

DISTRIBUTION AND ABUNDANCE OF PIPING PLOVERS: RESULTS AND IMPLICATIONS OF THE 1991 INTERNATIONAL CENSUS¹

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Abstract. Assessing status and recovery of the endangered Piping Plover (*Charadrius melodus*) requires knowledge of the species' current distribution and abundance throughout the annual cycle. To address this issue, over 1,000 biologists and volunteers from 10 nations collaborated in the 1991 International Piping Plover Census. Approximately 2,099 sites were censused yielding the highest number of breeding (5,482 adults) and wintering (3,451 birds) Piping Plovers ever recorded. Most winter birds occurred in Texas (55%) and along other United States Gulf Coast sites (93%). Among winter birds, 51% used ocean beaches, 43% used sand or algal flats in protected bays, and 6% used areas where protected bays met ocean beaches. Breeding birds were widely distributed in small populations in the Northern Great Plains/Prairie (63.2%) and on the Atlantic Coast (36%). Few birds ($N = 39$) remain on the Great Lakes. Habitat use among breeding birds varied considerably across the species range. While most Atlantic (93.9%) and Great Lakes (100%) birds used sandy beaches, 59.6% of Northern Great Plains/Prairie birds used shorelines around small alkaline lakes, 18.2% used large reservoir beaches, 19.9% used river islands and adjacent sand pits, 2% used beaches on large lakes, and 0.4% used industrial pond shorelines.

Change in status from previous censuses was difficult to determine. New populations were found in Montana, Colorado, and Saskatchewan, Canada; however, the distribution gap between Atlantic and Northern Great Plains/Prairie Piping Plover distribution grows as numbers decline in Minnesota; Manitoba, Canada; and the Great Lakes. Repeated international censuses every five years and a better assessment of reproductive success in local populations will help determine future population trends for the species.

Key words: Abundance; *Charadrius melodus*; distribution; endangered species; Piping Plover; population trends.

INTRODUCTION

Over the past 15 years, tremendous effort has been expended by biologists across North America to determine and mitigate factors producing the decline of the endangered Piping Plover (*Charadrius melodus*). Efforts have focused on documenting the species' distribution (Cairns and McLaren 1980, Adams 1984, Haig and Oring 1985, Nicholls and Baldassarre 1990a, Boyd 1991), monitoring demographic factors (Haig and Oring 1987; Haig and Oring 1988a, 1988b; Prindiville Gaines and Ryan 1988; Schwabach 1988; MacIvor 1990; Patterson et al. 1991; Root et al. 1991; Powell and Cuthbert 1992), characterizing habitats, (Brown 1987, Johnson and Baldassarre 1988, Prindiville Gaines and Ryan 1988, Nich-

olls and Baldassarre 1990b, Nordstrom 1990, Melvin et al. 1991, Weber and Martin 1991, Flemming et al. 1992, Sidle et al. 1992, Ziewitz et al. 1992), and determining the effects of human disturbance (Flemming et al. 1988, MacIvor et al. 1990, Strauss 1990). Although these actions benefitted local populations, a coordinated census effort across the species' range was necessary to monitor species recovery.

A coordinated, comprehensive census of both breeding and wintering areas accomplishes several goals critical to assessing Piping Plover status and facilitating more efficient recovery. First, it is difficult to design recovery activities when a species' distribution is not understood. Prior to the 1991 census, breeding sites on the western periphery (e.g., Montana, Colorado, and Saskatchewan) of their range had not been completely censused. Despite several intense efforts, the winter distribution was also poorly under-

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TABLE 1. Numbers of wintering Piping Plovers and winter sites censused in 1991.

Location	Birds	Sites ¹	Plover sites ²	Census coordinator
U.S. Atlantic	178	132	30	
North Carolina	20	32	7	Henson
South Carolina	51	27	8	Spinks/Wilkinson/Murphy
Georgia	37	14	6	Johnson
Florida	70	59	9	Kale
U.S. Gulf	3,206	197	126	
Florida	481	66	31	Runde
Alabama	12	6	1	Clay
Mississippi	59	13	7	McDearman
Louisiana	750	29	23	Martin
Texas	1,904	83	64	Eubanks
Mexico Gulf	27	18	4	Sada
Caribbean	40	11+	2	
Bahamas	29	1	1	Fettig
Turks and Caicos	0	1	0	Bradley/Fabian/Fabian
Cuba	11	2	1	Blanco/Garrido
Jamaica	0	n.a.	0	Levy
Puerto Rico	0	5	0	Lee
Cayman Islands	0	n.a.	0	Marsden
Total	3,451	358+	162	

¹ Total number of sites censused for Piping Plovers.

² Number of sites where Piping Plovers occurred.

stood; less than half the breeding birds were accounted for on previous winter counts. Second, without comprehensive and species-wide population estimates, it is difficult to assess numerical status over time, let alone the importance of local populations relative to regional and species population estimates. Since Piping Plovers are fairly mobile throughout the annual cycle, simultaneous censusing provided a novel opportunity to count birds without having to account for problems encountered in past efforts with census overlap due to movements of birds between sites. Finally, design and implementation of a comprehensive, simultaneous, easily repeatable census was necessary so that future population trends could be assessed with greater assurance after several similar censuses were carried out. Recovery objectives for Piping Plovers in the Great Lakes and Northern Great Plains of the United States stipulate that the species may not be considered for removal from the U.S. endangered species list until recovery goals have been maintained for 15 years, assuming that at least three major international censuses have been carried out during this time (Haig et al. 1988). While recovery goals have not yet been met in any of the areas, this first international census

will serve as the baseline for comparison of future censuses.

Therefore, in 1991, biologists from Canada, the United States, Mexico, and several Caribbean nations carried out a simultaneous census of Piping Plovers at all known breeding and wintering sites. Census goals were to establish baseline population levels for all known Piping Plover sites and to census additional potential breeding and wintering sites.

METHODS

The 1991 International Piping Plover Census was designed by the U.S. Great Lakes/Northern Great Plains Piping Plover Recovery Team and carried out in coordination with the Atlantic Coast Piping Plover Recovery Teams in the U.S. and Canada, and the Prairie Canada Piping Plover Recovery Team. Each recovery team leader was responsible for collecting census data from a coordinator in each state or province that participated in the census. State/provincial coordinators organized groups of state and federal biologists and volunteers. The winter census was conducted from approximately 12 to 20 January 1991 along the Gulf Coast of the U.S. and Mexico, the southern Atlantic coast of the U.S., and

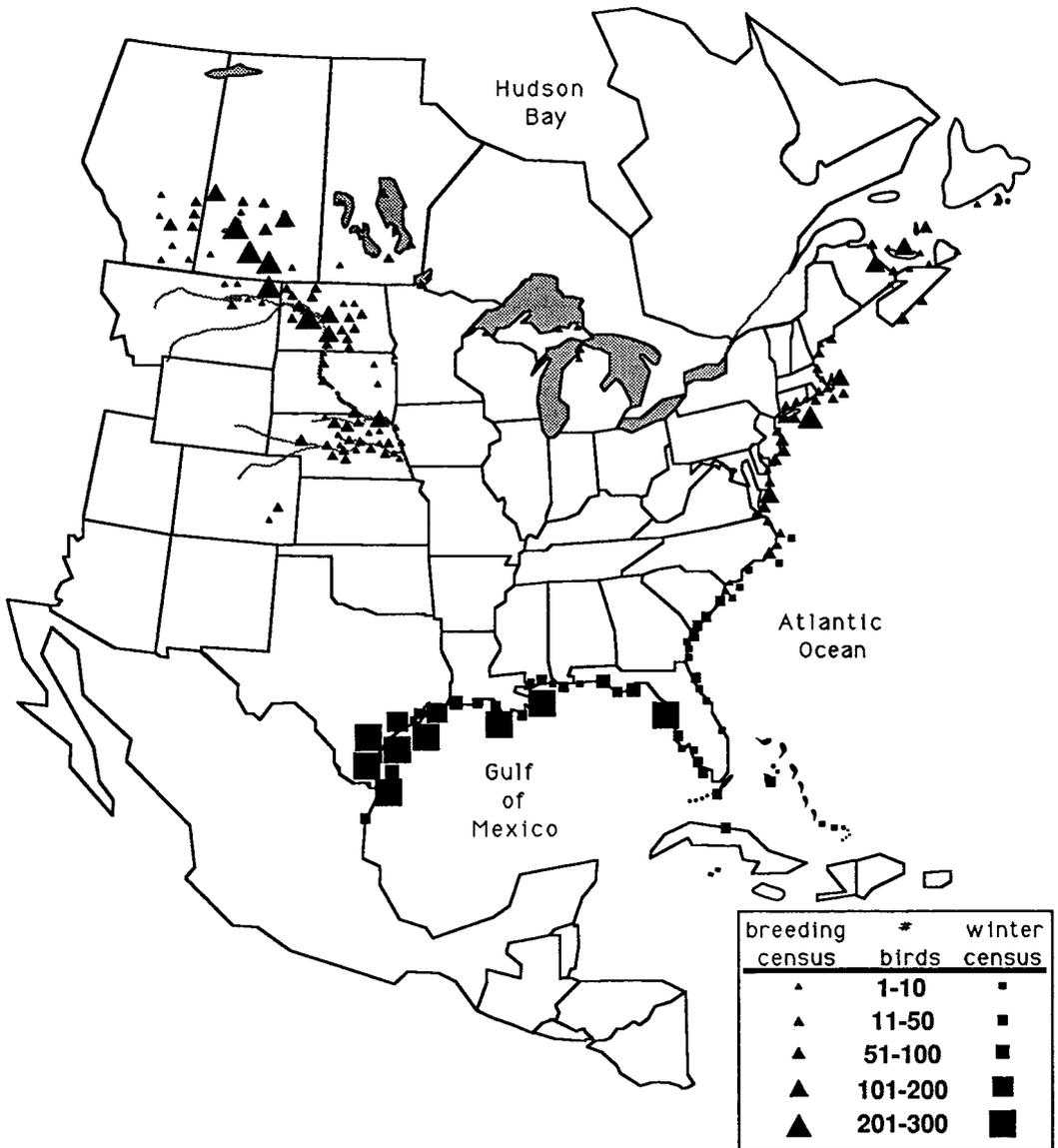


FIGURE 1. Breeding and winter distribution of Piping Plovers in 1991.

the coast of Cuba and several other Caribbean countries (Fig. 1, Table 1). The breeding census was carried out across the species' range from approximately 1 to 9 June 1991 (Fig. 1, Table 3). Areas to be censused were determined by reviewing previous records of Piping Plovers, examining aerial photos and topographic maps for appropriate habitat types, and conducting aerial surveys of habitat. Observers walked, drove or boated along a predetermined stretch of beach

or sandflat and recorded the number and location of Piping Plovers seen. Piping Plover presence or absence was noted at all sites. Color-banded birds, weather, tide stage, time of day, habitat type (e.g., river, lake, beach, mudflat, sandflat), and kilometer of habitat covered were also recorded.

Piping Plovers are fairly easy to identify and count. However, to conduct a census of this scale, methods were simplified to maximize consistent-

TABLE 2. Major Piping Plover winter sites in 1991.

Site	County	State	No. birds	% total census
Mustang Island	Nueces	Texas	281	8.1
Port Mansfield Pass	Willacy	Texas	247	7.1
St. Joseph Island	Aransas	Texas	210	6.0
Matagorda Peninsula South	Matagorda	Texas	154	4.4
Brazos Island/South Bay	Cameron	Texas	151	4.3
Chandeleur Islands	St. Bernard	Louisiana	131	3.8
Matagorda Island	Calhoun	Texas	116	3.3
Honeymoon Island	Pinellas	Florida	102	2.9
West Timbalier Island	Terrebonne	Louisiana	89	2.6
Breton Island	St. Bernard	Louisiana	88	2.5
Western East Island	Terrebonne	Louisiana	86	2.5
Curlew Island	St. Bernard	Louisiana	85	2.4
Redfish Bay islands	Nueces	Texas	82	2.4
South Padre Island	Cameron	Texas	82	2.4
Padre Island	Kleberg	Texas	77	2.2
Bolivar Flats	Galveston	Texas	72	2.1
Three Rooker Bar	Pinellas	Florida	59	1.7
Matagorda Peninsula North	Matagorda	Texas	53	1.5
Buena Vista Ranch	Cameron	Texas	46	1.3
Anna Maria Island	Manatee	Florida	45	1.3
Last Island	Terrebonne	Louisiana	43	1.2

cy among observers and to insure ease of repeatability in future censuses. Age and sex were not recorded due to the difficulty of field identification. Nests, eggs, and chicks were not counted in order to decrease disturbance to breeding areas. The length and remoteness of many census routes made it impossible to carry out all censuses at specific times or tide stages (e.g., at high tide when birds are roosting and easier to count). Finally, censuses were not carried out in rain or exceptionally cold or hot conditions. All raw data and maps from the census are found in Haig and Plissner (1992).

RESULTS AND DISCUSSION

The 1991 International Piping Plover Census represents a benchmark in recovery efforts for Piping Plovers and serves as a model of international cooperation for other endangered species programs. Approximately 1,052 people from 10 nations participated in the census, making it the largest endangered species census ever undertaken in North America. Birds in 2,099 sites were censused resulting in the highest number of breeding (5,482 adults) and wintering (3,451 birds) Piping Plovers ever recorded. The census will have to be repeated three or four more times over the next 15–20 years before population trends are better understood. However, the 1991 census represents a beginning assessment.

Winter census. The January 1991 winter census was conducted at all known U.S. Piping Plover wintering sites and at many Mexican and Caribbean sites where habitat appeared suitable (Table 1, Fig. 1). The winter census was conducted prior to the breeding census so that birds that would become 1991 breeders were censused. Thus, estimates of the percent of 1991 breeding birds accounted for during the winter accurately reflect a comparison of winter birds potentially occurring in 1991 breeding sites. If the winter census had been conducted in late 1991, juveniles that would be 1992 breeders would have been counted instead.

The total number of wintering birds reported comprised 63% of the breeding birds counted (Tables 1, 3). The majority of birds (55%, $N = 1,898$) were found in Texas where census efforts concentrated on birds in previously uncensused stretches of Laguna Madre's back bays. The highest concentration of birds in local sites was also reported in Texas (Table 2). Although the 1991 census resulted in discovery of more wintering birds than had been previously reported, a large proportion of Piping Plovers were not seen in the winter census. Better census effort in Louisiana, northern Cuba and on many of the smaller Caribbean islands may reveal additional winter sites. Previous reviews of museum records and historic accounts of Piping Plovers did not in-

dicating that birds moved farther south than the Caribbean (Haig and Oring 1985).

Since few birds are seen on the Atlantic Coast in winter, the largest gap in our understanding of Piping Plover distribution during winter appears to be in locating winter sites for Piping Plovers that breed on the Atlantic Coast. If more extensive censuses of birds in Laguna Madre in Texas and Mexico begin to account for more Piping Plovers than are found during the breeding season in inland areas, we perhaps could conclude that Atlantic Coast birds are wintering on the Gulf. However, we are currently left with a dilemma.

Identification of marked birds from specific breeding sites in winter sites is helpful in addressing this problem. Knowledge of breeding populations for which we are accounting during the winter may shed light on where future winter censuses should be focused. For example, there are so few records of Atlantic Coast breeders during winter that we may not have adequately determined the winter distribution for these birds. Winter sightings of birds banded in inland breeding sites indicate that we may have better data for inland breeding bird distribution during winter (Fig. 2).

Fourteen banded birds observed in the 1991 winter census were traced to their breeding site. Piping Plovers observed in the Florida Keys were traced to Assateague Island, Maryland ($N = 1$), and Lake of the Woods, Minnesota ($N = 3$). On Florida's gulf, birds were identified from southern Manitoba ($N = 1$) and either North Dakota or Minnesota ($N = 1$). Piping Plovers that wintered in North Carolina were banded in Massachusetts ($N = 1$) and North Dakota ($N = 1$). Piping Plovers seen in Texas were traced to Massachusetts ($N = 3$) and Minnesota ($N = 1$). Merging these data with past reports of banded birds in the winter (Haig and Oring 1985; Haig and Oring 1988b; U.S. Fish and Wildlife Service Bird Banding Lab, unpubl. data) indicates that most inland nesting Piping Plovers winter on the Gulf of Mexico (151/177 inland records, not including 13 inland birds that wintered in the Florida Keys; Fig. 2) and most Atlantic breeders winter farther south on the Atlantic Coast (41/46 Atlantic records, not including three birds that were observed on the Florida Keys; Fig. 3). However, some crossover occurred among inland and Atlantic Coast birds; 26 inland birds crossed over to winter in North and South Carolina, whereas

5 Atlantic Coast nesting birds wintered in Alabama, Florida's Gulf coast, or Texas. Because there is a moratorium on banding of Piping Plovers from the U.S. Atlantic Coast, few birds have been banded in the past two years. Hence, the magnitude of cross-over is difficult to discern.

Piping Plovers occurred in less than half of the seemingly appropriate winter sites censused. Among areas where birds were found, 51% ($N = 1,762$) occurred on ocean beaches, 43% ($N = 1,486$) used sand or algal flats in protected bays, and 6% ($N = 203$) used areas where protected bays met ocean beaches. Discovery of the extensive use of Laguna Madre sand and algal flats will refocus some habitat protection efforts for winter birds. Traditionally, only sand beaches were protected for wintering Piping Plovers.

Breeding census. All known Piping Plover breeding sites were censused in 1991 (Table 3). Piping Plovers were widely distributed in small populations across their breeding range (Fig. 1). Most adults (63.2%) bred in the Northern Great Plains and Prairies of the U.S. and Canada. Thirty-six percent were found on the Atlantic Coast and less than 1% occurred on the Great Lakes. Sites with the highest concentrations of breeding birds also were found in the Northern Great Plains/Prairie, however each local population comprised only a small (<8%) proportion of the total breeding population (Table 4). Local populations were even smaller on the Atlantic Coast. For example, Chincoteague National Wildlife Refuge in Virginia had the highest concentration of breeding Piping Plovers on the Atlantic Coast, representing only 1.6% of all breeding birds (Table 4).

In 1991, Piping Plovers were found more extensively in several breeding areas where previous censuses had only reported a few birds. These include the Missouri River Coteau region of Saskatchewan, several areas in northeastern Montana, and the Prewitt Reservoir in Colorado. However, the birds have all but disappeared from the Great Lakes (Table 5). The gap in distribution between birds from The Atlantic Coast and Northern Great Plains/Prairie increases as the number of birds decline at Lake of the Woods in Minnesota and Ontario, and in Manitoba. Thus, the species may soon have two distinct populations. Genetic studies do not support this claim (Haig and Oring 1988c). However, it will take far more time for genotypes to diverge than for the range to change.

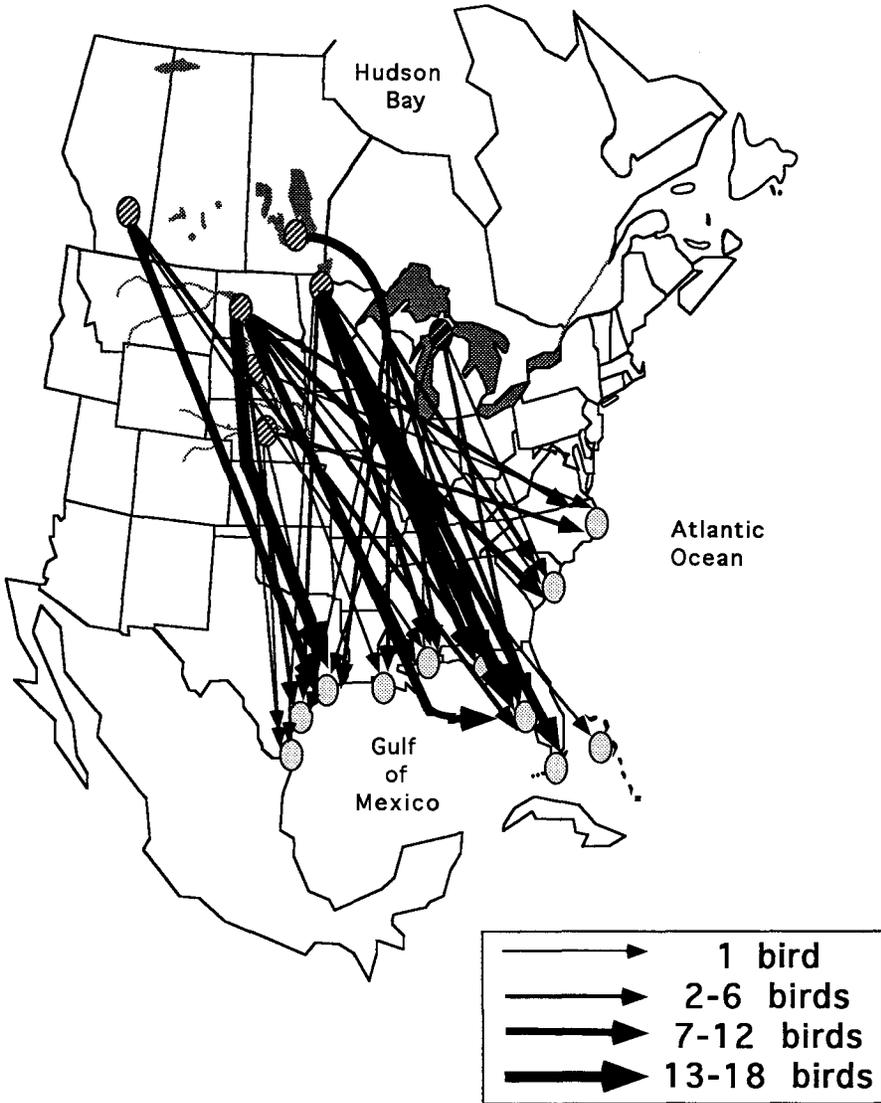


FIGURE 2. Winter sightings of Piping Plovers banded on the Great Lakes, Northern Great Plains, or Prairies during the breeding season (1983–1991).

Because simultaneous, comprehensive censuses were not conducted in the past, assessing population trends is difficult. Examination of long-term census data at specific sites is useful in some cases. Most sites on the Northern Great Plains/Prairie that were monitored for 10 years or more have experienced a decline (Table 5). Atlantic Coast numbers remain stable. However, there has been unprecedented effort to protect Piping Plovers on the Atlantic Coast of the U.S. Results from previous censuses presented in Table 5

should be considered only rough population estimates, as we have little information regarding the intensity of census efforts used to attain those population estimates.

Piping Plovers used various habitat types across their breeding range. On the Atlantic coast, 93.9% ($N = 1,854$) of breeding birds were found on ocean beaches, whereas the remainder ($N = 112$) used protected bays adjacent to the coast. All Great Lakes birds used Great Lakes beaches. In the Northern Great Plains/Prairie: 59.6% ($N =$

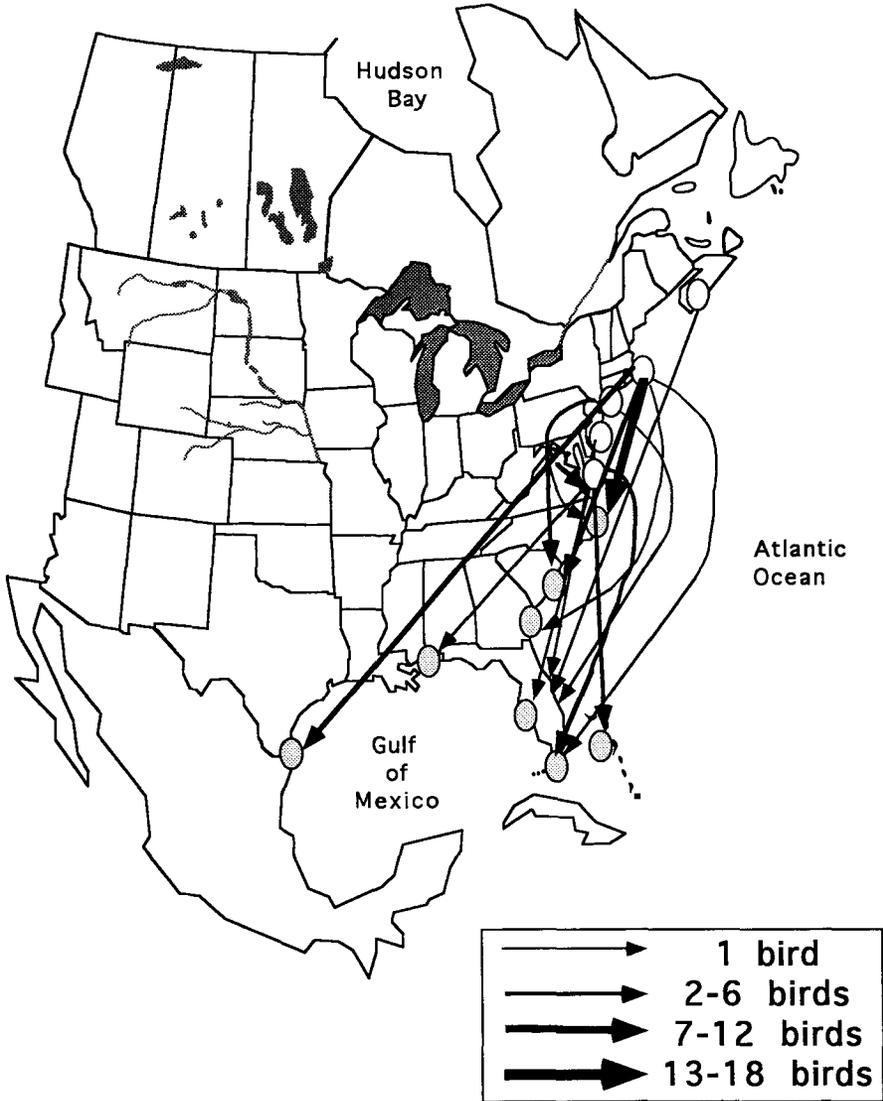


FIGURE 3. Winter sightings of Piping Plovers banded on the Atlantic Coast during the breeding season (1983-1991).

2,067/3,467 sites where habitat was classified) of Piping Plovers used shorelines on alkaline lakes, 18.2% ($N = 632$) used reservoir beaches such as those at Lake Diefenbaker in Saskatchewan, 19.9% ($N = 689$) used river islands and adjacent sand pits, 2% ($N = 68$) used beaches of large freshwater lakes, and 0.4% ($N = 13$) used shorelines of industrial ponds. Similar to the winter census, less than half of the seemingly appropriate sites censused contained breeding birds (Table 3). Thus, extrapolation of bird numbers from

one site to the amount of seemingly available breeding habitat does not yield accurate population estimates.

Overall assessment of total population estimates attained in 1991 depends on the amount of available habitat censused and the intensity with which local areas were censused. In the 1991 census, we emphasized the need to carry out the census during a specific time frame to prevent double-counting of birds moving into new areas. In doing so, some biologists were not able to

TABLE 3. 1991 Piping Plover breeding census.

Location	Adults	Pairs	Total sites ¹	Plover sites ²	Census coordinator
Atlantic Coast	1,975	938	573	288	
Canada	513	236	234	92	
New Brunswick	203	91	41	24	Johnson/Chiasson/Dietz
Newfoundland	7	3	11	1	Brazil
Nova Scotia	113	51	73	34	Austin-Smith
Prince Edward I.	110	51	57	20	McAskill/Hoteling/Ristau
Quebec	76	38	48	11	Laporte
St. Pierre/Miquelon	4	2	4	2	Brazil
United States	1,462	702	339	196	
Maine	38	18	8	8	Logan
Massachusetts	293	148	86	50	Melvin
Rhode Island	47	22	12	7	Raithel
Connecticut	67	30	20	7	Victoria
New York	338	181	101	69	Liebelt
New Jersey	280	122	51	22	Jenkins
Delaware	10	5	7	3	Gelvin-Innvaer
Maryland	35	16	1	1	MacIvor
Virginia	270	131	15	14	Terwilliger
North Carolina	86	30	37	14	Murdock
South Carolina	2	1	1	1	Murdock
Great Lakes	40	17	47	15	
Duluth, MN	0	0	2	0	Pfannmuller
Wisconsin	1	0	12	1	Matteson
Michigan	39	17	32	14	Wiese
Long Point, Ontario	0	0	1	0	Heyens
Northern Great Plains/Prairie	3,467	1,486	1,121+	425	
Canada Prairie	1,437	589	561	111	
Alberta	180	70	48	27	Hoffman
Saskatchewan	1,172	481	485	71	Skeel/Hjertaas
Manitoba	80	36	26	12	Koonz
Lake of Woods, Ontario	5	2	2	1	Heyens
United States Great Plains	2,030	897	560+	314	
Montana	308	105	79	39	Christopherson
North Dakota	992	496	172+	115	Kreil
South Dakota	293	142	64+	47	McPhillips
Lake of Woods, Minnesota	13	6	3	1	Maxson
Colorado	13	3	36	4	Nelson
Nebraska	398	139	200+	106	Sidele
Iowa	13	6	2	2	Howell
Kansas	0	0	1	0	King
Oklahoma	0	0	3	0	Boyd
Totals					
Canada	1,950	825	795	203	
United States	3,532	1,616	946+	525	
Total	5,482	2,441	1,741+	728	

¹ Total number of sites censused for Piping Plovers.² Number of sites where Piping Plovers occurred.

spend as much time at some sites as they would have had they spent the entire season censusing. Hence, some birds may not have been counted. While this is a problem inherent in large-scale

censuses, the degree to which this was a problem in the 1991 breeding census can be assessed by comparing results of the 1991 International Census with population estimates attained after an

TABLE 4. Major Piping Plover breeding sites in 1991.

Site	County/area or river system	m	State/province	No. birds	% regional total	% total breeding pop.
Northern Great Plains/Prairie sites						
Lake Diefenbaker	S. Saskatchewan R.		Saskatchewan	276	8.0	5.0
Gavins Pt.–Sioux City	Missouri River		South Dakota/Nebraska	165	4.8	3.0
J. E. Williams Preserve	McLean Co.		North Dakota	162	4.7	3.0
Lake Sakakawea	Missouri River		North Dakota	162	4.7	3.0
Niobrara River	Niobrara River		Nebraska	152	4.4	2.8
Big Quill Lake	Big Quill Lake		Saskatchewan	151	4.4	2.8
L. Sakakawea–L. Oahe	Missouri River		North Dakota	124	3.6	2.3
Chaplin Lake	Missouri Coteau		Saskatchewan	113	3.3	2.1
Manitou Lake	North West		Saskatchewan	111	3.2	2.0
Platte River sand pits	Platte River		Nebraska	107	3.1	2.0
Lake Oahe	Missouri River		North Dakota/South Dakota	101	2.9	1.8
Lostwood NWR	Missouri Coteau		North Dakota	78	2.2	1.4
Medicine Lake	Sheridan Co.		Montana	65	1.9	1.2
Lake McConaughy	N. Platte River		Nebraska	64	1.8	1.2
Ft. Randall–Gavins Pt.	Missouri River		South Dakota/Nebraska	57	1.6	1.0
Atlantic Coast sites						
Chincoteague NWR	Accomack Co.		Virginia	87	4.4	1.6
North Metomkin Island	Accomack Co.		Virginia	72	3.6	1.3
Breezy Point	Queens Co.		New York	49	2.5	0.9
Forsythe NWR	Ocean Co.		New Jersey	44	2.2	0.8
Little Beach Island	Atlantic Co.		New Jersey	43	2.2	0.8
Gateway NRA	Monmouth Co.		New Jersey	39	2.0	0.7
Assateague Island NS	Worcester Co.		Maryland	35	1.8	0.6
Brigantine Jetty	Atlantic Co.		New Jersey	25	1.3	0.5
Cobb Island	Northampton Co.		Virginia	24	1.2	0.4
Crane Beach	Essex Co.		Massachusetts	24	1.2	0.4
Orient Point SP	Suffolk Co.		New York	20	1.0	0.4
Great Lakes sites						
Grand Marais Inner	Alger Co.		Michigan	8	23.5	0.1
Cross Village North	Emmet Co.		Michigan	6	17.6	0.1
Point Island	Emmet Co.		Michigan	4	11.8	<0.1
Vermillion SP	Chippewa Co.		Michigan	3	8.8	<0.1

entire breeding season had been carried out. Comparison of U.S. Atlantic Coast numbers from the International Census with population estimates compiled as a result of an entire breeding season indicate that while 702 pairs were counted during the International Census, 742 pairs were counted during the entire 1991 breeding season (Hecht 1992). This 5.4% difference is not significant. Some Piping Plovers may not have been counted during the International Census for a number of reasons, including poor weather or tide conditions on the day of the census, variance in observation skills among observers, or differences in breeding stages of individual birds (i.e., birds whose nests had been destroyed near the time of the International Census may not have been on their territories and easily counted). Piping Plover numbers obtained over the entire

summer may have been overestimated in some local breeding sites due to movement of birds that had already been counted in one area to a new site. While it is helpful to know that there may be discrepancies in population estimates based on methodologies used, adjusting our International Census population estimate with results from more intense local studies would introduce even more bias that could not be accounted for. If future International Piping Plover Censuses are carried out using our current methodology, the importance of miscounting some birds may be diminished as results will be comparable between years.

Migration areas. Atlantic Coast Piping Plovers are commonly seen on east coast beaches during spring and fall migration. However, migration routes of inland birds are poorly understood.

TABLE 5. Changes in numbers of Piping Plovers at specific breeding areas.

Location	Date 1st est.	1st est. ¹	Date 2nd est.	2nd est. ¹	1991 ² census	% Change 1st est. --1991	% Change 2nd est. --1991
Atlantic Coast							
Newfoundland	1968	30	1984	4	7	-72	+75
Cadden Beach, Nova Scotia	1976	56	1983	28	20	-64	-29
Maine	1976	48	1982	12	38	-21	+217
Rhode Island	1945	80	1983	20	47	-41	+135
Connecticut	1980	40	1983	34	67	+68	+97
Long Island, New York	1939	1,000	1983	200	338	-66	+69
New Jersey	1980	118	1983	64	280	+137	+338
Delaware	1978	80	1984	18	10	-88	-44
Maryland	1972	85	1984	25	35	-59	+40
Great Lakes							
Michigan	1979	77	1982	14	39	-49	+179
Wisconsin	1900	140	1983	6	1	-99	-83
Northern Great Plains/Prairie							
Big Quill Lake, Saskatchewan	1978	210	1984	186	151	-28	-19
Chain Lakes, Alberta	1976	50	n.a.	n.a.	9	-72	n.a.
Lake Manitoba, Manitoba	1980	27	1984	9	3	-89	-67
Lake of the Woods, Minnesota	1982	44	1986	32	13	-70	-59
Niobrara River, Nebraska	1981	92	1985	100	110	+20	+10

¹ Sources are listed in Haig and Oring (1985).

² Sources are listed in Table 2.

While identification of migration sites was not a focus of the census, only a few occurrences of Piping Plovers were reported at seemingly appropriate inland migration sites such as Kirwin National Wildlife Refuge in Kansas, Cheyenne Bottoms National Wildlife Refuge in Kansas, and Great Salt Plains National Wildlife Refuge in Oklahoma. It appears that inland birds may fly non-stop to Gulf Coast sites. Future work should seek to better identify these migration paths.

Threats to Piping Plovers. As a result of the 1991 census, we gained some perspective into the relative threats facing Piping Plovers. In the Northern Great Plains, water-level regulation policies on the major rivers (e.g., Platte River, Missouri River) serve as a direct source of chick mortality and an indirect source of habitat loss through vegetation encroachment and flooding (Schwalbach 1988, Sidle et al. 1992). As a result of the 1991 Census, we know that 20% of Northern Great Plains/Prairie birds use river sites. Hence, loss of Missouri River productivity can have a significant effect on annual productivity for the species. A 1990 biological opinion issued by the United States Fish and Wildlife Service regarding management on the Missouri River is intended to mitigate this problem in some areas. However, discovery of more Piping Plovers on

ivers in Montana and Colorado as a result of the 1991 census suggests that these current mitigative actions may need to be extended into other areas.

A similar threat to Piping Plovers occurs on Lake Diefenbaker in Saskatchewan, where each year water levels are raised soon after clutch completion and all nests consequently are lost. As a result of 1991 population estimates, we now know that this site is the largest Piping Plover breeding site and that washout of nests represents a significant loss of annual productivity for the species.

Avian and mammalian predation continues to be a problem throughout the species' breeding range (Mayer and Ryan 1991). However, population numbers appear to be stabilizing on the Atlantic Coast and the Great Lakes as a result of using predator exclosures over nests (Rimmer and Deblinger 1990, Melvin et al. 1992). Human disturbance continues to be a problem on the Atlantic Coast and, in the Great Lakes, Piping Plovers may also be suffering from a lack of viable habitat. Comparison of food availability at Northern Great Plains sites with Great Lakes sites indicated lower diversity and abundance of invertebrates on the Great Lakes (Nordstrom 1990).

Discovery of the high proportion of wintering Piping Plovers on algal and sand flats has significant implications for future habitat protection. Previous studies alluded to the importance of sand and algal flats (Haig and Oring 1985, Nicholls and Baldassarre 1990b), but their use by Piping Plovers has never been quantified on such a large scale. Current development of these areas on Laguna Madre in Texas and Mexico, increased dredging operations, and the continuous threat of oil spills in the Gulf of Mexico will result in serious loss of Piping Plover wintering habitat. Clearly, additional research is needed to more fully understand the extent of these threats.

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