solid line off shore is the 1.8 m water depth contour; dashed lines indicate the channel. Twelve landing locations not shown were farther into Green Bay and off the map. The inserted circles represent the percent of cormorant flights (n = 316) by direction over three time periods. See Figure 1 legend for further explanation.

and ≥9.1 m deep. The area of the four water types (not including ponds and lakes) that existed within the maximum foraging range of cormorants from each colony was estimated with an electronic digitizer on NOAA map 14909 for Spider Island and NOAA map 14918 for Cat Island.

The nesting season was divided into three periods roughly corresponding to late incubation through hatching (18 May–7 June), nestling (8 June–7 July) and fledgling (8–25 July) periods. Only flights greater than 5 km from each colony were considered in the analysis of flight speed over land.

Chi-squared goodness of fit tests were used to compare frequencies. For the analysis of flight distance, number of leaving cormorants, and number of landing cormorants, variances were unequal among groups and log transformation greatly increased the homogeneity of variances. A two-factor analysis of variance (ANOVA) was used to assess differences between colonies and among periods; multiple comparison tests were used to quantify the differences. The level of significance was 0.05 unless otherwise stated.

Each landing location was categorized into one of eight compass directions, each 45°, away from the center of the colony arranged clockwise from north. The directions of landing sites from the colony were compared among the three time periods for each colony separately with Mardia's k-sample test (Batschelet 1981). If directional differences were noted among periods, the Mardia two-sample test (Batschelet 1981) was used to identify how the three periods differed. For the Mardia two-sample tests, the overall α level of 0.05 was divided by the number of paired comparisons (3) and this corrected α level was applied to each comparison.

RESULTS

Of 222 cormorants followed from Spider Island, 15 (7%) were lost from sight during the flight; 10 of 326 (3%) followed from Cat Island were lost from sight. The mean distance flown to a landing site for 207 cormorants was 2.4 km (SE = 0.18) for Spider Island and for 316 cormorants was 2.0 (SE = 0.10) km for Cat Island (Table 1, Fig. 3). The maximum distance flown was 11.6 km for Spider Island and 40 km for Cat Island.

Differences in distances flown by cormorants between Spider and Cat islands were not the same in all periods (Table 1; interaction $F = 4.0$; df = 2, 517; $P = 0.0189$). In period 2, cormorants from Cat Island flew significantly shorter distances than birds from Spider Island, although flight differences were similar between colonies in periods 1 and 3. Cormorants from Cat Island in periods 1 and 3 flew farther than those in period 2. Cormorants from Spider Island few similar distances in all three periods.

More cormorants left the colony per flight from Spider Island than Cat Island (Table 2; $F = 7.1$; df = 1, 508; $P = 0.0079$). For the number of cormorants landing at the end of the flight, differences between colonies were not similar in the three periods (Table 2; interaction $F = 12.8$; df

TABLE 1. Geometric mean flight distances of Double-crested Cormorants at two colonies in Wisconsin over three periods.

Period	Geometric mean distance (km) and (*n*)	
	Cat Island	Spider Island
18 May–7 June	2.3 B[1] (57)	2.4 A (56)
8 June–7 July	1.7 A (176)	2.6 A (91)
8–25 July	2.5 B (83)	2.3 A (60)
Overall	2.0 (316)	2.4 (207)

[1] Means among periods by colony not sharing the same letter are significantly different ($P < 0.05$).

= 2, 507; $P < 0.0001$). In periods 2 and 3, the number of cormorants landing in flights from Spider Island was greater than the number landing from Cat Island; no differences were noted in period 1. Throughout the study, the number of cormorants landing at the end of flights from Spider Island was similar. At Cat Island the number landing in period 1 was higher than in periods 2 and 3.

Cormorants joined flights from the colonies and the frequency of these additions varied between colonies and periods. Of the flights from Spider Island, 58% had more birds landing than leaving the colony; this frequency did not vary significantly among periods (Table 2, $\chi^2 = 2.9$, df = 2, $P = 0.235$). In contrast, only 18% of the flights from Cat Island had more birds landing than leaving, and the frequency was significantly higher in

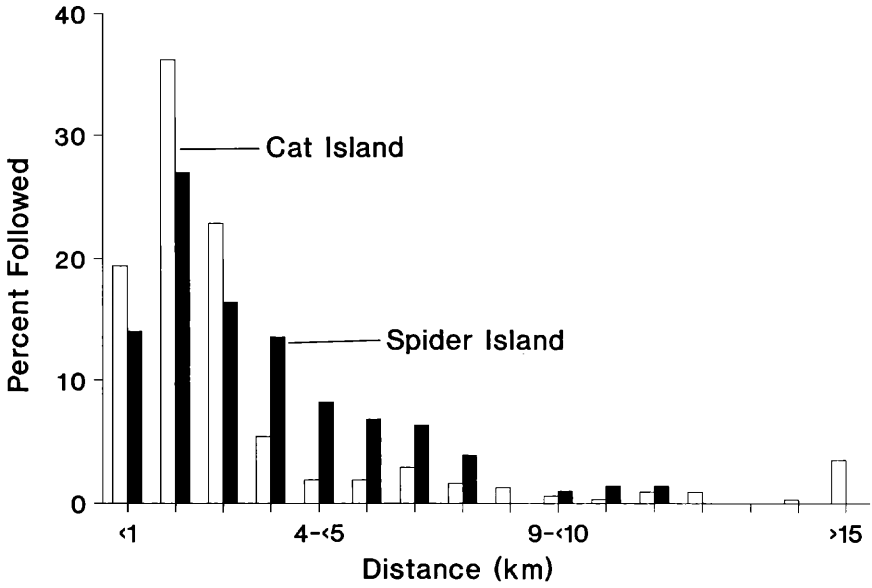

FIGURE 3. Frequency distribution (%) of flight distances (km) of Double-crested Cormorants followed from Spider Island ($n = 207$) and Cat Island ($n = 316$).

period 1 than period 2 or 3 (overall $\chi^2 = 24.98$, df = 2, $P < 0.001$). The frequencies of flights joined by other cormorants were similar between colonies for period 1 ($\chi^2 = 0.495$, df = 1, $P = 0.482$), but were higher at Spider Island than Cat Island for periods 2 ($\chi^2 = 74.07$, df = 1, $P < 0.001$) and 3 ($\chi^2 = 30.80$, df = 1, $P < 0.001$).

The frequency of cormorants landing at sites with other cormorants or gulls present did not vary by period ($P > 0.05$ for each colony among time periods) but did vary between colonies. Flights from Spider Island (87 of 207 = 42%) more frequently ($\chi^2 = 30.83$, df = 1, $P < 0.001$) ended at locations where other cormorants and gulls were present than did flights from Cat Island (62 of 316 = 20%).

Cormorants from Cat Island generally landed east of the colony and the mean direction was not significantly different among time periods (Mardia k-sample test, $W = 5.36$, df = 4, $P = 0.2526$, Fig. 2). In contrast, the mean direction of landing sites for cormorants from Spider Island was significantly different among time periods ($W = 61.71$, df = 4, $P < 0.0001$) and each time period was different than the other (Mardia two-sample tests, df = 2, $P < 0.0167$, Fig. 1). Landing sites were generally westerly in period 1 for Spider Island; south and west in period 2; and north and east in period 3.

Nearly all cormorants landed in Green Bay or Lake Michigan (Table 3, Figs. 1 and 2); 4 of 316 (1%) cormorants followed from Cat Island landed in inland lakes and ponds, however. The most frequent water depth used by cormorants followed from Cat Island was water <1.8 m, followed by water 1.8–9.0 m. In contrast, the most frequent water depth used by cormorants followed from Spider Island was 1.8–9.0 m, followed by ≥9.1 m. Cormorants followed from Cat Island landed in water <1.8 m deep more frequently (58%) than it was available (12%) within 40 km of the colony, the maximum recorded flight distance from that colony ($\chi^2 = 317.3$, df = 3, $P < 0.001$); water depth ≥9.1 m was selected less frequently (1%) than available (30%). Cormorants followed from Spider Island landed in water 1.8–9.0 m more frequently (78%) than it was available (19%) within 11.6 km of the colony, the maximum flight distance from that colony ($\chi^2 = 187.3$, df = 2, $P < 0.001$); water depth of ≥9.1 m was selected less frequently (17%) than available (77%).

The average ground speed for cormorants from both colonies combined was 61.2 km/h ± 2.0 SE ($n = 42$ Spider Island, $n = 39$ Cat Island) for flight distances >5 km.

DISCUSSION

Our results support the hypothesis that prey fed to cormorant chicks originate from near the colony and thus contaminants accumulated in chicks are from local sources. Earlier studies based on wing span of cormorants (Owre 1967, Pennycuick 1987) and qualitative description of distance (Mendall 1936, Palmer 1962) suggested foraging areas near the colony. The average flight distance of cormorants from the two colonies in this study was less than 3 km.

This study and earlier studies (Lewis 1929, Palmer 1962) suggest that

TABLE 2. Number of Double-crested Cormorants leaving and landing from two Wisconsin colonies for three periods.

Period	Geometric mean # leaving (n)		Geometric mean # landing		Percent of flights where # landing > # leaving	
	Cat Is.	Spider Is.	Cat Is.	Spider Is.	Cat Is.	Spider Is.
18 May–7 June	1.2 (52)	1.3 (56)	2.3 B[1]	2.8 A	42% B[2]	49% A
8 June–7 July	1.2 (175)	1.3 (91)	1.2 A	4.1 A	12% A	63% A
8–25 July	1.1 (80)	1.4 (60)	1.3 A	2.9 A	16% A	62% A
Overall	1.2 A[3]	1.3 B	1.4	3.3	18%	58%

[1] Means among periods by colony not sharing the same letter are significantly different from one another ($P < 0.05$).

[2] Percentages among periods by colony not sharing the same letter are significantly different from one another ($P < 0.05$).

[3] Means between colonies not sharing the same letter are significantly different from one another (P Colony = 0.0079).

Double-crested Cormorants prefer to feed in shallow water. Lewis (1929) observed fishing depths of 2–7 m and Mendall (1936) stated that cormorants feed in water less than 9 m. Palmer (1962) stated that they feed in moderately shallow water generally less than 9 m and sometimes as deep as 22 m. In our study, over 80% of feeding flights for either colony were to water <9.1 m deep. Additionally, water depths ≥9.1 m were used significantly less than available within the maximum observed foraging range for either colony.

In this study we assumed that the airplane did not disturb the normal activity of the birds. As the birds generally left the colony singly rather than in large groups and they were regularly observed landing in the colony while the aircraft circled, aircraft disturbance did not seem to affect behavior. Another basic assumption was that the first landing site was indicative of the flight distance. Although data on this species are not available, radio-transmittered Shags (*Phalacrocorax aristotelis*) generally (>65%) flew back to the colony from the first landing site (Wanless et al. 1991).

TABLE 3. Frequency of water landing locations of Double-crested Cormorants followed from Cat Island and Spider Island, Wisconsin, and frequency of available habitat within maximum distance flown from Cat Island (40 km) and Spider Island (11.6 km).

Landing description	Cat Island				Spider Island			
	Flights		Habitat		Flights		Habitat	
	#	%	km²	%	#	%	km²	%
Inland lakes/ponds	4	1	—[a]	—	0	0	—	—
Channel	24	8	8	1	0	0	0	0
<1.8 m water depth	182	58	89	12	9	4	12	4
1.8–9.0 m	103	33	409	57	163	78	57	19
≥9.1 m	3	1	216	30	35	17	234	77

[a] Not measured.

The mean ground speed of cormorants in this study (61.2 km/h) was higher than the mean airspeed reported earlier (52.9 km/h, Pennycuick 1989), but was within reported limits (72 km/h maximum). The differences probably result from our lack of precision in measuring distance combined with the fact that we did not take into account surface wind. Russell (1947) reported that the ground speed of one cormorant was 77 km/h close to the water in no wind.

Cormorants from Spider Island were more social than cormorants from Cat Island. Larger groups of cormorants left Spider Island than Cat Island on feeding flights and a higher percentage of landing sites of flights from Spider Island than Cat Island had cormorants or gulls present on the water. Also, for periods 2 and 3, more cormorants joined flights from Spider Island than Cat Island. These differences in behavior were probably due to the larger number of cormorants nesting on Spider Island. The difference may have been enhanced by a rainfall of 12.4 cm on 22 Jun. 1990, which muddied the waters of lower Green Bay for several weeks, however. We suspect that the lowered visibility in the water decreased the effectiveness of group foraging near the Cat Island colony.

ACKNOWLEDGMENTS

We thank Michael Samuel for statistical assistance; Christine Mitchell, Kenneth Stromborg, J. Christian Franson, Harry Coulombe, Thomas Erdman, John Braastad and Danny Custer for recording data; Jane Woosencraft and Robert Prey for piloting the aircraft; Dick Birger, Manager Horicon NWR, for access to Spider Island; Randolph Loatsch, Ron Oberg, Rich Pahlik and the Brown County Sheriff's Department for their timely rescue efforts; David Rueff for assistance with the graphics; and R. Michael Erwin, Gary Heinz, Charles Henny, Keith Hobson and an anonymous reviewer for comments on the manuscript.

LITERATURE CITED

BATSCHELET, E. 1981. Circular statistics in biology. Academic Press Inc., New York, New York. 371 pp.

CUSTER, T. W., AND R. G. OSBORN. 1978. Feeding habitat use by colonially-breeding herons, egrets, and ibises in North Carolina. Auk 95:733–743.

HOBSON, K. A., R. W. KNAPTON, AND W. LYSACK. 1989. Population, diet and reproductive success of Double-crested Cormorants breeding on Lake Winnipegosis, Manitoba, in 1987. Colonial Waterbirds 12:191–197.

LEWIS, H. F. 1929. The natural history of the Double-crested Cormorant (*Phalacrocorax auritus auritus* (Lesson)). Ru-Mi-Lou Books, Ottawa, Canada. 94 pp.

MENDALL, H. L. 1936. The home-life and economic status of the Double-crested Cormorant *Phalacrocorax auritus auritus* (Lesson). Maine Bull. 39:1–159.

OWRE, O. T. 1967. Adaptations for locomotion and feeding in the Anhinga and the Double-crested Cormorant. Ornithol. Monogr. No. 6. 138 pp.

PALMER, R. S. 1962. Handbook of North American birds, Volume 1. Yale University Press, New Haven, Connecticut. 567 pp.

PENNYCUICK, C. J. 1987. Flight of seabirds. Pp. 43–62, *in* J. P. Croxal, ed. Seabirds: feeding ecology and role in marine ecosystems. Cambridge Univ. Press, Cambridge, United Kingdom.

———. 1989. Span-ratio analysis used to estimate effective lift : drag ratio in the Double-crested Cormorant *Phalacrocorax auritus* from field observations. J. Exp. Bio. 142:1–15.

RUSSELL, J. 1947. Flight speed of the Florida Cormorant. Florida Nat. 19:66.

WANLESS, S., M. P. HARRIS, AND J. A. MORRIS. 1991. Foraging range and feeding locations of Shags *Phalacrocorax aristotelis* during chick rearing. Ibis 133:30–36.

Received 29 Jul. 1991; accepted 22 Oct. 1991.