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Abstract.—The 5589 recovery records for Double-crested Cormorants (*Phalacrocorax auritus*) banded in North America from 1923 to 1988 were analyzed to determine migration patterns and the source of populations wintering in the lower Mississippi Valley and Gulf of Mexico coastal region. Autumn migration from areas north of latitude 42°N primarily occurred in October and November. Spring migration occurred mainly in April for birds >2 yr old and in May for birds <1 yr old. During summer, 1-yr-old birds were recovered significantly farther from their natal colony than were older birds. Cormorants nesting in Canada and the northern United States from Alberta to the Gulf of St. Lawrence migrated in winter primarily to the southern United States between Texas and Florida. There was considerable mixing and overlap in winter of nesting populations from widely divergent areas. From 38 to 70% of the birds from Saskatchewan through the Great Lakes region were recovered in the lower Mississippi Valley as were 10% of the birds from such disparate areas as Alberta and the New England coast. There was little mixing of populations from east and west of the Rocky Mountains.

PATRÓN MIGRATORIO DE *PHALACROCORAX AURITUS* AL ESTE DE LAS ROCALLOSAS

Sinopsis.—Datos de 5589 recobros de cormoranes (*Phalacrocorax auritus*) anillados en Norte America entre 1923 y 1988 fueron analizadas para determinar los patrones migratorios y la fuente de origen de poblaciones invernales de estas aves en el bajo valle de Mississippi y la región del Golfo de México. Migraciones otoñales de aves al norte de la latitud 42°N ocurrieron en octubre y noviembre. La migración primaveral ocurrió principalmente en abril para aves > a 2 años, y en mayo para pájaros < de un año. Durante el verano, las aves de un año se recobraron significativamente más lejos de sus lugares natales que aves de mayor edad. Los cormoranes que anidan en Canada y el norte de los Estados Unidos, desde Alberta hasta el Golfo de St. Lawrence, migran durante el invierno particularmente al sur de los Estados Unidos entre Texas y Florida. Durante el invierno ocurre mezcla y solapamiento de poblaciones residentes de una gran diversidad de áreas. Del 38% al 70% de las aves de Saskatchewan, a través de la región de los Grandes Lagos, se recobraron en la parte baja del valle del Mississippi; el 10% de las aves resultaron ser de lugares como Alberta y la costa de Nueva Inglaterra. Hay muy poca mezcla entre las poblaciones de cormoranes del este y el oeste de las Rocallosas.

Double-crested Cormorants (*Phalacrocorax auritus*) breed in North America in several disjunct areas on both coasts and inland on large freshwater lakes and rivers. Most of the interior populations are located from the Great Lakes west across the northern prairies of the United States and Canada. Populations have shown a pronounced growth in the past 20 yr related to decreased pesticide contamination and increased legal protection (Ludwig 1984, Vermeer and Rankin 1984). In recent years, cormorant populations wintering in the lower Mississippi Valley have come into serious conflict with the expanding fish-farming industry of the region (Stickley and Andrews 1989). The objective of this study was

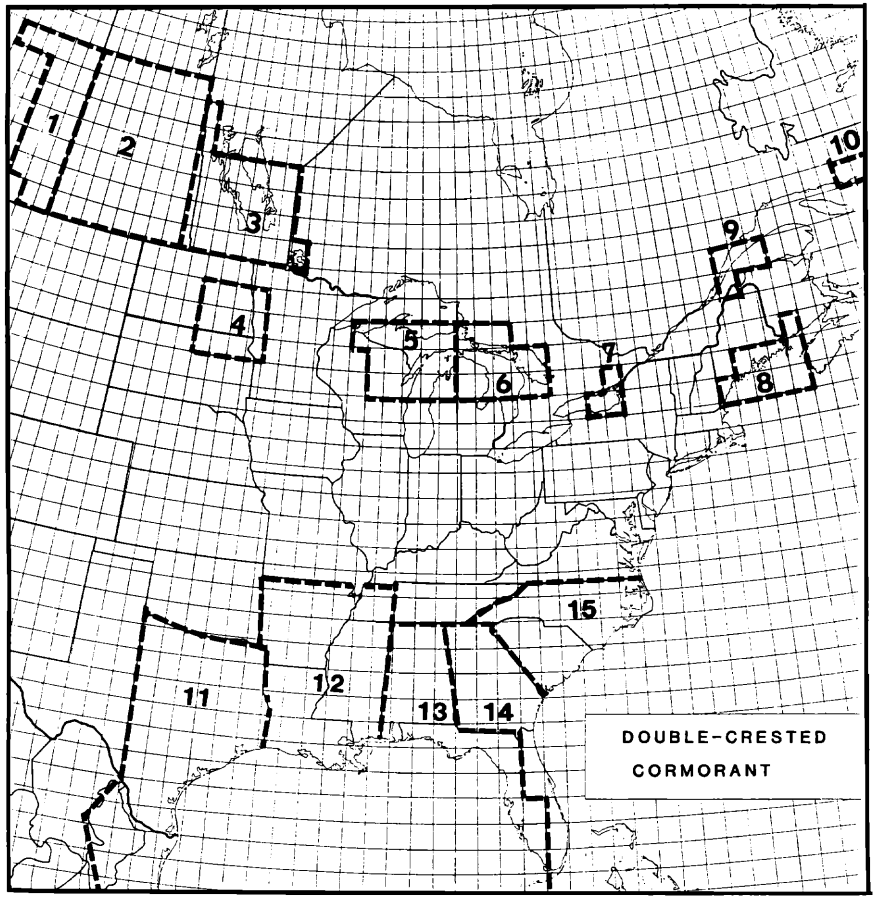

FIGURE 1. Regions 1–10 in Canada and the northern United States where most banding of Double-crested Cormorants has occurred and regions 11–15 in the southern United States and eastern Mexico where most winter recoveries have occurred. The regions are listed in Table 5.

to determine the migration patterns and origins of Double-crested Cormorants wintering in the lower Mississippi Valley and along the northern Gulf of Mexico coastal region.

METHODS

Band recovery records for Double-crested Cormorants from 1923 to 1988 were obtained from the U.S. Fish and Wildlife Service, Laurel, Maryland. Records that did not contain the month or location of recovery were excluded. In addition, recoveries with "How Obtained" codes 50, 56, 96 or 98 (Canadian Wildlife Service 1984), which imply the month

TABLE 1. Age class and month of banding for the 5589 Double-crested Cormorants recovered from 1923 to 1988.

Month of banding	Age at banding			Total recovered
	Hatching year	Unknown	Adult	
June	1724	46	3	1773
July	3220	182	9	3411
August	325	34	0	359
Other months	36	4	6	46
Total	5305	266	18	5589

or location of recovery may not have been accurately known, were excluded.

An initial analysis of the banding location by degree block of latitude and longitude for all recovery records revealed 10 geographical regions of North America east of the Rocky Mountains with ≥85 recoveries of birds banded as nestlings or fledglings. These regions, all north of 42°N latitude, encompass the banding locations for 93% of the total recovery records east of the Rocky Mountains (Fig. 1). The regions were selected to be representative of cormorant populations from Alberta, Canada, in the west to the Gulf of St. Lawrence in the east.

To examine the timing and distance of cormorant migration for these regions, I determined the mean and median distance from banding to recovery locations for birds banded as nestlings or fledglings and recovered at subsequent monthly intervals (Moore and Dolbeer 1989). Mean distances were compared among age classes by analysis of variance after transformation of the data ($\log x + 1$, where x = distance from band to recovery site) to normalize the distribution of recovery distances (Steel and Torrie 1960). I also examined the distribution of recoveries in winter (December through February) by degree block of latitude and longitude and by five regions in eastern Mexico and the southern United States (Fig. 1). I did not examine migration patterns for birds banded in or west

TABLE 2. Distribution of band recoveries of Double-crested Cormorants by "How Obtained" codes. Birds with codes 50, 56, 96, or 98 were excluded from the analyses.

"How Obtained" code number[a]	No. of recoveries (% of total)	Definition
0	2026 (36)	Found dead
1	1535 (27)	Shot
4, 17, 26	908 (16)	Nets, fishing gear, traps or drown
50, 56, 96, 98	503 (9)	Skeleton found or no information
29, 52	167 (3)	Sight record
16	115 (2)	Scientific collection
29 other codes	335 (6)	Misc. (e.g., injury, dead on highway)

[a] Canadian Wildlife Service 1984.

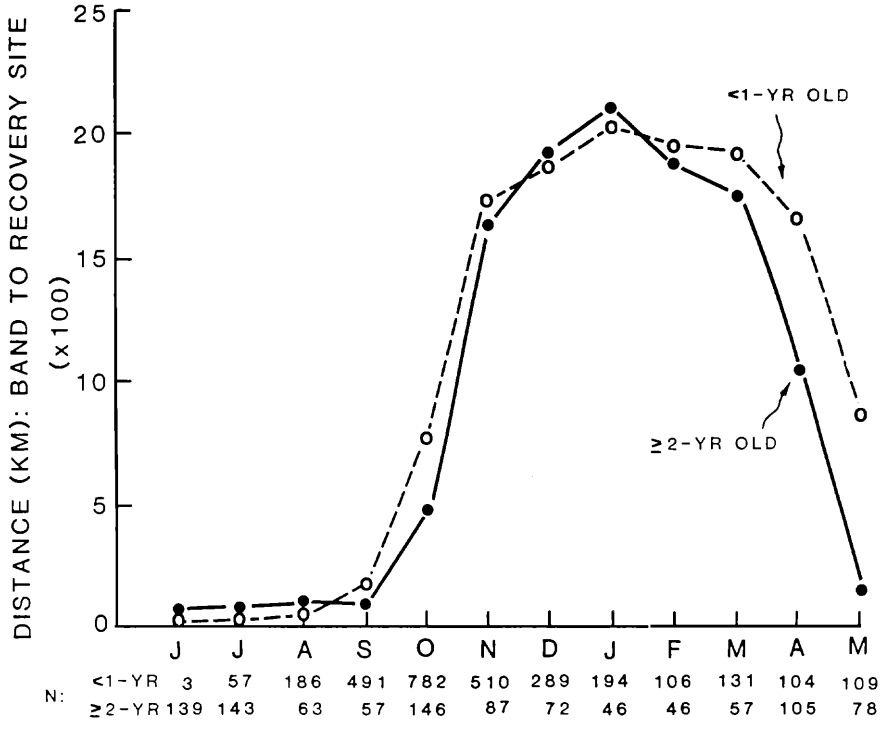

FIGURE 2. Median distance from banding site to recovery site by month for Double-crested Cormorants banded as nestlings or fledglings in North America north of latitude 42°N from the Gulf of St. Lawrence to Alberta. Sample sizes for each age class are listed below the months.

of the Rocky Mountains other than to determine the degree of interchange across the continental divide. In all analyses, I assumed that the probability of recovery was equal among locations.

RESULTS

Sample sizes and characteristics of data.—Of the 5589 recovery records available through 1988, 95% represented birds banded as nestlings or recently fledged birds. Over 99% of the birds were banded in June through August (Table 1). About 80% of the birds were either found dead, shot, or caught in fishing gear, nets or traps. About 9% of the records were excluded from analysis because the "How Obtained" codes indicated inadequate information regarding the date or location of recovery (Table 2). About 9% of the recovery records (520) were from birds banded west of the continental divide.

Recovery distance from hatching site by monthly interval.—Autumn migration from areas north of latitude 42°N primarily occurred in October and November (Fig. 2). Both immature (<1 yr old) and adult (>2 yr

TABLE 3. Mean and median distance from banding site to recovery site for Double-crested Cormorants banded as nestlings in areas north of latitude 42°N from the Gulf of St. Lawrence to Alberta and recovered during winter (December–February).

Age (yr) at recovery (Dec.–Feb.)	*N*	Distance (km) from banding to recovery site		
		$\bar{x}$[a]	SD	Median
0.5	589	1998	534	1909
1.5	114	1937	702	1805
≥2.5	164	1925	721	1903

[a] Means are not different ($P = 0.27$) among age classes, analysis of variance ($F = 1.31$, df = 2 and 864).

old) Double-crested Cormorants were at their greatest median distance from nesting areas in December through March (Fig. 2). Maximum migration distance in winter from nest site was similar ($P = 0.27$) among age classes (Table 3). Spring migration occurred mainly in April for birds >2 yr old and in April and May for birds <1 yr old (Fig. 2). In June and July, 1-yr-old birds were found significantly ($P < 0.05$) farther from their natal colonies ($\bar{x} \pm SD = 846 \pm 953$ km) than were birds 2 yr old (548 ± 777 km) or ≥3 yr old (232 ± 560 km). Once birds reached ≥3 yr old, there were no significant differences among age classes in the mean dispersal distance from natal colony (Table 4).

Distribution of recoveries in winter.—Cormorants nesting in Canada and the northern United States from Alberta to the Gulf of St. Lawrence migrated primarily to the southern United States between Texas and Florida (Table 5). In general, cormorants from Alberta through the Great Lakes region concentrated in winter either in southeastern Texas or in the lower Mississippi Valley whereas cormorants from the New England coast, St. Lawrence River and Gulf of St. Lawrence migrated to the southern Atlantic coast, Florida and Alabama. However, there was con-

TABLE 4. Distance from banding site to recovery site for Double-crested Cormorants banded as nestlings in areas north of latitude 42°N from the Gulf of St. Lawrence to Alberta and recovered during June or July in subsequent years.

Age (yr) at recovery (June–July)	*N*	Distance (km) from banding to recovery site		
		$\bar{x}$[a]	SD	Median
1	98	846 a	953	490
2	51	548 b	777	138
3	66	241 c	635	25
4	41	235 c	527	21
5	34	294 c	540	31
≥6	90	200 c	536	19

[a] Means with different letters are significantly ($P < 0.05$) different, analysis of variance ($F = 19.7$, df = 5 and 374) and Duncan's multiple range test.

TABLE 5. Location of recoveries for Double-crested Cormorants banded during the nesting season (May–August) in 10 regions of North America and recovered during winter (December–February).

Banding region[a]	No. recovered in winter	% of winter recoveries[a]					
		Western Gulf of Mexico (11)	Lower Miss. Valley (12)	Eastern Gulf of Mexico (13)	South Atlantic coast (14)	Mid-Atlantic coast (15)	Other
1. Alberta	149	77	9	0	0	0	14
2. Saskatchewan	120	35	46	7	2	0	10
3. Manitoba	25	52	40	8	0	0	0
4. Dakotas/Western Minnesota	134	43	46	3	0	0	11
5. Lake Michigan and Lake Superior	50	6	70	16	0	2	6
6. Lake Huron	93	5	42	32	8	2	11
7. Eastern Lake Ontario	16	6	38	25	19	6	6
8. New England Coast	215	<1	11	47	24	8	10
9. St. Lawrence River	67	0	6	34	25	18	17
10. Gulf of St. Lawrence	16	0	0	25	31	25	19

[a] See Figure 1 for location of regions.

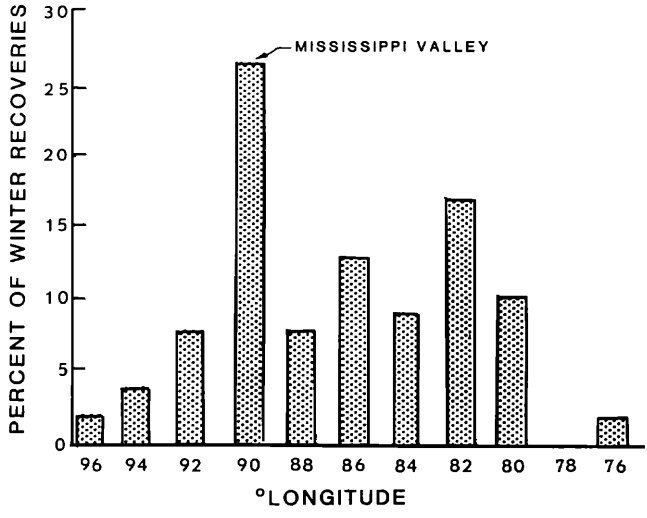

FIGURE 3. Distribution of 93 winter (December–February) recoveries by longitude from Texas to North Carolina for Double-crested Cormorants banded as nestlings or fledglings in the Lake Huron region (region 6 in Fig. 1).

siderable overlap and mixing in winter of nesting populations from widely divergent areas. For example, about 10% of the cormorants from both the New England coastal and Alberta populations, which are separated by over 3000 km, migrated to the lower Mississippi Valley. From 38 to 70% of the birds from Saskatchewan through the Great Lakes region were recovered in the lower Mississippi Valley (region 12).

Figure 3 demonstrates the broad longitudinal (east–west) distribution of winter recoveries for cormorants from the Lake Huron area. Although there was a concentration of recoveries in the Lower Mississippi Valley (longitude 90–91°W), birds from the Lake Huron area have been recovered in winter over a 2000-km band from Texas to North Carolina. Figures 4–6 depict the latitudinal and longitudinal distribution of winter recoveries for cormorants from Saskatchewan, Lake Huron and eastern Lake Ontario.

There was little intermixing between cormorant populations east of the Rocky Mountains and populations on the Pacific coast of North America. Only five of the 609 recoveries from birds banded in Alberta and none from birds banded in the other regions farther east were west of the Rocky Mountains. Conversely, none of the 520 recoveries from birds banded along the Pacific coast or in the Rocky Mountain region were east of the Rocky Mountains.

DISCUSSION

There was no evidence for difference in migration distance to wintering areas for first-year and older cormorants such as has been noted for certain

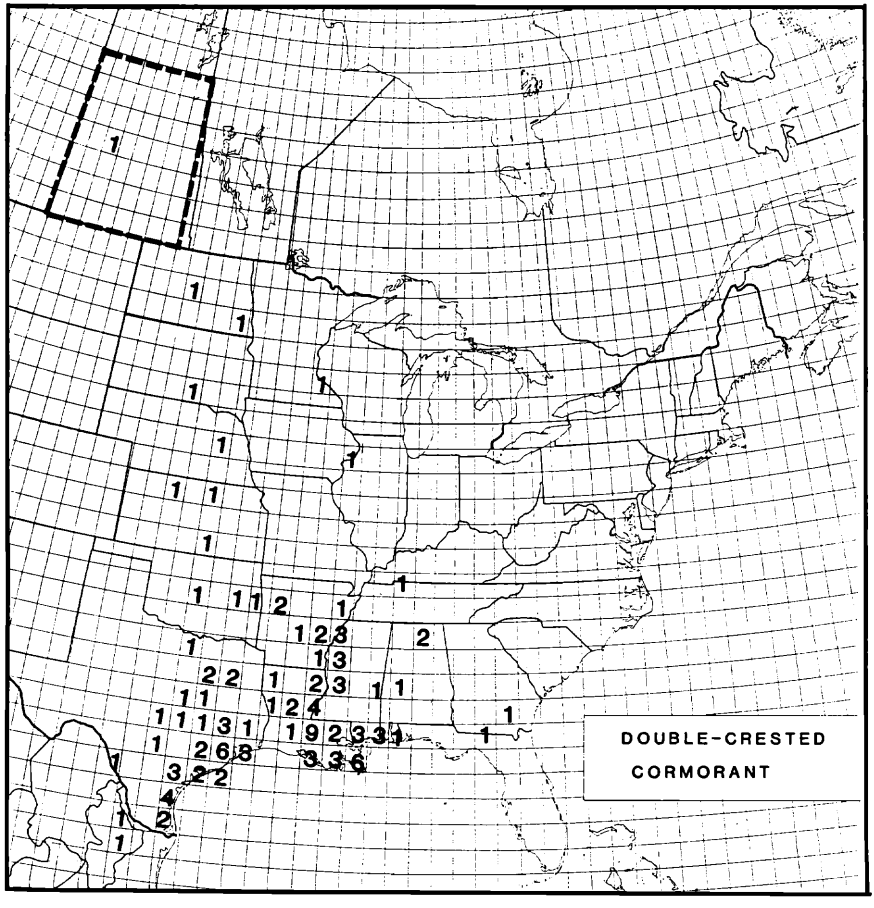

FIGURE 4. Distribution of 119 winter (December–February) recoveries by degree block of latitude and longitude of Double-crested Cormorants banded as nestlings or fledglings in Saskatchewan.

passerine species (Dolbeer 1982). However, first-year birds returned north later in the spring and remained farther from their site of hatching during summer than did older birds, especially birds ≥3 yr old (Table 4). This is likely because cormorants do not typically breed until they are 2 or 3 yr old (Price and Weseloh 1986). The finding that birds ≥3 yr old were recovered in June and July at median and mean distances of 25 and 232 km, respectively, from their natal colony suggests that although most cormorants return to the proximity of their natal colony, some cormorants disperse considerable distances to their sites of nesting. Dispersal distance from natal colony did not change with age after age 2 yr.

The lack of significant interchange between populations east and west

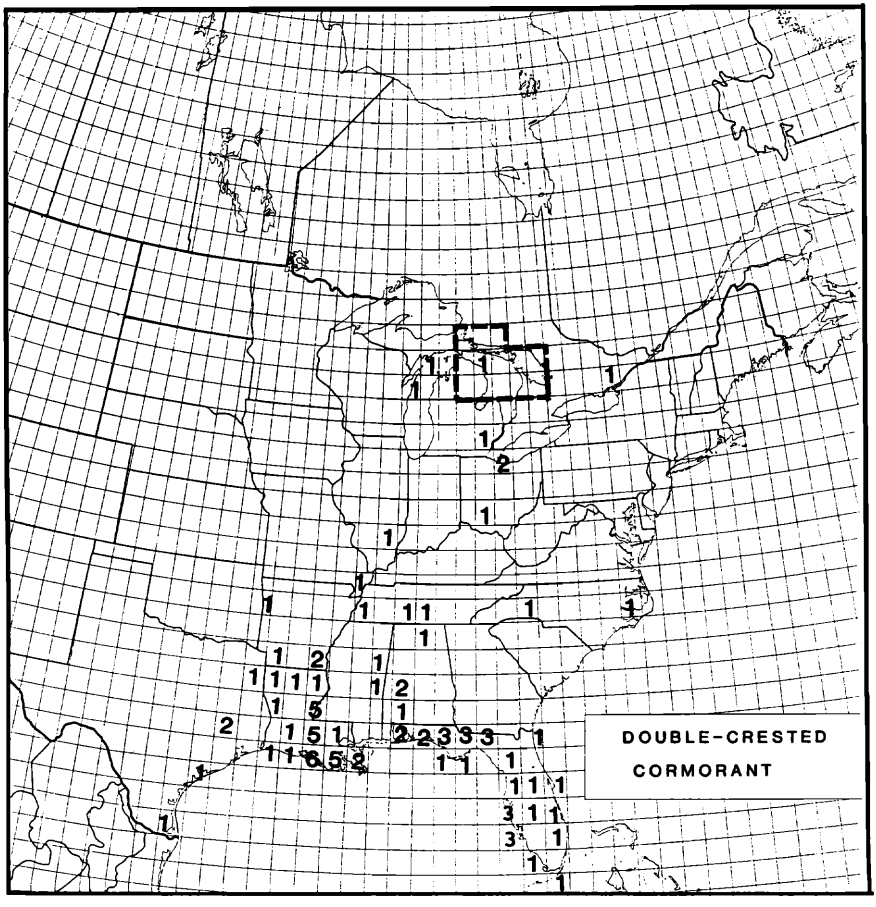

FIGURE 5. Distribution of 92 winter (December–February) recoveries by degree block of latitude and longitude of Double-crested Cormorants banded as nestlings or fledglings in the Lake Huron region.

of the Rocky Mountains was previously indicated by Houston (1967, 1968) and Palmer (1962). However, east of the Rockies, birds from widely divergent nesting areas intermixed in winter in the lower Mississippi Valley and along the Gulf of Mexico coast. Thus, there is no apparent "focal point" of cormorants nesting in the northern United States or Canada that is the source of the birds conflicting with the fish-farming industry in the southern United States.

An advantage of the broad dispersal in winter of localized breeding populations is that a high mortality rate at a given winter roost or group of roosts due to weather or food shortage would be spread among populations indigenous to a wide area. Local breeding populations would not

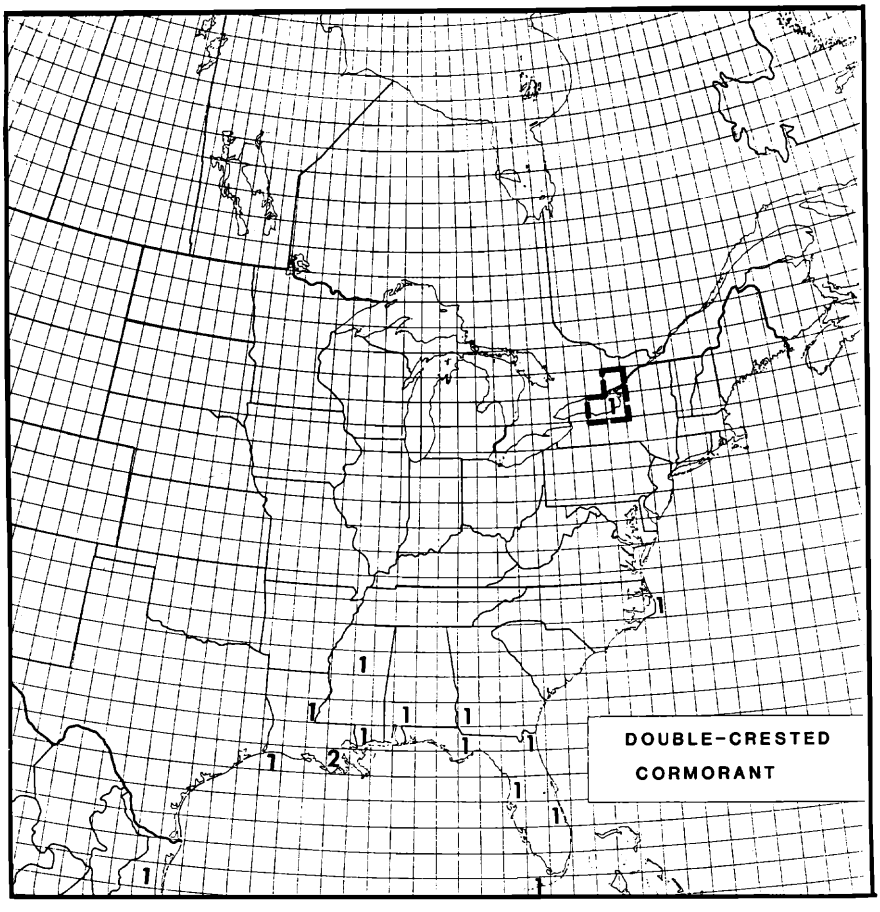

FIGURE 6. Distribution of 16 winter (December–February) recoveries by degree block of latitude and longitude of Double-crested Cormorants banded as nestlings or fledglings in the eastern Lake Ontario region.

likely be decimated by a localized high mortality rate at a winter roost site.

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