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PIPING PLOVER SURVIVAL IN THE GREAT PLAINS

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Abstract.—Survival was estimated for the Great Plains population of the threatened/endangered Piping Plover (*Charadrius melodus*) from resightings of 352 (214 adult, 138 juvenile) uniquely color-banded individuals in 1984–1990. One hundred one (47.2%) adults and 19 (13.8%) juveniles returned to the North Dakota study site in years after banding. Low return rates of juveniles precluded estimation of survival for that age class. Mean annual survival of adult Piping Plovers in the Great Plains was 0.664 (SE = 0.057), slightly lower than that reported for congeneric species. Recovery of the species will require conservation efforts to assure no decrease in survival rates and to increase reproductive success.

SOBREVIVENCIA DE *CHARADRIUS MELODUS* EN LAS GRANDES PLANICIES

Sinopsis.—Se estimó la sobrevivencia de la población de *Charadrius melodus* que habita las Grandes Planicies. Los datos consistieron del re-avistamiento de 352 individuos (214 adultos, 138 juveniles) anillados con bandas de colores entre 1984–1990. Ciento-un (47.2%) adulto y 19 (13.8%) juveniles retornaron al área de estudio en Dakota del Norte un año luego de haber sido anillados. Una baja tasa de retorno por parte de los juveniles evitó que se pudiera hacer un estimado de sobrevivencia de este grupo (de edad) de las aves. En los adultos, el promedio anual de sobrevivencia resultó ser de 0.664 (EE = 0.057); ligeramente más bajo que el informado en congéneres. La recuperación de esta especie, considerada amenazada/en peligro de extinción, requiere esfuerzos de conservación que aseguren un incremento en el éxito reproductivo, y que no haya una disminución en la tasa de sobrevivencia.

Piping Plovers (*Charadrius melodus*) were listed under the Endangered Species Act as Threatened or Endangered throughout their range in 1985 (U.S. Fish and Wildlife Service 1985). Since then the Great Plains population has continued to decline, from an estimated 1500 pairs in 1985 to <1100 pairs in 1990 (Great Lakes & Northern Great Plains Piping Plover Recovery Team, unpub. data). To understand the causal factors responsible for this decline and to develop recovery strategies, knowledge of the population biology of Piping Plovers is essential. Several studies have reported on the reproductive success of Piping Plovers in the Great Plains (Haig and Oring 1988a, Prindiville Gaines and Ryan 1988, Schwalbach 1988, Wiens and Cuthbert 1984, Whyte 1985). No data, however, are available on survival of the species anywhere in its range. Wilcox (1959) conducted a 20-yr banding study on Long Island, new York, but reported only longevity records. Whereas it might be possible to analyze his data for survival rates, no one has attempted such analysis. In 1984, we began a large-scale banding and resighting effort of Piping Plovers in central North Dakota to assess survival rates in the Great Plains.

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STUDY AREA AND METHODS

Study area.—We estimated survival of Piping Plovers in 1984–1990 at the Chain-of-Lakes wetlands in the John E. Williams Memorial Nature Preserve (JWMNP), McLean County, North Dakota. Mean population size was 90.4 pairs (range = 46–152) during our study (Mayer 1990), making the site one of the largest concentrations of Piping Plovers in the Great Plains (Haig et al. 1988). JWMNP, owned and managed by The Nature Conservancy, contains seven alkali wetlands varying in size from 2.6 to 283.0 ha. Plovers nest on >50 salt-encrusted, gravel beaches at these wetlands. For detailed descriptions of our study site see Prindiville Gaines and Ryan (1988) and Mayer (1990).

Capture and banding.—Capture, banding and resighting efforts were conducted throughout the breeding season, from arrival of Piping Plovers in late April through departure in late August. Incubating Piping Plovers were captured with a wire mesh box-trap placed over nests. A sliding drop-door was hand-triggered when adults returned to the nests. Post-nesting adults and fledglings were captured with mist nets. Non-flying juveniles were caught by hand. All adults and some juveniles were uniquely marked with USFWS aluminum bands and three colored leg-bands. Resightings were made during weekly (1985–1987) or bi-weekly (1988–1990) counts and nest monitoring at all plover nesting sites at JWMNP in subsequent years. Other breeding areas on six Missouri River sandbars (1988–1990) and at Lostwood National Wildlife Refuge (1986–1990) were monitored approximately bi-weekly. Other known breeding sites were censused annually by us or North Dakota Game and Fish Department personnel.

Analyses.—We estimated survival rates for the JWMNP plover population with the Jolly-Seber capture-recapture model (Jolly 1965, Seber 1965) using program JOLLY (Brownie et al. 1986). The model accounted for both death and immigration. We used recapture (1984–1987) and resighting (1984–1990) data collected at JWMNP to generate capture histories for individual plovers. For our analyses, we considered resightings and recaptures to be equivalent forms of band "returns," similar to Cormack (1964), Brownie and Robson (1983) and Stromborg et al. (1988). New "captures" in 1988–1989 were plovers originally banded as juveniles that were first resighted as adults in 1988–1989.

We defined yearly survival rate as the probability that a banded plover captured or observed on JWMNP in one breeding season would return to JWMNP the following breeding season. Sighting probability was defined as the probability that a banded plover at JWMNP was seen during that breeding season. To fulfill the Jolly-Seber model requirements, we assumed that 1) within a given breeding season every plover had equal survival and sighting probabilities, 2) plovers did not lose their color bands and 3) any emigration from JWMNP was permanent. We used a chi-squared goodness-of-fit test (Brownie et al. 1986, Pollock et al. 1985) to test assumption 1. Band loss was assessed by recording the number of plovers observed with at least one missing color band. Obser-

TABLE 1. Program JOLLY capture-recapture input data (Leslie Method B Table format, Brownie et al. 1986) for 214 adult Piping Plovers at the John E. Williams Memorial Nature Preserve, North Dakota, 1984–1990. Entries show the number of plovers resighted in year j that were last resighted in year i.

Year last resighted (i)	Year resighted (j)						
	1984	1985	1986	1987	1988	1989	1990
1984	0	3	1	0	0	0	0
1985		0	16	12	6	0	0
1986			0	51	4	3	1
1987				0	30	8	3
1988					0	15	5
1989						0	8
Resighted	0	3	17	63	40	26	17
Captured	8	55	111	29	10	1	0

vations of plovers banded at JWMNP, but subsequently resighted at other breeding areas, also were recorded.

RESULTS AND DISCUSSION

In 1984–1989, 352 Piping Plovers (214 adult, 138 juvenile) were captured, individually color-banded and released at JWMNP. We resighted 101 adults (47.2%) at least once (other than in the year that they were initially banded), with a total of 166 resightings ($\geq$1 location/bird/year). Only 19 juveniles (13.8%) were resighted at JWMNP in subsequent years, too few to generate survival estimates. Adult capture histories are summarized in Table 1.

The goodness-of-fit test showed a poor fit of our data to the Jolly-Seber model ($\chi^2 = 18.56$, 8 df, $P = 0.017$), suggesting that survival and/or sighting probabilities were heterogeneous within years. Adult Piping Plovers nesting at JWMNP probably were exposed to similar mortality risks within years. Most Piping Plovers banded in the Great Plains, including those at JWMNP, winter along the coast of the Gulf of Mexico (Haig and Oring 1988b; T. Eubanks, pers. comm.) and seemingly migrate along the same routes. Sighting probabilities, however, likely were biased because some nesting beaches were visited more frequently to monitor higher densities of plover nests at those sites. Changing Piping Plover densities at JWMNP over the 7-yr study also may have contributed to variability in sighting probabilities. This was true especially in 1986, when drought conditions in parts of the Great Plains may have forced plovers to concentrate at remaining breeding areas (e.g., JWMNP). Sighting probabilities were >0.48 for all years except 1986 (Table 2). Greater than 70% of the total χ^2 value resulted from a higher than expected number of birds banded in 1984–1985 being resighted in subsequent years, especially in 1986–1987. Fortunately, Jolly-Seber survival estimates are robust to heterogeneous sighting probabilities (Carothers 1973,

TABLE 2. Jolly-Seber survival (S) and sighting (*P*) probabilities for adult Piping Plovers at the John E. Williams Memorial Nature Preserve, North Dakota, 1984–1990.

Year[a]	S	SE (S)	95% CL	*P*	SE (*P*)
1984	0.586	0.222	0.150–1.022		
1985	0.933	0.134	0.671–1.200	0.640	0.267
1986	0.563	0.063	0.439–0.686	0.305	0.074
1987	0.619	0.097	0.429–0.810	0.670	0.070
1988	0.617	0.159	0.306–0.928	0.523	0.087
1989				0.482	0.122
Mean	0.664	0.057	0.552–0.775	0.524	0.021

[a] For values of S, year corresponds to the time interval year–year + 1.

1979; Pollock and Raveling 1982; Stromborg et al. 1988), and any resulting biases were probably small.

Twenty-one plovers (6.0%) were resighted with at least one missing color band. Over the 6 yr of resighting effort, this is a relatively low rate of band loss, and should cause only a slight negative bias in the survival estimate (Nelson et al. 1980). Three plovers (0.8%) banded at JWMNP were observed at two other breeding areas in subsequent years. Although resighting efforts were not as thorough at other sites, this suggests that emigration of plovers from JWMNP was relatively unimportant to the survival analysis.

Annual Piping Plover survival rates ranged from 0.563 to 0.933 (Table 2). Adult Snowy Plovers (*Charadrius alexandrinus*) breeding on alkaline beaches at Mono Lake had an annual survival rate of 0.743 (Page et al. 1983). Pienkowski (1984) observed adult Common Ringed Plover (*C. hiaticula*) survival rates to be ≥ 0.80 in Greenland and northeastern England. Survival estimates for these congenerics were higher than the mean Piping Plover annual survival rate (0.664) for the Great Plains, but similar to the upper 95% confidence limit (Table 2).

Causes of Piping Plover mortality are as yet unknown. Adult plover survival during the breeding period is seemingly high. In 7 yr, we recorded no adult mortality at JWMNP. The only observation of adult Piping Plover mortality during the breeding season is a report (S. Haig, pers. comm.) of breeding adults killed by mink (*Mustela vison*) at Lake-of-the-Woods, Minnesota. Seemingly, most adult mortality occurs during migration or on the wintering grounds. Unfortunately, no data concerning Piping Plover survival during these periods are available. Cause- and time-specific survival rates are needed before management strategies can be designed to increase survival.

Annual adult Piping Plover survival in the Great Plains was only slightly lower than that reported for congeneric species. Information on mortality factors during migration or the winter period is needed. Conservation actions seem unlikely to increase substantially Piping Plover

survival rates, however. Delisting of the species from protection under the Endangered Species Act will require efforts to assure no decrease in survival rates and greater focus on increasing reproductive success.

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