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Migration Patterns of Double-crested Cormorants Wintering in the Southeastern United States

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Abstract.—Migration patterns of Double-crested Cormorants (*Phalacrocorax auritus*) wintering in the southeastern U.S. are poorly understood. Movement data were analyzed from 28 cormorants captured in Alabama, Arkansas, Louisiana and Mississippi and equipped with satellite transmitters. Four (three immature, one adult) cormorants did not migrate and stayed in the southeastern U.S. throughout the year. During spring, cormorants captured in Alabama migrated east of the Mississippi River and primarily west of the Appalachian Mountains. Cormorants from Arkansas, Louisiana and Mississippi migrated north along the Mississippi River Valley, the Missouri River Valley and/or the Ohio River Valley. The earliest departure for spring migration was 26 March, whereas the latest departure was 12 May. Adult cormorants departed for spring migration earlier than immature cormorants. The average departure date for fall migration was 1 October. Mean duration of spring migration was twelve days, and cormorants traveled an average of 70 km per day. *Received 16 September 2007, accepted 7 November 2009.*

Key words.—Double-crested Cormorant, migration timing, migration routes, movement patterns, *Phalacrocorax auritus*, Platform Transmitters, PTT, satellite telemetry.

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Numbers of Double-crested Cormorants (*Phalacrocorax auritus,* hereafter cormorants) wintering in the southeastern United States have greatly increased during the last 30 years (Glahn and Stickley 1995; Glahn and King 2004). These cormorants commonly forage at commercial aquaculture facilities and come into conflict with farmers (Glahn *et al.* 1995; King *et al.* 1995; Glahn and King 2004). Glahn *et al.* (2000) estimated that cormorant predation on Channel Catfish (*Ictalurus punctatus*) costs the Mississippi aquaculture industry up to $25 million annually. Three previous studies have provided useful information about local winter movements and behavior of cormorants in northwestern Mississippi (King *et al.* 1995; King 1996; Tobin *et al.* 2002), but little is known about their migratory behavior and ecology (Palmer 1962; Dolbeer 1991; Johnsgard 1993; Hatch and Weseloh 1999). Dolbeer (1991) found that fall migration typically occurred from October through November, and spring migration occurred primarily from April through May for cormorants banded at interior colonies of the northern U.S. and southern Canada. He further determined that interior cormorants generally migrated to the southern U.S. between Texas and Florida. Recent evidence suggests that some cormorants are year-round residents in the southeastern U.S. These birds do not migrate north to breed but nest in the southeastern U.S. (Reinhold *et al.* 1998). Specific information regarding cormorant migration patterns is needed to better understand whether aquaculture in the southeastern U.S. influences the distribution of cormorant nesting colonies.

Advances in satellite telemetry technology have enabled researchers to monitor the movements of many smaller birds and mammals during migration. Information gained through the use of satellite telemetry can improve our knowledge of cormorant life-history characteristics and aid in the development of viable management strategies.

The objectives of this study were to: (1) determine the proportion of satellite-marked cormorants that did not migrate from the southeastern U.S.; (2) describe the varying routes satellite-marked cormorants followed during migration; (3) estimate average departure dates and duration for adult and immature cormorants during migration; (4) estimate average daily distances traveled during migration; and (5) determine whether average body mass differs between migrating and non-migrating cormorants.

Methods

Study Area

The study area comprised the Mississippi River Alluvial Valley regions of southeast Arkansas, northeast Louisiana, and northwest Mississippi and the Tennessee-Tombigbee and Alabama River Valleys in eastern Mississippi and western Alabama (Fig. 1). Subsequent migratory movements of these birds encompassed North America east of the Rocky Mountains.

Cormorants were captured in their winter night roosts (King *et al.* 1994) near aquaculture-intensive areas from November 1999 through February 2001 (Fig. 1). Cormorants were fitted with satellite platform transmitter terminals (PTTs) using a backpack harness designed by Dunstan (1972) with modifications described by King *et al.* (2000) and released in the capture roost. The sex of captured cormorants was not determined. The age of each captured cormorant was estimated based on plumage. A bird with light-tan chest and neck feathers was classified as immature, and a black bird was classified as an adult (Palmer 1962). The research was conducted under the following permits: US Department of Agriculture, Wildlife Services, National Wildlife Research Center's Institutional Animal Care and Use Committee Protocol QA-742 and US Department of Interior, US Geological Survey, Federal Bird Banding Permit 20873.

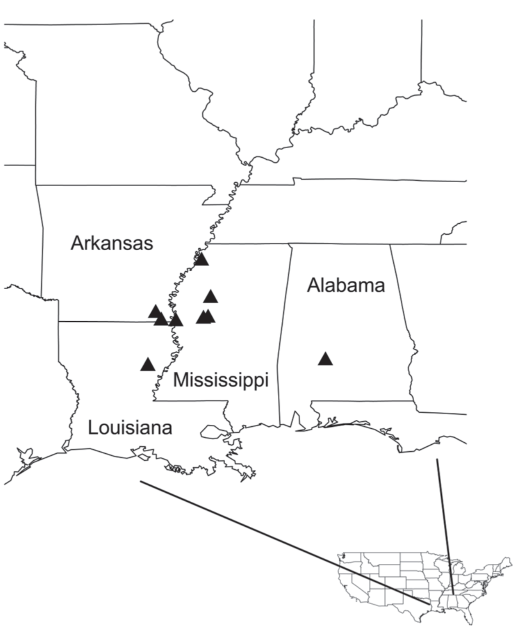

Figure 1. Capture locations (triangles) for Double-crested Cormorants fitted with satellite transmitters, November 1999 to February 2001.

During the winter of 1999–2000, 45-g PTTs were programmed to transmit for eight hours every 48 h from October through May, and eight hours every ten days from June through September. Microwave Telemetry, Inc. (Columbia, Maryland) subsequently reduced the weight and increased battery life of their small PTTs. Thus, during the winter of 2000–2001, 30-g PTTs were programmed to transmit six hours every 48 h from October through mid-June and six hours every ten days from mid-June through September. Using this programming, the expected longevity of the 45-g and 30-g PTTs was twelve months. Service Argos, Inc. (2001) provided data on the locations of the PTTs. Location error was reported by Service Argos, Inc. (2001) as one of six location classes (LC): LC3 = <150 m, LC2 = 150 to <350 m, LC1 = 350 to ≤1000 m, LC0 = >1000 m, LCA and LCB = no estimate of location accuracy.

Statistical Analyses

Douglas' (2000) PC-SAS ARGOS Filter Version 2.4 was used to parse and filter data obtained from Service Argos, Inc. A flight distance of ≤200 km/day and speed of ≤50 km/h (King *et al.* 1995; King 1996) were used for two LC filters: 1) a user-defined distance to determine location redundancy, and 2) distance, angle, and rate measurements designed to remove illogical locations. After filtering, the location data were plotted and analyzed using ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, California).

For each cormorant, the dates associated with the first location of spring and fall migration were used as departure dates. Those estimates may be biased because locations were not obtained from birds every day (i.e. a cormorant may have initiated migration several days before a location was recorded); therefore, estimates may be a few days later than the actual initiation date. Next, the average spring migration departure dates of immature birds and adult birds were tested to determine differences (Dolbeer 1991; Hatch and Weseloh 1999). For fall migration, there were not enough samples for comparisons between age classes; thus, a pooled average fall departure date was calculated. The same aforementioned starting and ending dates were used for each cormorant to determine whether the average duration (days) of spring migration differed between adult and immature cormorants.

To determine the minimum daily distance traveled during migration for each cormorant, all locations between migration starting and ending points were identified. The last location in the bird's wintering range was considered the starting point, and the first location in the summer range was considered the ending point.

An hourly rate of travel was calculated by dividing the linear distance (km) between the two locations by the difference in time (hours) between two successive locations. The process was repeated for each set of successive locations and calculated an average hourly rate for each individual. Next, the hourly rate was transformed to a daily rate by multiplying the rate by 24. Finally, the average daily distance traveled (km/day) during spring migration was tested to determine whether differences existed between immature and adult cormorants.

Body condition was hypothesized to affect the migratory patterns of cormorants wintering in the southeastern U.S. That is, cormorants in poor body condition may forgo migration and remain in the southeastern U.S. throughout the nesting season. Thus, the average body mass (at capture) of migrating and non-migrating cormorants was compared. However, because age class could be a confounding effect, it was first determined whether body mass differed between immature and adult cormorants. If body mass differed between age classes, body masses of migrating and non-migrating cormorants were compared within age classes; otherwise, adult and immature samples were pooled for comparisons.

Values reported in the results are means ± SD. Normality and variance assumptions were evaluated for all statistical tests. Based on these results, either a two-sample *t*-test or a Wilcoxon two-sample test was used to detect differences between populations at the $\alpha = 0.05$ level.

RESULTS

Satellite transmitters were attached to 53 cormorants, and their movements were monitored for ≤546 days. Twenty-five cormorants either died or their transmitters failed before migration occurred. Of the remaining 28 cormorants, four (three immature, one adult) did not migrate and stayed in the southeastern U.S. (Alabama, Arkansas, Louisiana and Mississippi). Thus, 24 cormorants (Alabama N = 6, Arkansas N = 5, Louisiana N = 2, Mississippi N = 11) provided adequate data for migration analyses.

During spring, cormorants captured in Alabama migrated east of the Mississippi River and primarily west of the Appalachian Mountains (Fig. 2). One Alabama bird appeared to migrate east of the Appalachian Mountains. Whether this bird traveled east or west of the Appalachian Mountains is uncertain because there were no data points between Alabama and eastern Pennsylvania. Cormorants from Arkansas, Louisiana and Mississippi migrated north along the Mississippi River Valley, the Missouri River Valley and/or the Ohio River Valley while moving to their summer locations (Fig. 2). Spring and fall migration data were received from eight cormorants; their spring and fall migratory paths were generally through the same regions (Fig. 2).

The earliest departure for spring migration was 26 March, whereas the latest departure was 12 May. Adult cormorants (N = 6; $\bar{x}$ = 9 April ± ten days) departed for spring migration earlier than immature cormorants (N = 18; $\bar{x}$ = 27 Apr ± eleven days; $t_{22} = -3.50$; P = 0.002). The average departure date for fall migration was 1 October ± 23 days (N = 8), with the earliest departure on 17 August and the latest on 25 October. Duration of spring migration (days) did not differ between adult and immature cormorants (*W* = 69.5; P = 0.74). Pooling samples from immature and adult birds yielded an average of 12 ± 10 days (N = 24; min = 2; max = 36).

Mean daily distance traveled (km/day) during spring migration did not differ between immature and adult cormorants (*W* = 74; P = 0.97; Table 1). Pooling samples from immature and adult birds yielded an average of 70 ± 46 km/day (N = 24; min = 22; max = 244).

The average body mass (kg) of adult cormorants did not differ from immature cormorants ($t_{26} = 1.04$; P = 0.31); thus samples were pooled to compare body mass of migratory and non-migratory cormorants. Body mass of cormorants did not differ by migratory status ($t_{26} = -0.68$; P = 0.50; $\bar{x}$ = 2.02 ± 0.16 kg).

DISCUSSION

Although the fate of some birds and their transmitters was unclear, we do not believe that the transmitter attachment technique had an effect on bird survival. During two separate captive trials, King *et al.* (2000) showed that the transmitter attachment technique used in this study had no adverse effects on cormorants. Contrary to the reviews of Palmer (1962) and Hatch and Weseloh (1999), some of our PTT-marked birds did not migrate. Four (14%) of the cormorants

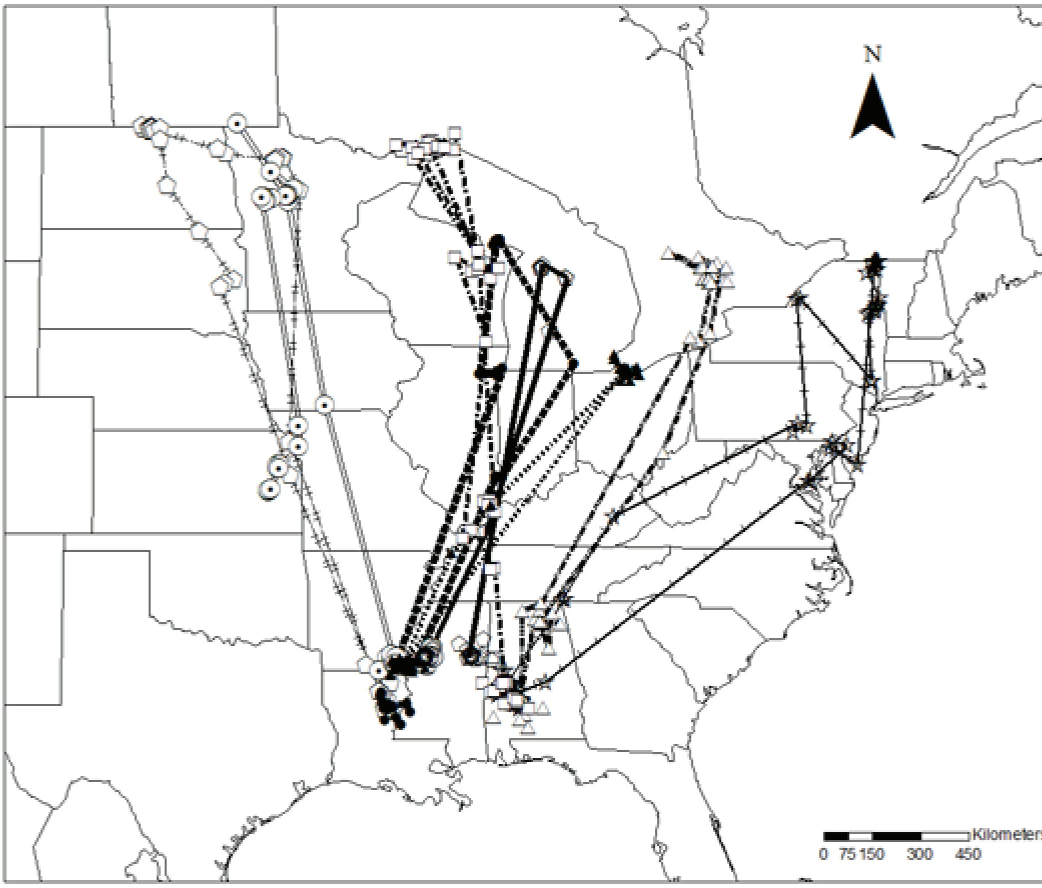

Figure 2. Spring and fall migration pathways for eight Double-crested Cormorants fitted with satellite transmitters, April to October 2000 (top) and March to November 2001.

remained in the southeastern U.S. throughout the summer. One adult non-migrant cormorant may have nested in the southeastern U.S., a phenomenon recently documented by Reinhold *et al.* (1998), although no attempt was made to locate the nest. Body mass was hypothesized to possibly influence migratory status; however, a difference in the body mass of migratory and non-migratory cormorants was not detected, and it was concluded that poor body condition at the time of capture was likely not the stimulus to forgo migration. Alternatively, by providing an abundant, readily available food source throughout the year, catfish aquaculture facilities may have reduced the tendency for some cormorants to migrate. Thus, the catfish aquaculture industry may influence life history characteristics such as migration in cormorants (Weseloh and Ewins 1994; Duffy 1995; Glahn *et al.* 1999).

Cormorants captured in Alabama may have migrated farther east than birds from Arkansas, Louisiana or Mississippi due to geography (i.e. the shortest distance from their wintering to their breeding areas). Similar to the findings of Palmer (1962) and Hatch and Weseloh (1999), these cormorants generally followed major river valleys. Our average spring departure date for migrating immature cormorants (9 April) was similar to that reported by Palmer (1962) and Robbins and Easterla (1992), but differed from the May departure date for birds less than one year old reported by Dolbeer (1991). Consistent with the findings of Dolbeer (1991) and Hatch and Weseloh (1999), immature cormorants departed for spring migration later

Table 1. Movement characteristics of 24 Double-crested Cormorants during migration from wintering to breeding grounds in 2000 and 2001. Age based on plumage: I = immature (tan chest and neck), A = adult (all black). N = number of days.

				Daily movement rate (km/day)			
ID	Age	Days	Distance (km)	N	Min	Max	$\bar{x} \pm$ SD
02	I	5	314	2	44.0	85.9	64.9 ± 29.6
04	I	13	684	5	0.2	89.3	53.3 ± 33.2
05	A	12	741	5	1.6	137.0	63.9 ± 50.2
16	I	7	674	3	71.7	124.4	92.2 ± 28.2
17	I	36	610	8	1.2	117.9	24.7 ± 39.3
18	I	5	354	2	61.6	94.0	77.8 ± 39.3
20	A	19	410	8	0.2	58.1	22.3 ± 25.3
21	A	5	368	2	39.7	121.7	80.7 ± 57.9
22	I	32	638	6	2.0	174.6	35.6 ± 68.2
26	I	5	487	2	95.5	102.3	98.9 ± 4.8
27	I	5	478	2	47.8	160.6	104.2 ± 79.8
28	A	15	535	6	0.5	137.5	37.4 ± 53.9
33	I	6	495	3	30.4	144.8	77.3 ± 59.9
34	A	2	463	1	243.5	243.5	
36	A	8	530	4	29.4	102.9	63.3 ± 32.5
43	I	19	580	5	0.9	106.1	34.9 ± 46.4
46	I	9	408	3	43.8	49.6	46.4 ± 2.9
47	I	10	511	3	18.7	106.4	58.4 ± 44.4
48	I	6	597	2	76.1	120.6	98.3 ± 31.5
49	I	6	530	2	80.7	88.1	84.4 ± 5.2
51	I	29	805	10	2.0	72.4	25.7 ± 26.0
52	I	9	498	3	24.5	76.6	51.9 ± 26.1
53	I	24	702	7	0.7	102.1	33.6 ± 36.4
54	I	6	671	2	105.0	107.6	106.3 ± 1.8

than adults. The average spring departure date for adult cormorants and the average fall departure date for all cormorants in this study were similar to the dates reported in other studies (Palmer 1962; Dolbeer 1991; Hatch and Weseloh 1999).

The 70 km/day that cormorants traveled in this study during migration was about twice the daily distance moved by cormorants in their winter areas (King *et al.* 1995). King (1996) also noted three cormorants moving about 350 km in <48 h during winter. Because the PTT duty-cycles were set to transmit every 48 h, the birds may have moved the entire distance between locations in <48 h. The average daily distance cormorants moved and the average duration of migration in this study are likely conservative, because only straight-line distances between known locations could be calculated.

Future research is suggested to: (1) better document the dynamics and locations of cormorant colonies in the southeastern U.S.; (2) better determine the source of cormorants wintering near aquaculture facilities; (3) develop more accurate techniques for determining the age and sex of cormorants; and (4) better document cormorant use of migration stopover sites.

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