PART I: INTRODUCTION

On January 10, 1986, the piping plover (*Charadrius melodus*) was listed as endangered and threatened under provisions of the Endangered Species Act of 1973 (ESA), as amended (U.S. Fish and Wildlife Service 1985). This species breeds only in North America in three geographic regions (Figure 1). The Atlantic Coast population breeds on sandy beaches along the east coast of North America, from Newfoundland to South Carolina. The Great Lakes population historically nested on sandy beaches throughout the Great Lakes, but has declined dramatically and now occurs on just a few sites on the upper lakes. The third population breeds on major river systems and alkali lakes and wetlands of the Northern Great Plains.

In the Final Rule listing the piping plover across its range, the U.S. Fish and Wildlife Service (USFWS) designated the Great Lakes population as endangered and the Atlantic Coast and Northern Great Plains populations as threatened. To facilitate recovery efforts for piping plovers over this wide geographic area, the USFWS appointed two recovery teams. The Great Lakes/Northern Great Plains Recovery Team developed a recovery plan (USFWS 1988a, 1994a) and makes management recommendations for those two plover populations, while the Atlantic Coast Recovery Team has fulfilled an identical role for plovers along the East Coast. Furthermore, two Canadian recovery teams provide guidance for activities to recover Atlantic Coast and Prairie piping plovers in that country (Canadian Wildlife Service 1989); coordination of recovery activities between the two countries is facilitated through exchange of observers (i.e., non-members) among recovery teams and frequent communications.

The plan outlined in this document is the first revision of the 1988 Atlantic Coast Piping Plover Recovery Plan (USFWS 1988e). It reports on progress to date and continuing recovery issues, and provides a strategy for recovery of the entire Atlantic Coast piping plover population, albeit site-specific recommendations are limited to the United States part of its range.

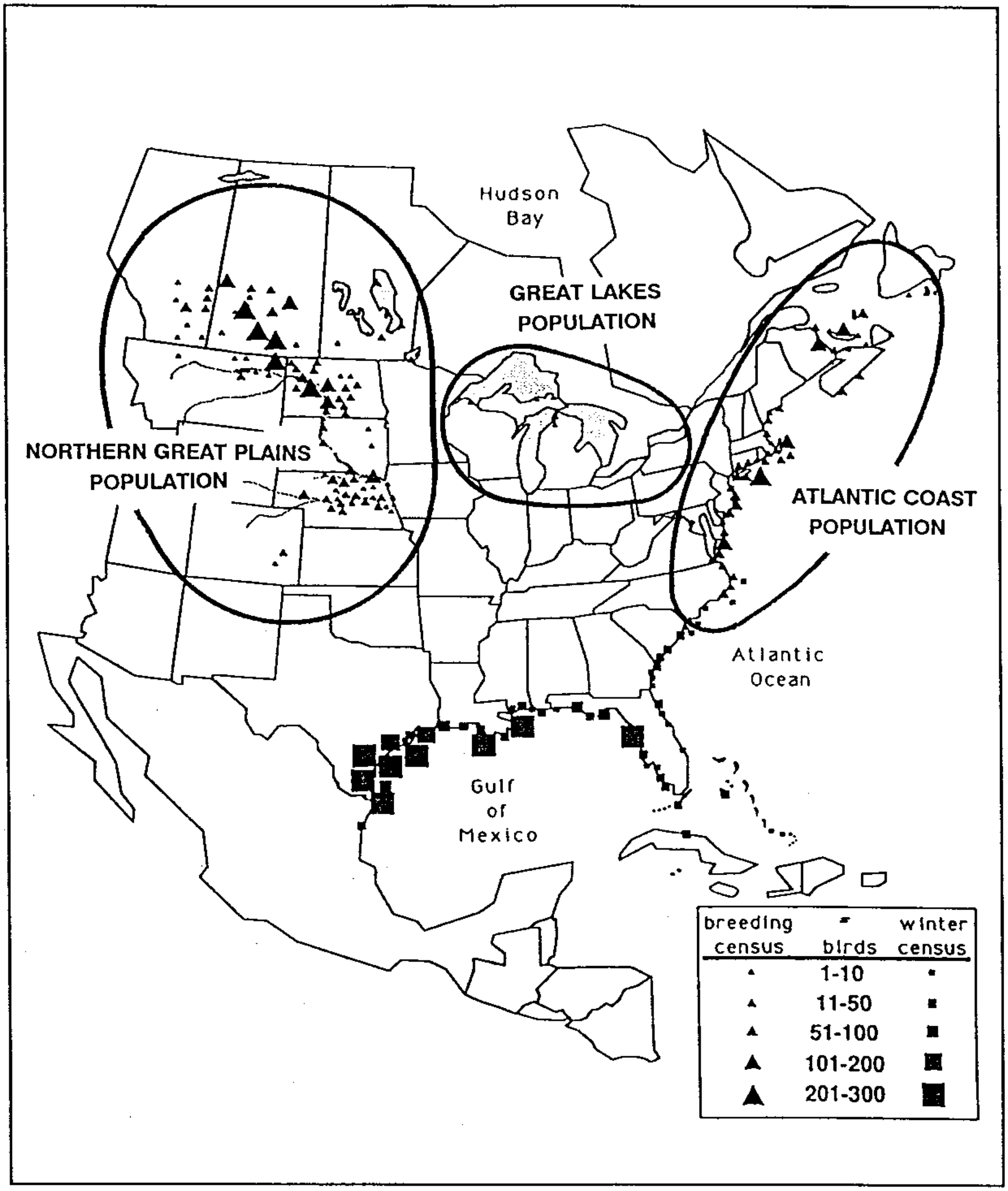

Figure 1. Current Breeding and Wintering Distribution of Piping Plovers in North America (taken from Haig and Plissner 1992)

DESCRIPTION AND TAXONOMY

The piping plover is a small Nearctic (i.e., North American) shorebird approximately 17 centimeters (7 inches) long with a wingspread of about 38 cm (15 in) (Palmer 1967). Wilcox (1959) found that breeding females were slightly heavier than males (55.6 grams vs. 54.9 g), had slightly shorter tail lengths (50.5 millimeters vs. 51.3 mm), but had similar wing lengths. Breeding birds have white underparts, light beige back and crown, white rump, and black upper tail with a white edge. In flight, each wing shows a single, white wing stripe with black highlights at the wrist joints and along the trailing edges. Breeding plumage characteristics are a single black breastband, which is often incomplete, and a black bar across the forehead. The black breastband and brow bar are generally more pronounced in breeding males than females (Wilcox 1939). The legs and bill are orange in summer, with a black tip on the bill.

In winter, the birds lose the black bands, the legs fade from orange to pale yellow, and the bill becomes mostly black. Palmer (1967) provides further details on the plumage and other characteristics of the piping plover.

For many years, ornithologists have debated the designation of two subspecies of piping plover. Moser (1942) argued that the extent and brightness of breastbands distinguished inland and Atlantic breeders, facilitating the acceptance of two subspecies, the inland *C. m. circumcinctus* and the coastal *C. m. melodus*, by the American Ornithologists' Union (AOU) (AOU 1945). Wilcox (1959) considered the subspecies *circumcinctus* of dubious validity, noting occurrence of complete breastbands on 18% of the birds that he trapped on Long Island, lack of appreciable differences in wing and tail measurements of birds with different plumage types, and absence of relationship among plumages of adults and offspring. Electrophoretic analyses (Haig and Oring 1988a) did not detect any genetic differences among local or regional populations in Saskatchewan, Manitoba, North Dakota, Minnesota, and New Brunswick. Although the AOU (1957, 1983) continues to officially recognize the two subspecies, Haig and Oring (1988a) conclude that current information does not support subspecies designation.

Protection of the entire species *Charadrius melodus* under the ESA reflects its precarious status rangewide, but the USFWS also recognizes three distinct piping plover population segments, one designated as endangered, two as threatened. Recovery objectives have been established for each population. Despite intensive censusing of breeding sites rangewide at least since 1986 as well as marking of more than 2,700 birds between 1981 and 1989 (J.L. Spinks, U.S. Fish and Wildlife USFWS, *in litt.* 1989), no interchange between Atlantic Coast and inland breeding populations has been reported. Although some mingling of birds from various breeding populations occurs in wintering habitat (Haig and Oring 1988b, Haig and Plissner 1993), all available evidence shows that Atlantic Coast piping plovers form a distinct breeding population. Dispersal within the Atlantic Coast population is discussed under Breeding Site Fidelity and Dispersal, page 28.

LIFE HISTORY AND ECOLOGY

BREEDING

The breeding chronology of the Atlantic Coast *Charadrius melodus* populations in the United States part of its range is illustrated in Figure 2. A description of breeding behavior and habitat use is provided below.

Arrival and Courtship

Piping plovers have been observed as early as February 24 in Virginia (Cross 1991), March 11 in New York (Goldin 1990), March 15 in Massachusetts (MacIvor 1990), and March 28 in Nova Scotia (Mills 1976, cited *in* Cairns 1977). Cross (1991) reported that feeding was the most common plover activity during March in Virginia. Cairns (1977) also reports early season flocking of unpaired birds in neutral feeding areas (i.e., areas not defended through territorial behaviors) in Nova Scotia.

By early April, males begin to establish territories (Patterson 1988, MacIvor 1990, Cross 1991), which they defend aggressively against adjacent males by performing "horizontal threat," "parallel run," and aerial displays, characterized by Cairns (1982). Parallel runs may cover distances up to 100 meters, while aerial displays may be performed from just above ground level up to approximately 35 m and are generally accompanied by continuous vocalization. Courtship rituals include tilt displays, tossing of shell fragments, and scraping of multiple shallow depressions in the sand. Cairns (1982) also provides descriptions of copulatory activities.

Piping plovers are monogamous, but usually shift mates between years (Wilcox 1959, Haig and Oring 1988c, MacIvor 1990) and, less frequently, between nesting attempts in a given year (Haig

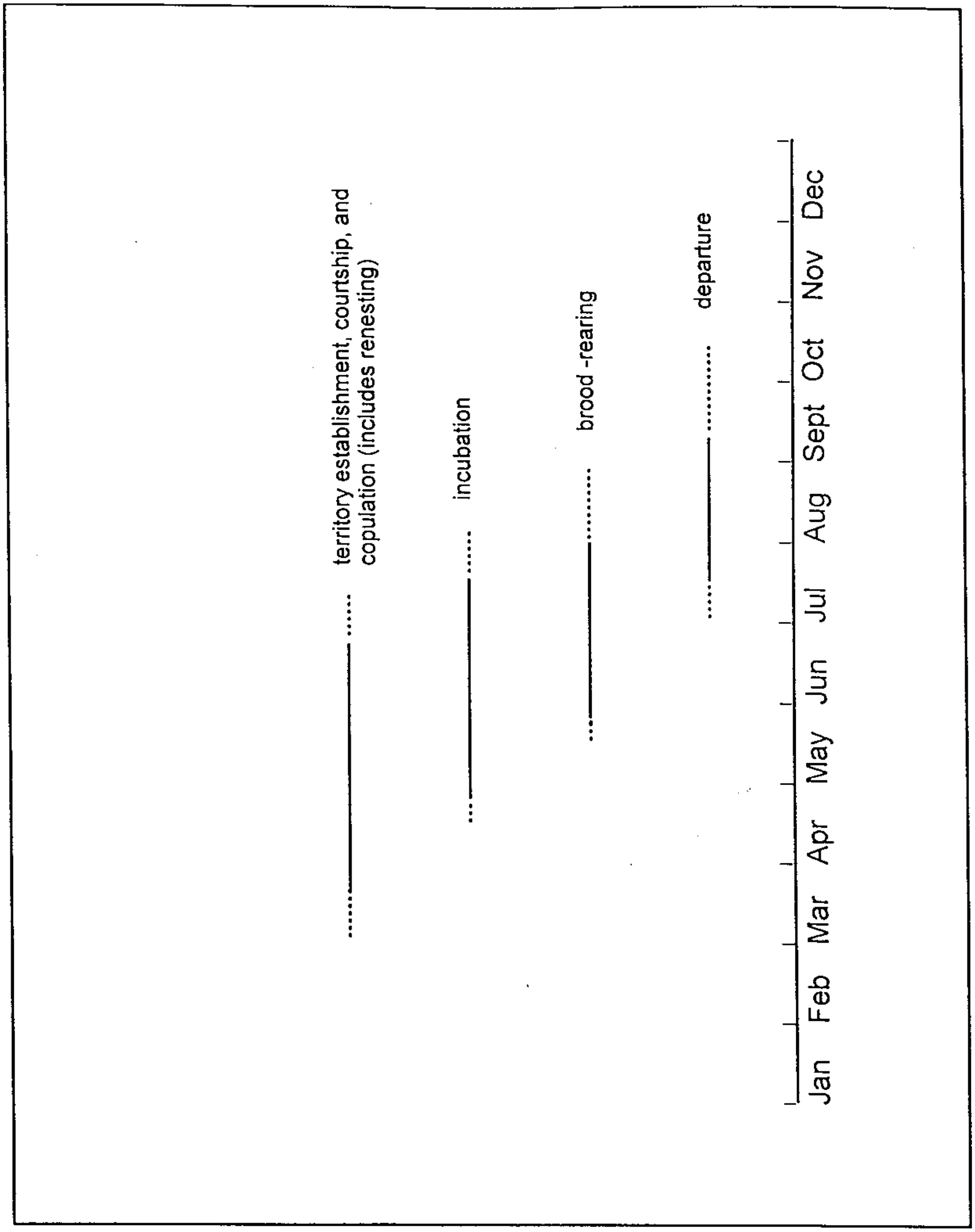

Figure 2. Atlantic Coast Breeding Chronology

and Oring 1988c, MacIvor 1990, Strauss 1990). Plovers are known to breed at one year of age (MacIvor 1990, Strauss 1990, Haig 1992), but the rate at which this occurs is unknown.

Nests

Piping plover nests are situated above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout[1] areas behind primary dunes, and washover[2] areas cut into or between dunes. They may also nest on areas where suitable dredge material has been deposited. Nest sites are shallow scraped depressions in substrates ranging from fine grained sand to mixtures of sand and pebbles, shells, or cobble (Bent 1929, Burger 1987a, Cairns 1982, Patterson 1988, Flemming *et al.* 1990, MacIvor 1990, Strauss 1990). Nests are usually found in areas with little or no vegetation although, on occasion, piping plovers will nest under stands of American beachgrass (*Ammophila breviligulata*) or other vegetation (Patterson 1988, Flemming *et al.* 1990, MacIvor 1990).

Nesting Densities

Piping plovers are territorial nesters, defending both nesting and brood rearing territories from conspecifics[3] (Wilcox 1959, Cairns 1977). Observed nesting densities are highly variable, however. Wilcox (1959) reported that nests of adjacent pairs are usually spaced 200 feet or more apart and are seldom closer than 100 feet. Nests in Cairns' (1977) primary study area in Nova Scotia averaged about 50 m apart, but the shortest distance between two simultaneously active nests was 3 m. Elias-Gerken (1994) noted contrasting densities of pairs within her study area on New York's central barrier islands; in 1992, she located 2.1 pairs per kilometer on Westhampton Island and 1.8 pairs per km on Jones Island, compared with 0.2 pairs per km on Fire Island.

Data gathered to date at New England sites where productivity has been high and the population has increased in recent years suggest that, at most sites, observed nesting densities may be

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1 Blowouts are distinctive "bowl-like" areas within the interdune area caused by wind erosion behind the primary dune ridge; the ocean view is often obstructed.

2 Washover areas are created by the flow of water through the primary dune line with deposition of sand on the barrier flats, marsh, or into the lagoon, depending on the storm magnitude and the width of the beach (Leatherman 1979). Nests may be situated on portions of these storm-created areas that are relatively dry during the nesting season, while plovers may feed on any portions that stay moist.

3 Conspecifics are other members of the same species, in this case, other piping plovers.

a function of available breeding birds, which may be limited because of depressed productivity for many years. Dramatic increases in breeding densities have occurred without declines in productivity that might suggest overcrowding. For example, the piping plover population on the Cape Cod National Seashore in Massachusetts increased from 13 pairs in 1988 to 72 pairs in 1994, while average productivity in the same area increased from 0.9 chicks per pair in 1988 to 2.1 and 2.5 chicks per pair in 1993 and 1994, respectively (Brown and Hoopes 1993; S.M. Melvin, Massachusetts Division of Fisheries and Wildlife, *in litt.* 1994). Similarly, the number of breeding pairs at Crane Beach, Massachusetts increased from five pairs in 1986 to 18 in 1993; the lowest productivity recorded on the site during this period was 1.8 chicks per pair in 1990 (Rimmer 1994). In Maine, 15 pairs with average productivity of 1.7 chicks per pair nested at Seawall/Popham/Hunnewell Beach in 1993, where only two pairs were recorded in 1981 (J. Jones, Maine Audubon Society, *in litt.* 1992, 1993). The nesting population on about eight hectares at Goosewing Beach in Rhode Island increased from three pairs in 1986 to nine pairs in 1994, when productivity was over 2.6 chicks per pair (C. Raithel, Rhode Island Division of Fish and Wildlife, *in litt.* 1994).

Egg-laying and Incubation

Eggs may be present on the beach from mid-April to late July. Clutch initiation dates have been recorded as early as April 21 in Virginia (Cross 1991), April 15 in New York (C. Brittingham, The Nature Conservancy, pers. comm. 1994), April 20 in Massachusetts (MacIvor 1990), and April 24 in Nova Scotia (Cairns 1977).

Piping plovers generally fledge only a single brood per season, but may renest several times if previous nests are lost or, infrequently, if a brood is lost within several days of hatching (Wrenn 1991, Goldin 1994a, Rimmer 1994). A few extremely rare instances of adults renesting following fledging of an early brood have also been observed (J. Victoria, Connecticut Department of Environmental Protection, *in litt.* 1994; Bottitta *et al.* 1994). One female on Cape Cod was observed in five nesting attempts laying a total of 19 eggs in a season (MacIvor 1990). Renests often occur on the same site, but movements between sites have also been recorded (Cross 1990, MacIvor 1990).

A comparison of data from North Carolina (Coutu *et al.* 1990, McConnaughey *et al.* 1990, Wrenn 1991), Rhode Island (C. Raithel, files), and Nova Scotia (Cairns 1977), reveals completed clutches from first nest attempts as early as mid-April and as late as mid-June, with a peak in all three areas between April 30 and May 7. Nest initiation appears to be slightly later in Quebec, Prince Edward Island, and on the eastern shore of New Brunswick, with a peak of nest initiation in mid-May to early June (Morse 1982, Tull 1984, Shaffer and Laporte 1992). Although nests may be initiated as late as July 25, few nests hatch after July 15, and the latest recorded hatch date is July 31 in Massachusetts (MacIvor 1990).

Clutch size for an initial nest attempt is usually four eggs, one laid every other day. Eggs are pyriform in shape, with variable buff to greenish ground color marked with black or brown spots. Cairns (1977) and Wilcox (1959) reported mean egg lengths of 32.5 mm (n = 215) and 31.7 mm (n = 26), respectively. Plover nests and eggs are very difficult to detect, especially during the 6-7 day egg-laying phase when the birds generally do not incubate (Goldin 1994a).

Full-time incubation usually begins with the completion of the clutch, averages 27-30 days, and is shared equally by both sexes (Wilcox 1959, Cairns 1977, MacIvor 1990).

Brood-rearing

Eggs in a clutch usually hatch within four to eight hours of each other, but the hatching period of one or more eggs may be delayed by up to 48 hours (Cairns 1977, Wolcott and Wolcott 1994). Chicks are precocial[1], often leaving the nest within hours of hatching (Wilcox 1959, Cairns 1982, Wolcott and Wolcott 1994), but are tended by adults who lead the chicks to and from feeding areas, shelter them from harsh weather, and protect the young from perceived predators (see following section). Broods may move hundreds of meters from the nest site during their first week of life (Table 1). Chicks remain together with one or both parents until they fledge (are able to fly) at 25 to 35 days of age. Depending on date of hatching, flightless chicks may be present from mid-May until late August, although most fledge by the end of July (Patterson 1988, Goldin 1990, MacIvor 1990, Howard *et al.* 1993). After fledging, adults and young may congregate on neutral (non-territorial) feeding grounds prior to southward migration (Cairns 1977).

Most time budget studies reveal that chicks spend a very high proportion of their time feeding (Table 2). Cairns (1977) found that piping plover chicks typically tripled their weight during the first two weeks after hatching; chicks that failed to achieve at least 60% of this weight gain by day 12 were unlikely to survive. Loegering (1992) found that chick weight and length of exposed bill measured at four or five days of age were significantly higher for chicks that ultimately fledged than for those not surviving.

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1 Precocial birds are mobile and capable of foraging for themselves within several hours of hatching.

Table 1. Summary of Chick Mobility Data

Source	Location	Data
Patterson (1988: 40)	Maryland and Virginia	Eighteen of 38 broods moved to feeding areas more than 100 meters from their nests; 5 broods moved more than 600 meters (distance measured parallel to wrack line).
Cross (1989: 23)	Virginia	At 3 sites, observers relocated broods at mean distances from their nests of 153 m +/-97 m (44 observations, 14 broods), 32 m +/-7 m (8 observations, 3 broods), and 492 m +/-281 m (12 observations, 4 broods).
Coutu *et al.* (1990: 12)	North Carolina	Observations of 11 broods averaged 212 m from their nests; 3 broods moved 400-725 m from nest sites.
Strauss (1990: 33)	Massachusetts	Ten chicks moved more than 200 m during first 5 days post-hatch while 19 chicks moved less than 200 meters during same interval.
Loegering (1992: 72)	Maryland	Distances broods moved from nests during first 5 days post-hatch averaged 195 m in bay habitat (n=10), 141 m in interior habitat (n=36), and 131 m in ocean habitat (n=41). By 21 days, average movement in each habitat had, respectively, increased to 850 m (n=1), 464 m (n=10), and 187 m (n=69). One brood moved more than 1000 m from its nest.
Melvin *et al.* (1994)	Massachusetts and New York	In 14 incidents in which 18 chicks were killed by vehicles, chicks were run over ≤ 10 m to ≤ 900 m from their nests. In 7 of these instances, mortality occurred ≥ 200 m from the nest.

Table 2. Summary of Chick Time Budget Data

Source	Location	Data
Flemming (1984: 27)	Nova Scotia	Major chick activities were feeding (80.5% of time) and being brooded (15.7%). Percent of time spent feeding was 34% for chicks ages 0-5 days, and above 89% for all age-classes over 5 days old.
Loegering (1992: 74)	Maryland	Chicks 3-10 days old in bay beach, interior, and ocean habitats spent 76%, 80%, and 37% of their time feeding, respectively. Time spent foraging by chicks 11-20 days in the respective habitats was 82%, 88%, and 56%.
Elias-Gerken (1994: 51)	New York	On average, chicks spent 73-75% of their time foraging and 13-16% resting. Foraging accounted for 58-73% of time of chicks 0-2 days old, 73-75% for chicks 3-10 days old, 82-77% for chicks 11-20 days old, and 76-75% for chicks 21-25 days old.
Goldin (1993b: 44)	New York	In 1988, 61% of chick observations were of feeding, 11% being brooded or guarded, 10% maintenance, 10% locomotion, and 6% disturbance. In 1989, percentages were 59% feeding, 24% maintenance, 7% disturbance, 6% locomotion, and 4% being brooded or guarded.
Hoopes (1993: 33)	Massachusetts	Chicks devoted 35% of their time to feeding behaviors, 39% to maintenance, 15% to disturbance-related behaviors, 4% to locomotion, 2% to being brooded, and 5% to other behaviors.
Burger (1991: 44)	New Jersey	Chicks spent 22% of their time feeding, 27% alert, 39% running away from people, and 10% crouched.
Goldin (1993a: 16)	Rhode Island	Chicks devoted 72% of their time to feeding and 17% to maintenance behaviors; 4% of their time was spent in disturbance behaviors. All other behaviors accounted for 7% of their time.

Defense of Nests and Chicks

Cryptic coloration is a primary defense mechanism for this species; nests, adults, and chicks all blend with their typical beach surroundings. Chicks sometimes respond to vehicles and/or pedestrians by crouching and remaining motionless (Cairns 1977, Tull 1984, Goldin 1993b, Hoopes 1993). Adult piping plovers also respond to intruders (avian and mammalian) in their territories by displaying a variety of distraction behaviors, including squatting, false brooding, running, and feigning injury. Distraction displays may occur at any time during the breeding season, but are most frequent and intense around the time of hatching (Cairns 1977). Distances at which plovers react to human disturbance are summarized in Table 3.

Feeding Habitat and Habits

Plover foods consist of invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks (Forbush 1925, Bent 1929, Cairns 1977, Nicholls 1989, Gibbs 1986, Shaffer and Laporte 1994). Burger (1994) found more polychaete worms in core samples taken from intertidal areas where plovers were feeding than in random samples.

Feeding areas include intertidal portions of ocean beaches, washover areas, mudflats, sandflats, wrack lines[1], and shorelines of coastal ponds, lagoons, or salt marshes (Gibbs 1986, Coutu *et al.* 1990, Hoopes *et al.* 1992, Loegering 1992, Goldin 1993b). Studies have shown that the relative importance of various feeding habitat types may vary by site (Gibbs 1986, Coutu *et al.* 1990, McConnaughey *et al.* 1990, Loegering 1992, Goldin 1993b, Hoopes 1993, Elias-Gerken 1994) and by stage in the breeding cycle (Cross 1990). Adults and chicks on a given site may use different feeding habitats in varying proportion (Goldin *et al.* 1990). During courtship, nesting, and brood-rearing, feeding territories are generally contiguous to nesting territories (Cairns 1977), although instances where brood-rearing areas are widely separated from nesting territories are not uncommon (see Table 1). Feeding activities of both adults and chicks may occur during all hours of the day and night (Burger 1994) and at all stages in the tidal cycle (Goldin 1993b, Hoopes 1993).

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[1] Wrack is organic material including seaweed, seashells, driftwood and other materials deposited on beaches by tidal action.

Table 3. Summary of Data on Distances at which Piping Plovers React to Disturbance

Source	Location	Data
FLUSHING OF INCUBATING BIRDS BY PEDESTRIANS:		
Flemming *et al.* (1988: 326)	Nova Scotia	Adults usually flushed from the nests at distances <40 m; however, great variation existed and reaction distances as great as 210 m were observed.
Cross (1990: 47)	Virginia	Mean flushing distances in each of two years were 47 m (n=181, range = 5 m to 300 m) and 25 m (n=214, range = 2 m to 100 m).
Loegering (1992: 61)	Maryland	Flushing distances averaged 78 m (n=43); range was 20 m to 174 m. Recommended use of 225 m disturbance buffers on his site.
Cross and Terwilliger (1993)	Virginia	Mean flushing distance for all years on all sites (Virginia plover sites, 1986-91) was 63 m (n=201, SD=31, range = 7 m to 200 m). Differences among years were not significant, but differences among sites were.
Hoopes (1993: 72)	Massachusetts	Mean flushing distance for incubating plovers was 24 m (n=31).
DISTURBANCE TO NON-INCUBATING BIRDS:		
Hoopes (1993: 89)	Massachusetts	Mean response distance (all ages, all behaviors) was 23 m for pedestrian disturbances (range = 10 m to 60 m), 40 m for vehicles (range = 30 m to 70 m), 46 m for dogs/pets (range = 20 m to 100 m), and 85 m for kites (range = 60 m to 120 m).
Goldin (1993b: 74)	New York	Average flushing distance for adult and juvenile plovers was 18.7 m for pedestrian disturbances (n=585), 19.5 m for joggers (n=183), and 20.4 m for vehicles (n=111). Pedestrians caused chicks to flush at an average distance of 20.7 m (n=175), joggers at 32.3 m (n=37), and vehicles at 19.3 m (n=7). Tolerance of individual birds varied; one chick moved 260 m in direct response to 20 disturbances in 1 hour.

MIGRATION

Atlantic Coast piping plover migration patterns are not well documented. Most piping plover surveys have focused on breeding or wintering sites, and it is sometimes difficult to distinguish local nesting birds and fledged young feeding on neutral feeding areas from non-local breeders on stopover during southward migration. References to piping plover migration are contained in Bent (1929), Griscom and Snyder (1955), Bull (1964), Cairns (1977), Raithel (1984), Tull (1984), Haig and Oring (1985), McConnaughey *et al.* (1990), Nicholls and Baldassarre (1990a), Haig and Plissner (1993), and Collazo *et al.* (1995). Northward migration to the breeding grounds occurs during late February, March and early April, and southward migration to the wintering grounds extends from late July, August, and September. On the breeding grounds, transient birds have been observed following early autumn hurricanes (C. Raithel pers. obs.) and are occasionally sighted during October.

Both spring and fall migration routes are believed to follow a narrow strip along the Atlantic Coast. Appendix B identifies many breeding sites where concentrations of post-breeding and migrating plovers have been observed. There are several North Carolina sites where relatively large numbers of plovers have been observed during migration, including Oregon Inlet, Ocracoke Inlet/Portsmouth Flats, and New Drum Inlet, within the Cape Hatteras and Cape Lookout National Seashores (McConnaughey *et al.* 1990; S. Wrenn, North Carolina State University, pers. comm. 1994). In addition, plover numbers fluctuate at Ohio Key, Florida during spring and fall periods, suggesting use by migrant plovers (M. Brown pers. comm. 1988).

Sightings away from the outer beaches, either inland or offshore, are rare (Bull 1964, Barbour *et al.* 1973, Imhof 1975, Potter *et al.* 1980). Observations of color-marked birds from the Atlantic Coast suggest some crossover to Gulf Coast wintering areas (Haig and Plissner 1993); however, routes are unknown. Occasional sightings of piping plovers at distant islands, such as Bermuda (American Birds 1987, 1990; D. Wingate, Bermuda Aquarium and Natural History Museum, *in litt.* 1988), demonstrate that long-distance migrations are possible. Intensified survey efforts during migration periods should result in identification of additional important stopover areas.

WINTERING

Distribution

The piping plover's winter range extends along the Atlantic and Gulf Coasts from North Carolina to Mexico and into the Bahamas and West Indies (USFWS 1985, Haig and Oring 1985, Haig and Oring 1988b, Hoopes *et al.* 1989). Two fairly comprehensive surveys, one conducted between January 1983 and April 1984 and the other between December 1986 and March 1988, provided preliminary insight into winter distribution and contributed to the identification of specific wintering sites (Haig and Oring 1985, Nicholls and Baldassarre 1990a). The most comprehensive survey to date was the 1991 International Piping Plover Census, which tallied a total of 3,451 plovers, the largest number of birds ever accounted for during the winter period (Haig and Plissner 1993). While approximately 63% of the known adult plovers were observed during this rangewide survey, a large number of plovers are still unaccounted for during the wintering period.

Pooling sightings of banded birds from the 1991 International Census and earlier reports, Haig and Plissner (1993) reported 49 band sightings on the wintering grounds of plovers banded on the Atlantic Coast breeding grounds, including 41 birds (84%) sighted on the southern Atlantic Coast, five (10%) on the Gulf Coast, and three (6%) in the Florida Keys. Twenty-six piping plovers from inland breeding populations (14% of band sightings) were also reported wintering in North or South Carolina. The magnitude of crossover between coasts is difficult to ascertain, because few birds are seen on the Atlantic Coast in winter, and a relatively small proportion of the Atlantic Coast plovers are banded. The development of refined techniques for genetic testing may eventually assist in addressing this issue (S. Haig, National Biological Survey, *in litt.* 1994).

Plovers wintering on the Atlantic Coast are generally distributed in small groups; six was the average number of piping plovers per site during Nicholls' 1986-87 survey (Nicholls 1989). The barrier islands off Georgia and South Carolina (especially Deveaux Bank) appear to host the largest numbers of wintering birds. A few sites in North Carolina (e.g., Bird Shoals and Figure 8 Island) and Florida (Ward's Bank, Little Talbot Island, Ohio Key, Boca Grande Key) also have relatively high numbers for the Atlantic Coast.

Several sightings have been recorded in the Caribbean and more intensive searches may locate more birds. Haig and Oring (1985) reviewed museum records and did not find any records of birds wintering farther south than the Lesser Antilles. Additional searches along the Louisiana, Texas, and

Mexico Gulf beaches may result in upward revisions in wintering plover counts there. Indeed, the large proportion of birds found in Louisiana and Texas during the 1991 International Census suggests the possibility that more birds from the Atlantic Coast breeding population may be wintering on the Gulf Coast than previously surmised (Haig and Plissner 1993).

Habitat Selection

In general, wintering plovers on the Atlantic Coast are found at accreting ends of barrier islands, along sandy peninsulas, and near coastal inlets. Plovers appear to prefer sandflats adjacent to inlets or passes, sandy mudflats along prograding spits, and overwash areas as foraging habitats. These types of substrates may have a richer infauna than the foreshore of high energy beaches and attract large numbers of shorebirds. Roosting plovers are generally found along inlet and adjacent ocean and estuarine shorelines and their associated berms (with wrack and other debris often used as wind-shields), and on nearby exposed tidal flats (Fussell 1990, Nicholls and Baldassarre 1990a).

Nicholls and Baldassarre (1990b) attempted to develop a predictive model of habitat use along the Atlantic and Gulf Coasts and identified variables that could be measured over a broad spectrum of sites. While a few general features, such as the presence of large inlets and large areas of sand or mudflats, appeared important, no single variable dominantly identified typical habitats. Thus, plover distribution may be influenced by a number of habitat variables, and it may be the presence of a diversity of microhabitats in close juxtaposition that separates the sites commonly used by wintering plovers from non-plover sites. While this study provided a preliminary overview of plover winter habitat, more investigation is needed to provide a fuller habitat characterization. Research is presently underway along the Texas Coast to more precisely characterize wintering habitat and to identify features predictive of plover use (Zonick and Ryan 1993). One important discovery from this latter study and the 1991 census was the high use of blue-green algal mats by wintering plovers in the Laguna Madre area. This discovery may broaden the search image for new wintering areas in Mexico and the Caribbean.

Habitat Use and Movements

Investigations during winter are few and have focused primarily on population density and distribution (Haig and Oring 1985, Haig and Oring 1988b, Nicholls and Baldassarre 1990a, Haig and Plissner 1993). Studies on the Alabama and Texas Coasts have provided insight into habitat use and movements, foraging efficiencies, and interspecific interactions. Johnson and Baldassarre (1988) found that different microhabitats in coastal Alabama -- sandflats, mudflats, beaches -- may serve different functional roles for wintering plovers depending on tidal stage, weather, and time of day. The study also found that plovers spend a high percentage of time foraging relative to other activities during the fall and midwinter. Tidal height appeared to be the most important factor affecting foraging time; higher tide negatively correlated with foraging. Zivojnovich and Baldassarre (1987) radio-tracked several wintering plovers in coastal Alabama and found them to utilize several sites within the general barrier island complex of Mobile Bay depending on tidal stage and weather. Ongoing research on the Texas Coast (Zonick and Ryan 1993) also indicates the importance of tides in plover habitat use.

The periodicity of local tides greatly influences the diurnal availability of foraging habitat (Zonick and Ryan 1993). Habitat along the Atlantic Coast is primarily influenced by lunar tides and is regularly available; thus, plover use of sites may be more predictable than in areas such as south Texas where tides are influenced by winds. Indeed, plovers may stay within one inlet area or barrier island complex on the Atlantic Coast (Fussell 1990). Observations of banded birds in Texas suggest that individual plovers shuttle between small, discrete areas from algal or tidal flats to beaches (Zonick and Ryan 1993). Haig and Oring (1985) noted a seasonal difference in habitat use along the Gulf Coast, with larger numbers of plovers occurring on sandflats adjacent to beaches and coastal inlets during the winter; more birds were observed on beaches during migration. Observations along the Texas Coast also suggest this seasonal habitat preference (T. Eubanks, Great Lakes/Northern Great Plains Piping Plover Recovery Team, pers. comm. 1992).

Winter Site Fidelity

Johnson and Baldassarre (1988) found relatively high site fidelity for plovers wintering in the Mobile Bay area in Alabama. Similarly, there are several reports of banded birds returning year after year to the same wintering sites on both the Atlantic and Gulf Coasts (S. Bogert pers. comm. 1988; T. Below, National Audubon Society, pers. comm. 1988; T. Eubanks pers. comm. 1989; Zonick and Ryan 1993; J. Fussell pers. comm. 1995).

Intra- and Inter-specific Interactions

During the winter, piping plovers are often found in association with several other shorebird species (Nicholls and Baldassarre 1990b, Eubanks 1992). Territorial and agonistic interactions have been observed with other piping plovers and similar-sized plover species -- semipalmated and snowy plovers (Johnson and Baldassarre 1988, Zonick and Ryan 1993). In Alabama, combined time spent in territorial and agonistic activities largely involved intraspecific interactions (Johnson and Baldassarre 1988). Piping plovers appear to be aggressive and may defend food patches during the winter period (Zonick and Ryan 1993). Piping plovers also appear to roost in multi-species flocks (Nicholls and Baldassarre 1990b, Zonick and Ryan 1993), but are often found in a tight cluster on the fringes of a flock (J. Nicholls, U.S. Fish and Wildlife Service, pers. obs.).

POPULATION STATUS AND DISTRIBUTION

ABUNDANCE

Trends Prior to 1985

Historical population trends for the Atlantic Coast piping plover have been reconstructed from scattered, largely qualitative records. Nineteenth-century naturalists, such as Audubon and Wilson, described the piping plover as a common summer resident on Atlantic Coast beaches (Haig and Oring 1987). By the beginning of the 20th century, uncontrolled hunting (primarily for the millinery trade) and egg collecting had greatly reduced the population, and in some areas along the Atlantic Coast the piping plover was close to extirpation. Following passage of the Migratory Bird Treaty Act in 1918 and changes in the fashion industry, piping plover numbers recovered to some extent (Haig and Oring 1985).

Raithel (1984) showed that Rhode Island piping plover numbers reached a 20th-century peak following the 1938 hurricane, which flattened dunes and destroyed shoreline developments. Rhode Island piping plover numbers declined after World War II, as habitat was lost to dune stabilization efforts and summer home construction. The population partially recovered following another severe hurricane in 1954 before beginning a steady decline which continued through the early 1980's.

Wilcox (1959) documented major fluctuations in piping plover numbers between Moriches Inlet and the village of Southhampton on Long Island, which he correlated with habitat changes. An increase from 20 pairs before the hurricane in 1938 to 64 pairs in 1941 attests to the piping plover's ability to rapidly colonize newly available habitat. The population then declined as habitat was lost to dune stabilization, summer homes, and road construction.

Available data suggest that the most recent Atlantic Coast-wide population decline began in the late 1940's or early 1950's (Haig and Oring 1985). Starting in 1972, the National Audubon Society's "Blue List" of birds with deteriorating status included the piping plover. Johnsgard (1981) described the piping plover as "... declining throughout its range and in rather serious trouble." The Canadian Committee on the Status of Endangered Wildlife in Canada designated the piping plover as "Threatened" in 1978 and elevated the species' status to "Endangered" in 1985 (Canadian Wildlife Service 1989).

Reports of local or statewide declines between 1950 and 1985 are numerous and many are summarized by Cairns and McLaren (1980) and by Haig and Oring (1985). While Wilcox (1939) estimated more than 500 pairs of piping plovers on Long Island, a 1990 survey recorded 197 pairs (Litwin *et al.* 1993). B. Blodget (Massachusetts Division of Fisheries and Wildlife, pers. comm. 1991) reports that there was little focus on gathering quantitative data on piping plovers in Massachusetts through the late 1960's, because the species was commonly observed and presumed to be secure. However, numbers of pairs of breeding piping plovers declined 50-100% at seven Massachusetts sites between the early 1970's and 1984 (Griffin and Melvin 1984). Further, recent experience of biologists surveying piping plovers has shown that counts of these cryptic birds sometimes go up with increased census effort. This suggests that some historic counts of piping plover numbers by one or a few observers, who often recorded occurrences of many avian species, may have underestimated the piping plover population. Thus, the magnitude of the species' decline may have been even more severe than available numbers imply.

Trends Since Listing under the Endangered Species Act

Table 4 and Figure 3 summarize 1986-1995 nesting pair counts furnished to the U.S. Fish and Wildlife Service by the State wildlife agencies and Canadian Wildlife Service (CWS). Table 5 compares 1991 and 1994 nesting pair counts shown in Table 4 with those obtained during the 1991 International Census and similar "window" censuses conducted in 1994. Estimates drawn from Table 4 are based on methodologies that vary slightly among the States and that, in most cases, may result in some double counting of birds that renest during the season. The 1991 International Census reflected a single survey of breeding sites conducted during the peak of the nesting season, June 1-9, 1991. A similar window census was conducted between May 28 and June 5, 1994. Most State coordinators believe that the International Census methodology undercounts their plover populations because some plovers that nest before or after are unpaired during the census window. The actual 1991 and 1994 nesting populations probably lie somewhere between the two figures shown in Table 5.

Table 4. Summary of Atlantic Coast Piping Plover Population Estimates, 1986 to 1995

STATE/REGION	PAIRS									
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Maine	15	12	20	16	17	18	24	32	35	40
Massachusetts	139	126	134	137	139	160	213	289	352	441
Rhode Island	10	17	19	19	28	26	20	31	32	40
Connecticut	20	24	27	34	43	36	40	24	30	31
NEW ENGLAND	184	179	200	206	227	240	297	376	449	552
New York	106[1]	135[1]	172[1]	191	197	191	187	193	209	249
New Jersey	102[2]	93[2]	105[2]	128	126	126	134	127	124	132
NY-NJ REGION	208	228	277	319	323	317	321	320	333	381
Delaware	8	7	3	3	6	5	2	2	4	5
Maryland	17	23	25	20	14	17	24	19	32	44
Virginia	100	100	103	121	125	131	97	106	96	118
North Carolina	30[3]	30[3]	40[3]	55	55	40	49	53	54	50
South Carolina	3	-	-	-	1	1	-	1	-	-
SOUTHERN REGION	158	160	171	199	201	194	172	181	186	217
U.S. TOTAL	550	567	648	724	751	751	790	877	968	1150
ATLANTIC CANADA	240	223	238	233	229	236	236[4]	236[4]	182	199
ATLANTIC COAST	790	790	886	957	980	987	1026	1113	1150	1349

[1] The recovery team believes that this estimate reflects incomplete survey effort. See discussion on page 22.

[2] The New Jersey plover coordinator conjectures that one quarter to one third of the apparent population increase between 1986 and 1989 is due to increased survey effort.

[3] The recovery team believes that the apparent 1986-1989 increase in the North Carolina population is due to intensified survey effort. See discussion on page 22. No actual surveys were made in 1987; estimate is that from 1986.

[4] 1991 estimate.

Table 5. Comparison of 1991 and 1994 Population Estimates Based on "Window" Census with Estimates Based on 1990 Census Methodologies

STATE/REGION	1991		1994	
	Estimate Based on "Window" Census	Estimate Based on 1990 Census Methodology	Estimate Based on "Window" Census	Estimate Based on 1990 Census Methodology
Maine	18	18	33	35
Massachusetts	148	160	329	352
Rhode Island	22	26	29	32
Connecticut	30	36	25	30
NEW ENGLAND	218	240	416	449
New York	181	191	209	209[1]
New Jersey	122	126	102[2]	124
NY-NJ REGION	303	317	311	333
Delaware	5	5	2	4
Maryland	16	17	30	32
Virginia[3]	131	131	96	96
North Carolina	30	40	51	54
South Carolina	1	1	-	-
SOUTHERN REGION	183	194	179	186
U.S. TOTAL	704	751	906	968
ATLANTIC CANADA	236	236	182	182
ATLANTIC COAST TOTAL	940	987	1088	1150

[1] In 1994, New York adopted the window count as its standard census methodology.

[2] The 1994 New Jersey window census was conducted by relatively inexperienced surveyors. State biologists believe that some birds were present but undetected during the "window," and that the actual State population is closer to the estimate based on 1990 methodology.

[3] Virginia uses only a window census.

The apparent rangewide increase in numbers of pairs from 790 pairs in 1986 to 957 pairs in 1989 is thought to at least partially reflect the effects of increased survey effort following the proposed listing in 1985. Intensified survey effort may have played an especially important role in population estimates for three States:

- North Carolina: 1986-87 estimates were made by compiling results of site surveys from previous years (R. Dyer, U.S. Fish and Wildlife Service, pers. comm. 1993). The first comprehensive state-wide field survey in North Carolina was conducted by volunteers in 1988 (Carter 1988). Piping plover research conducted in 1989 and 1992-94 on the two national seashores that together account for more than 80% of the North Carolina population involved intensive search effort in those years (Coutu *et al.* 1990, McConnaughey *et al.* 1990, Collazo *et al.* 1994). LeGrand (1991) states that, while the North Carolina population trend over the last few decades is unknown, "it can be assumed that the apparent increase in the past 10 years is due to much better survey coverage, especially on the relatively remote Core Banks and Portsmouth Island."

- New York: K. Wich (New York State Department of Environmental Conservation, *in litt.* 1993) states that although protection of beach-nesting birds in New York increased after 1983, survey effort also intensified, especially at sites such as Breezy Point in Queens County and Westhampton Beach in Suffolk County. While the relative contributions of each cannot be determined, he believes that "the stability of more recent estimates probably accurately reflects the status of New York's plover population." Ducey-Ortiz *et al.* (1989) documented an increasing plover monitoring effort in New York between 1984 and 1988 and found that, when results from 54 uniformly monitored sites in that State were analyzed, the population trend did not increase or decrease significantly.

  Downer and Leibelt (1990) likewise cite intensified survey effort as a major contributor to the increased estimate of the New York population between 1984 and 1989. Furthermore, inferences that the apparent 1986-88 New York population gain was caused by increased efforts to protect beach-nesting birds there fail to explain why the State population estimate has remained static since 1989, despite continuing improvements in protection.

- New Jersey: C.D. Jenkins (New Jersey Division of Fish, Game and Wildlife, *in litt.* 1993) conjectures that increased survey intensity accounts for one-quarter to one-third of the population increase observed between 1987 and 1989 in New Jersey.

The recovery team believes that increases in U.S. Atlantic Coast population estimates between 1989 and 1995 reflect the actual population trend. However, the net increase of 426 pairs was very unevenly distributed. The New England subpopulation increased 346 pairs (+168%), while the New York-New Jersey and the Southern (DE-MD-VA-NC) subpopulations gained 62 (+19%) and 18 (+9%) pairs, respectively.

Census data suggest that the overall piping plover population in Atlantic Canada is declining (Flemming and Gautreau *in* CWS 1994; B. Johnson, Canadian Wildlife Service, *in litt.* 1994). Estimates obtained during the 1991 International Census reflect by far the most intensive survey effort to date for the Canadian portion of the plover's Atlantic Coast range. During the second half of the 1980's and through 1991, numbers of breeding pairs appeared stable or slightly improving in Newfoundland, Quebec, New Brunswick, and Prince Edward Island (provincial summaries *in* CWS 1994). A decline from 66-71 pairs counted in Nova Scotia in 1983 to 48-54 pairs in 1987 seemed to have been arrested but not reversed as of 1991 (Austin-Smith *et al.* in CWS 1994). A comprehensive census of all sites that were occupied by plovers in 1991 was conducted in 1994. Results of that census suggest that the Atlantic Canada subpopulation is currently experiencing a sharp decline, except in Newfoundland (eight pairs and one single adult in 1994 compared with three pairs and one single adult in 1991) and the Magdalen Islands (up to 48 pairs in 1994 from 38 in 1991). Substantial declines were recorded in New Brunswick (63 pairs and 19 single adults in 1994, compared with 203 adults [91 pairs] in 1991) and Prince Edward Island (26 pairs and eight single adults, compared with 110 adults [51 pairs] in 1991). Reports from Nova Scotia placed the Provincial population at 37 pairs and 8 single adults compared with 110 adults (51 pairs) in 1991. Some of this apparent decline may be attributable to surveying only the sites that were occupied in 1991, and it is possible that some birds nesting at sites that were unoccupied in 1991 went undetected in 1994. Surveys conducted in 1995 showed an increase in the Atlantic Canada subpopulation, from 182 pairs in 1994 to 199 pairs in 1995 (the latter figure includes three pairs in St. Pierre-et-Miquelon) (D. Amirault, Canadian Wildlife Service, *in litt.* 1995). The possibility that some plovers that formerly nested in Atlantic Canada have shifted their breeding sites to New England or other parts of the range also cannot be conclusively ruled out, but information about plover dispersal patterns gained from studies of banded birds (see pages 22-23) suggests that this is unlikely to be a substantial factor in the downward trend seen since 1991 in Canadian plover numbers (see Table 4). It is anticipated that results of the upcoming 1996 International Census and comparison with 1991 data will furnish the most accurate indicator of the five-year trend in the Atlantic Canada subpopulation.

PRODUCTIVITY

Comparisons of productivity data reported prior to 1989 were confounded by inconsistent definitions of "fledged young" and reporting methods (e.g., some reports provided fledged chicks per nesting pair while others provided the number of nests fledging at least one young). Beginning in 1989, the USFWS adopted "25 days of age or flying (whichever comes first)" as the standard definition of a fledged chick for the purposes of tracking plover productivity on the U.S. Atlantic Coast (USFWS 1988b). (It should be noted that 25-day-old chicks are often unable to fly, and, therefore, may remain vulnerable to off-road vehicles and other sources of mortality.) Since the vast majority of chick losses in most studies occurred during the first 15 days post-hatch (Elias-Gerken 1994, Loegering 1992, Coutu *et al.* 1990, MacIvor 1990, McConnaughey *et al.* 1990), data on chick survival for periods of less than 25 days may be informative, but care should be exercised when making comparisons among data sets.

Population modeling by S.M. Melvin and J.P Gibbs (1994) (see Appendix E) yielded an estimate of 1.24 chicks fledged per pair needed to maintain a stationary population. However, modeled populations with this productivity rate remained highly vulnerable to extinction (35% probability of extinction within 100 years for a 1,200-pair population with mean productivity of 1.25 chicks per pair). Modeling also revealed that extinction probabilities are very sensitive to changes in productivity. For example, extinction probability over 100 years for a 2,000-pair population with observed survival rates was 4% when average productivity was 1.50 chicks per pair; this extinction probability increased to 22% when other parameters were held constant and average productivity was 1.25 chicks per pair. The probability that the population would drop below 500 pairs over 100 years increased from 26% when average productivity was 1.5 chicks per pair to 82% when average productivity was 1.25 chicks per pair.

Table 6 and Figure 4 summarize productivity data from 1987 to 1995. Averages reflect data from 95% of nesting pairs in New England, 73% in New York-New Jersey, and 61% in the southern States. In general, the seven-year weighted averages correlate with population trends observed since 1989. New York and North Carolina productivity figures, which are below those needed to effect population growth, support the concept that the apparently large increases in those States' population estimates between 1986 and 1989 are due to increased survey effort (see discussion on page 22). Average productivity figures for Atlantic Canada appear to be high for a declining population, but

Table 6. Summary of Piping Plover Productivity Estimates for the U.S. Atlantic Coast, 1987-1995

STATE/REGION	CHICKS FLEDGED/PAIR[1]								
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1988-1995 AVG[2]
Maine	1.75 (12)	.75 (20)	2.38 (16)	1.53 (17)	2.50 (18)	2.00 (24)	2.38 (32)	2.00 (35)	2.38 (40)	2.05 (202/202)
Massachusetts	1.10 (89)	1.29 (114)	1.59 (123)	1.38 (125)	1.72 (156)	2.03 (206)	1.92 (264)	1.80 (334)	1.62 (426)	1.72 (1748/1865)
Rhode Island	1.13 (17)	1.60 (19)	1.47 (19)	.90 (26)	.77 (26)	1.55 (20)	1.80 (30)	2.00 (32)	1.68 (38)	1.50 (210/215)
Connecticut	1.29 (24)	1.70 (27)	1.79 (34)	1.63 (43)	1.39 (36)	1.45 (40)	.38 (24)	1.47 (30)	1.35 (31)	1.43 (265/265)
NEW ENGLAND		1.32 (180)	1.68 (192)	1.38 (211)	1.62 (236)	1.91 (290)	1.85 (350)	1.81 (431)	1.67 (535)	1.69 (2425/2547)
New York	.90 (39)	1.24 (42)	1.02 (62)	.80 (70)	1.09 (158)	.98 (130)	1.24 (125)	1.34 (131)	.97 (188)	1.09 (906/1589)
New Jersey	.85 (93)	.94 (105)	1.12 (128)	.93 (126)	.98 (126)	1.07 (134)	.93 (127)	1.16 (124)	.98 (117)	1.02 (987/1002)
NY-NJ REGION		1.03 (147)	1.09 (190)	.88 (196)	1.04 (284)	1.03 (264)	1.08 (252)	1.25 (255)	.97 (305)	1.05 (1893/2591)
Delaware		.00 (3)	2.33 (3)	2.00 (6)	1.60 (5)	1.00 (2)	.50 (2)	2.50 (4)	2.00 (5)	1.67 (30/30)
Maryland	1.17 (23)	.52 (25)	.90 (20)	.78 (14)	.41 (17)	1.00 (24)	1.79 (19)	2.41 (32)	1.73 (44)	1.33 (195/195)
Virginia		1.02 (64)	1.16 (32)	.65 (63)	.88 (43)	.59 (39)	1.45 (49)	1.65 (58)	1.00 (86)	1.05 (434/897)
North Carolina			.59 (49)	.43 (14)	.07 (14)	.42 (41)	.74 (53)	.36 (53)	.45 (49)	.49 (273/396)
SOUTHERN REGION		0.85 (92)	.88 (104)	.72 (97)	.68 (79)	.62 (106)	1.18 (123)	1.37 (147)	1.06 (184)	.97 (932/1518)
U.S. AVERAGE	1.04 (297)	1.11 (419)	1.28 (486)	1.06 (504)	1.22 (599)	1.35 (660)	1.47 (725)	1.56 (833)	1.35 (1024)	1.33 (5250/6656)
ATLANTIC CANADA		1.65 (46)	1.58 (99)	1.62 (105)	1.07 (137)	1.55 (135)	.69 (78)	1.25 (60)	1.69 (105)	1.39 (765/1789)

[1] Parentheses indicate number of pairs on which productivity is based.

[2] Parentheses indicate number of pairs on which productivity is based/estimated number of nesting pairs in the State or region between 1988 and 1995.

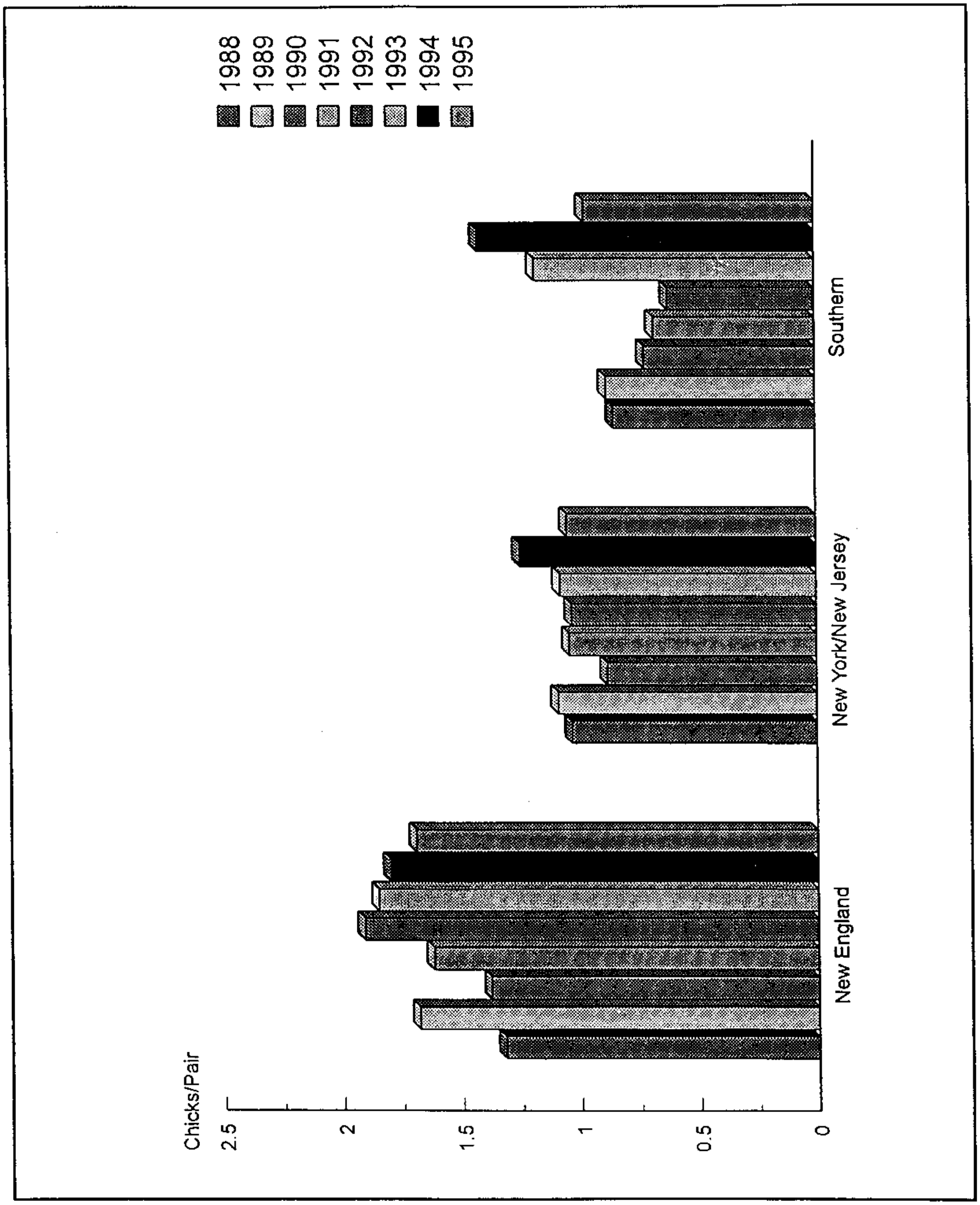


Figure 4. Average Productivity by Region, 1988-1995

productivity data are available for only 43% of nesting pairs. Since productivity data are often gathered at sites that are also the most intensively protected, available data may not be representative.

SURVIVAL

Resightings of 103 adult plovers and 61 chicks color-banded on Outer Cape Cod between 1985 and 1988 yielded estimates of mean annual survival of 0.74 for birds > 1 year old and 0.48 for chicks (see Appendix E). Loegering (1992) estimated annual survival rates of 0.67-0.72 for 53 adults and 0.41 for 29 chicks banded on Assateague National Seashore in Maryland between 1987 and 1989. R. Cross (Virginia Department of Game and Inland Fisheries, unpubl. data) estimated annual survival rates of 0.75 and 0.83 for adults and 0.44 for chicks.

Population viability modeling (Melvin and Gibbs 1994; Appendix E) shows that extinction probabilities are also very sensitive to changes in survival rates (such long-term declines in survival rates could occur due to continuing declines in availability or quality of wintering or migration habitat; increased human disturbance on wintering grounds; increased mortality due to disease, parasites, or environmental contaminants; increased predation; or reduced longevity or fitness due to unforeseen genetic factors). For example, modeling showed a 4% extinction probability over 100 years for a 2,000-pair population with average productivity of 1.5 chicks per pair and survival rates observed on outer Cape Cod, Massachusetts between 1985 and 1988. When declines in adult and chick survival rates of 5% and 10%, respectively, were modeled holding other parameters constant, the extinction probability increased from 4% to 32%, and the probability that population size would drop below 500 pairs increased from 26% to 90%.

CURRENT BREEDING DISTRIBUTION

Piping plovers continue to breed successfully at or near the extremes of their historic range. At the northern extent, piping plovers continue to breed on Newfoundland's southern coast, although they were not located on the northeastern or western coasts of Newfoundland, the Gaspe Peninsula, or the Lower North Shore of the Gulf of Saint Lawrence during the 1991 International Census (CWS 1994). The Magdalen Islands, north of Prince Edward Island, have reported increasing numbers of breeding pairs and recent productivity rates that range from 1.4 to 2.0 chicks per pair (Shaffer and LaPorte 1992). At the southern extent, breeding pairs have been documented sporadically at Waites Island, South Carolina near the border with North Carolina (Murray and McDavitt 1993; P. Wilkinson, South Carolina Department of Natural Resources, pers. comm. 1996). Four pairs nesting at Holden

Beach in southern North Carolina in 1993 fledged 1.0 chicks per pair (J. Nicholls *in litt.* 1993), well above the State average.

While the extent of the current range does not appear to be substantially different from the historic range, piping plovers are absent from many former nesting beaches on the Atlantic Coast (Cairns and McLaren 1980, Litwin *et al.* 1993, CWS 1994, Virginia Department of Game and Inland Fisheries 1994). Current sparsity of nesting pairs is of particular concern in the southern part of the plover's Atlantic Coast range. Although the New Jersey population increased between 1986 and 1989 and has remained stable since, the proportion of the State's population located in three areas administered by the National Park Service (NPS) and the USFWS has increased from 24% in 1987 to 49% in 1994. The proportion of birds nesting in the southern part of New Jersey during the same period declined from 43% to 31% (Jenkins 1993, C.D. Jenkins *in litt.* 1993 and 1994). C.D. Jenkins (pers. comm. 1993) attributes the multi-year decline in southern New Jersey to cumulative effects of low productivity and to habitat erosion during winter storms without reciprocal habitat accretion or creation (e.g., dune overwash). In Delaware, only 2-5 pairs of plovers nested between 1992 and 1995, compared with 40 birds estimated to have nested in the State in 1980 (J. Thomas, Delaware Division of Fish and Wildlife, *in litt.* 1986), and Assateague Island, Maryland is now the nearest nesting site south of Delaware. Only two pairs nested on Currituck Outer Banks in 1994, the sole remaining breeding site between Fisherman Island, Virginia on the northern side of the Chesapeake Bay and Cape Hatteras Point, North Carolina, and no nesting was documented at Currituck in 1995 despite 47 surveys between April 29 and July 30 (USFWS 1995b).

The relatively large distance between nesting sites in Atlantic Canada and New England decreases opportunities for movements of breeding birds into Atlantic Canada. This, in turn, heightens concerns about recent declines in plover nesting densities there.

BREEDING SITE FIDELITY AND DISPERSAL

In New York, Wilcox (1959) recaptured 39% of the 744 adult plovers that he banded in prior years (many were recaptured during several successive seasons and all but three of them were retrapped in the same nesting area), but recaptured only 4.7% of 979 plovers that he banded as chicks. He also observed that males exhibited greater fidelity to previous nest sites than females. Strauss (1990) observed individuals that returned to nest in his Massachusetts study area for up to six successive years. Also in Massachusetts, 13 of 16 birds banded on one site were resighted the following season, with 11 nesting on the same beach (MacIvor *et al.* 1987). Of 92 adults banded on

Assateague Island, Maryland, and resighted the following year, 91 were seen on the same site, as were 8 of 12 first-year birds (Loegering 1992). R. Cross (unpubl. data) reports that 10 of 12 juveniles banded on Assateague Island, Virginia and resighted one and/or two years later were on the Virginia or Maryland portions of Assateague Island, while the other two were observed on other Virginia barrier islands.

On the Atlantic Coast, almost all observations of inter-year movements of birds have been within the same or adjacent States. Of 316 birds color-marked in Massachusetts between 1982 and 1989 (L.H. MacIvor, C.R. Griffin, and S.M. Melvin, unpubl. data; Strauss 1990), only one instance of subsequent nesting outside of that State (in Connecticut) has been observed (S.M. Melvin pers. comm. 1993). Two of 121 plovers banded on Assateague Island were resighted breeding in New Jersey; one resighting took place during the same breeding season as the banding, while the second bird moved to New Jersey the following year (Loegering 1992). Because banding of Atlantic Coast piping plovers ceased after 1989 (see discussion on page 87), it is possible that more birds are now dispersing from highly productive States, although a strong correlation between high productivity and an increase in population size continues in New England. If populations in some areas approach carrying capacity of available habitat, it is possible that dispersal rates will increase.

HABITAT CARRYING CAPACITY

The carrying capacity of habitat to support breeding plovers is subject to fluctuation with the dynamic coastal formation processes that affect topography, vegetation, and other habitat characteristics. These fluctuations can be affected by natural factors, such as long-shore sand transport patterns and storm frequency, and by human intervention through shoreline development and stabilization projects (see discussion of loss and degradation of breeding habitat, pages 34-37). For this reason, estimates of carrying capacity, especially on a local basis, may be subject to change over time, and may require periodic revision to reflect changes in habitat conditions.

While it is expected that carrying capacity will fluctuate locally, and perhaps even within a State over time, it is anticipated that the long-term carrying capacity of the Atlantic Coast's piping plover habitat (and that of regional subpopulations, which correspond to the recovery units laid out on page 55) will be maintained if natural coastal habitat formation processes are not interrupted. *Shoreline development and stabilization projects may, however, erode carrying capacity locally and regionally (see pages 34-37) and, therefore, have potential to compromise the survival and recovery of the population.*

Appendix B provides estimates of carrying capacity of current and potential U.S. breeding sites in 1993. These estimates, made by the State plover coordinators in consultation with the recovery team and, in some cases, biologists who manage specific sites, were compiled to appraise the carrying capacity for the entire U.S. Atlantic Coast portion of the plover's range in order to facilitate population viability analysis (PVA) (see Appendix E). In some cases, estimates were based on knowledge that a larger population had occurred at one time on a site where habitat characteristics have remained similar during the intervening years. Other estimates were based on information about current activities on a site, recent productivity data, and knowledge of population densities at other sites with comparable habitat. Biologists based their projections on the assumption that most of the traditional human uses on the site would continue, although increased intensity of management efforts (including curtailing of off-road vehicle use) might be needed to attain capacity estimates on some sites. Estimates were also designed to be below levels at which density-dependent effects on productivity would be triggered. The recovery team believes that the carrying capacity of more than 1,925 pairs estimated for U.S. Atlantic Coast in 1993 (Appendix B) is *very conservative*. For example, revised estimates made by the Massachusetts Division of Fisheries and Wildlife (MDFW) in 1995 place the carrying capacity of habitat in that State at over 1,100 pairs (MDFW 1996); this upward revision of Massachusetts' carrying capacity is primarily due to an increase in projected nesting densities to 16-24 pairs per linear mile in the highest quality habitats, based on observations of productive nesting pairs approaching those densities in a rapidly increasing population rather than not on changes in habitat characteristics (S.M. Melvin pers. comm. 1995). However, all carrying capacity estimates in Appendix B, including those for New England, are based on much lower projections of nesting densities. Furthermore, in order to allow for the possibility that plover habitat requirements may be more stringent at the edge of the range than the core, estimates for the southern recovery unit are substantially more conservative than those for New England.

In Atlantic Canada, no systematic effort to estimate carrying capacity of all breeding habitat has been conducted; however, available information suggests that recent population numbers are far below carrying capacity. Based on analyses of nesting patterns between 1987 and 1992 in the Magdalen Islands, Shaffer and Laporte (1992) have projected capacity for 65 pairs, where 48 were counted in 1994. On Prince Edward Island, 57 beaches with suitable piping plover habitat were surveyed in 1991, but plovers were located at only 20 of these sites (McAskill *et al.* in CWS 1994). K. Knox (Newfoundland Wildlife Division, *in litt.* 1993) estimated that three sites where seven pairs bred in 1993 could support 20 pairs, while a currently unoccupied beach adjacent to one site could support another 8-10 pairs. Biologists surveying 24 sites in Antigonish, Pictou, and Shelbourne Counties in Nova Scotia estimated that these beaches could furnish habitat for more than 65 pairs, compared with the 20 pairs they actually observed there in 1994 (M. Goldin, The Nature Conservancy, *in litt.* 1994; S. von Oettingen, U.S. Fish and Wildlife Service, *in litt.* 1994). R. Williams (Nova Scotia Department of Natural Resources, *in litt.* 1993) estimated that six sites where 10 pairs nested in Queens County, Nova Scotia in 1993 could support 19 pairs if the regional population were to expand.

Data from Outer Cape Cod where the number of breeding pairs quadrupled between 1988 and 1993 show that relatively high nesting densities can be achieved without a loss of productivity (Figure 5). The breeding population at the Sandy Hook Unit of Gateway National Recreation Area in New Jersey grew from 18 pairs in 1990 to 36 pairs in 1994, and, again, productivity increased steadily over that time period, from 1.17 chicks per pair in 1990 to 1.94 in 1994 (Jenkins 1993, C.D. Jenkins *in litt.* 1993 and 1994). In Maryland, the plover population on Assateague Island increased from 19 pairs in 1993 to 44 pairs in 1995, yet high productivity -- 2.41 and 1.73 chicks per pair -- was achieved in both 1994 and 1995, respectively. Other examples of population increases attended by high productivity in New England are cited under Nesting Densities, pages 6-7.

VULNERABILITY TO EXTINCTION

Demographic Factors

The population viability analysis conducted by Melvin and Gibbs (1994) to assess the risk of population extinction (Appendix E) estimated probabilities of extinction as well as probabilities that the population would fall below thresholds of 50, 100, and 500 pairs during the next 100 years. Important model inputs, including fecundity (number of chicks fledged per pair) and mean annual survival rates for immature (less than one year old) and mature piping plovers, were based on actual field data.

Melvin and Gibbs (1994) calculated a mean fecundity of 1.21 chicks fledged per pair during the five-year period 1989-1993 for the U.S. portion of the Atlantic Coast population. The modeled scenarios that most closely approximate the current status of the Atlantic Coast piping plover population -- 1,200 and 1,500 pair populations with average productivity of 1.25 chicks per pair -- showed, respectively, extinction probabilities of 35% and 31% over 100 years, and 95% and 92% probabilities of the population dropping below 500 pairs during the same time period. Furthermore, the overall vulnerability to extinction is exacerbated by the fact that increases in both annual Atlantic Coast average fecundity and population over the last five years are largely attributable to the New England portion of the range. Because of their smaller size, subpopulations face an even larger risk of

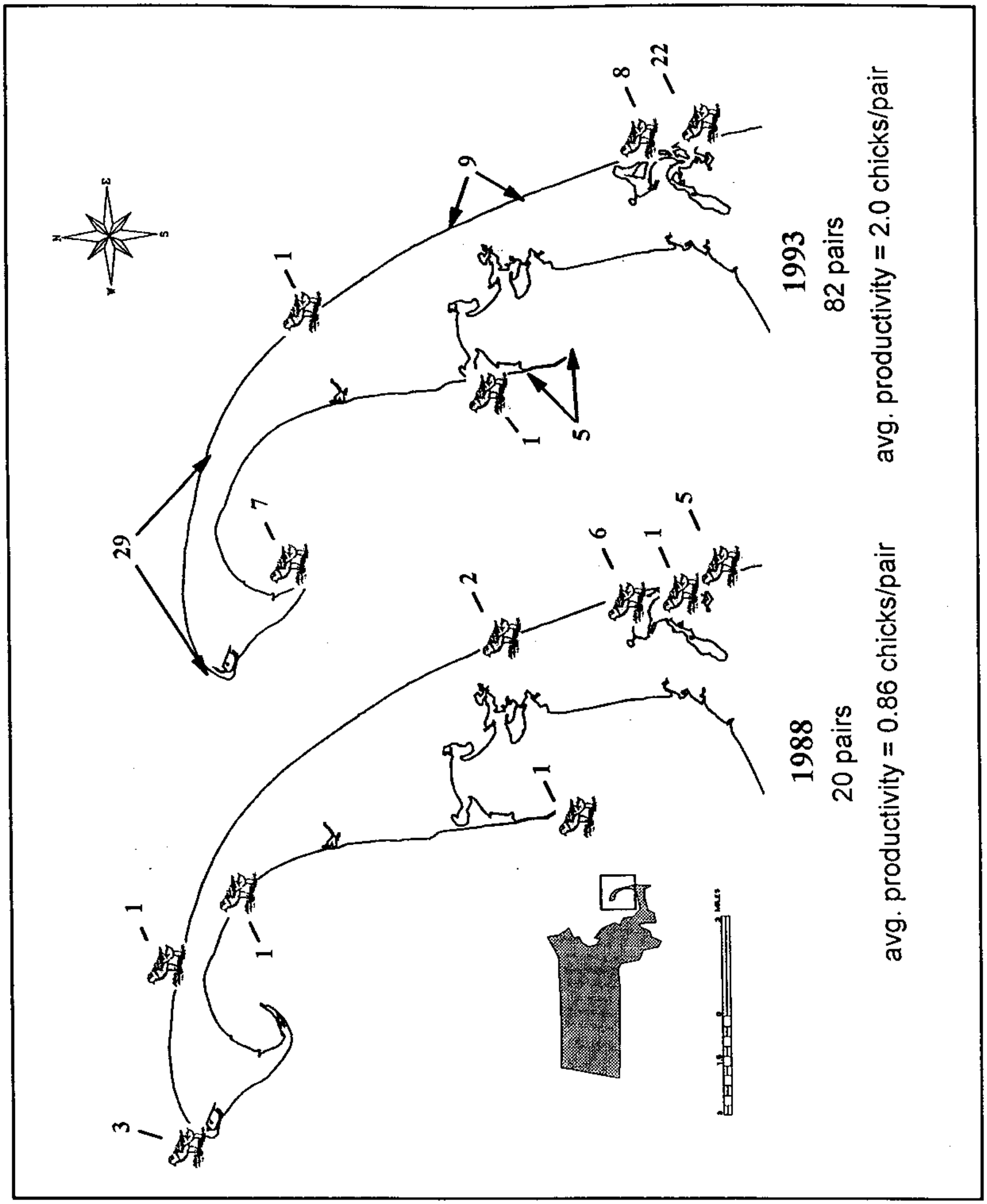


Figure 5. Distribution of Piping Plovers on Outer Cape Cod, 1988-1993

extirpation, and this is especially true in areas outside New England where average fecundity has been substantially below the coast-wide average.

The PVA indicates that extinction probabilities for Atlantic Coast plovers are very sensitive to changes in fecundity and survival rates and variability within these parameters (see pages 24 and 27). While extinction probabilities are less sensitive to initial population size, this does not diminish the importance of population size to population survival. Increasing population size will delay time to extinction, allowing implementation of measures to improve survival and productivity rates. The larger and more dispersed the Atlantic Coast population is, the less will be the overall effects of environmental stochasticity, catastrophes, or inconsistent management.

Genetic Factors

In addition to effects of demographic factors, modeled in the PVA, populations may be vulnerable to extinction due to loss of genetic diversity. The risk of loss of genetic diversity is related to effective population size (N_e), i.e., the number of individuals actually passing their genes on to the next generation. An N_e of 500 was cited by Franklin (1980) and Frankel and Soulé (1981) as the *minimum* necessary to maintain long-term genetic fitness and evolutionary potential. No formal estimates of N_e/N have been made for the Atlantic Coast piping plover. It appears that a large percentage of breeding plovers fledge young that are subsequently recruited into the breeding population, but the species' sparse distribution results in highly non-random mating that may pose a barrier to gene flow.

REASONS FOR LISTING AND CONTINUING THREATS

While hunting is thought to have been a major factor contributing to the decline of the piping plover in the late 19th and 20th centuries, shooting of the piping plover and other migratory birds has been prohibited since 1918 pursuant to the provisions of the Migratory Bird Treaty Act. Habitat loss and degradation, disturbance by humans and pets, and increased predation were cited as important causes of the downward trend that started in the late 1940's (USFWS 1985) and continues to the present time in some portions of the Atlantic Coast.

LOSS AND DEGRADATION OF BREEDING HABITAT

The wide, flat, sparsely vegetated barrier beaches preferred by the piping plover are an unstable habitat, dependent on natural forces for renewal and susceptible to degradation by development and shoreline stabilization efforts.

Destruction of beach habitat by residential, resort, and seawall development constitutes irrevocable habitat loss for piping plovers. The Coastal Barriers Task Force (1983) has stated:

> Prior to World War II, more than 90% of the nation's coastal barrier real estate existed as undeveloped natural areas, largely inaccessible to the public...
>
> By 1950, urbanized coastal barrier acreage in the Northeast amounted to 13% of the total coastal barrier acreage in Massachusetts, 22% in Connecticut, 23% in Rhode Island, 27% in New York, and 37% in New Jersey...
>
> By 1974, the amount of urban coastal barrier acreage had increased to 22% of the total acreage in Massachusetts (a 69% increase over 1950), 35% in Rhode Island (a 52% increase), 35% in New York (a 30% increase), 42% in Connecticut (a 91% increase), and 47% in New Jersey (a 27% increase).

In Maine, construction of seawalls, jetties, piers, homes, parking lots, and other structures has reduced historic nesting habitat by more than 70%; where more than 20 miles of historic habitat may have supported more than 200 pairs of piping plovers (Maine Department of Inland Fisheries and Wildlife 1994), 32 pairs nested in 1993 on habitat with an estimated capacity of 52 pairs (M. McCollough, Maine Department of Inland Fisheries and Wildlife, *in litt.* 1994). Wilcox (1959) pointed to summer home and road construction as causes of declining plover nesting along Moriches Bay on Long Island, New York between 1939 and 1951. Raithel (1984) cited coastal development and shoreline stabilization, including construction and dredging of permanent breachways, building of breakwaters, and planting of dune areas, as major contributors to the decline of the piping plover in Rhode Island. Creation of a parking lot in the early 1980's is cited by C. Raithel (*in litt.* 1994) as reducing habitat at East Matunuck State Beach, "formerly one of Rhode Island's largest Least Tern and Piping Plover sites," an area that he now estimates can provide habitat for only three pairs of plovers. Analysis of four years of piping plover nest location data on a New York site found that the nests were significantly farther from concrete walkways leading from the dunes to the berm than were random points, suggesting that the walkways decrease the carrying capacity of the beach (Hoopes 1995).

The location of developments on beaches where they are vulnerable to erosion often leads to impacts that go far beyond the footprint of the facilities themselves. Requests from private communities within the Fire Island National Seashore, New York to construct artificial dunes on adjacent undeveloped National Park Service lands in 1993 (NPS 1993a) exemplify situations where shoreline development has created demand to stabilize adjacent habitat.

The magnitude of impacts of development and shoreline stabilization on availability of piping plover habitat in Atlantic Canada is unclear. Austin-Smith *et al.* (*in* CWS 1994) "suspect that the intentional stabilization of beaches at some traditional breeding sites has led to decreased incidence of overwashes and blowout, thus reducing favored habitat for nesting plovers" in Nova Scotia. On the other hand, Chaisson *et al.* (*in* CWS 1994) state that "human-induced habitat change is a relatively minor concern in the coastal dune system" of northeastern New Brunswick.

Impacts of shoreline developments are often greatly expanded by the attendant concerns for protecting access roads. For example, much of Hatteras Island in North Carolina remains "undeveloped," but approximately 56 miles of continuous dune line is maintained to protect State Highway 12, which runs the length of the island, through Cape Hatteras National Seashore and Pea Island National Wildlife Refuge (NWR). Piping plovers nest only on the roadless spits at Cape Point and Hatteras Inlet (Coutu *et al.* 1990), no longer nesting on Pea Island, where they once occurred (Cairns and McLaren 1980). On unroaded Cape Lookout National Seashore, by contrast, piping plover nesting areas in 1990 included not only the spits at the current inlets, but several former inlets and large moist sand flats (McConnaughey *et al.* 1990). Biologists believe that dune maintenance conducted to protect more than eight miles of access road is one of several factors contributing to very low density of piping plovers at Island Beach State Park in New Jersey (C.D. Jenkins pers. comm. 1993). Almost five miles of beach habitat in Duxbury and Plymouth, Massachusetts, are affected by dune stabilization to protect over-land access to 290 homes located on upland habitat at the end of the peninsula (C. Wasserloos, Federal Emergency Management Agency, *in litt.* 1993).

Jetties and groins may cause significant habitat degradation by robbing sand from the down-drift shoreline. For example, the Coastal Barriers Study Group (1987) and the Ocean City, Maryland and Vicinity Water Resources Study Reconnaissance Report (U.S. Army Corps of Engineers 1994) attribute the accelerated, landward shoreline recession of the north end of Assateague Island in Maryland (the only remaining piping plover breeding area in that State) to cumulative effects on the natural drift system from inlet stabilization and nourishment of the rapidly eroding beaches at Ocean City. Loss of sand down-drift of a jetty or groin may be partially offset by habitat accretion on the up-drift side of a structure. Breezy Point at the western end of southern Long Island, New York serves as a striking example of concentrated piping plover numbers on the accreting side of a jetty (A. Hecht, U.S. Fish and Wildlife Service, pers. obs.). However, beaches on the accreting side of jetties may also be subject to plant succession that makes them less attractive to piping plovers over time.

Wilcox (1959) described the effects on piping plovers from catastrophic storms in 1931 and 1938 that breached the Long Island barrier islands, forming Moriches and Shinnecock Inlets and leveling dunes. Only 3-4 pairs of piping plovers nested on 17 miles of barrier beach along Moriches and Shinnecock Bays in 1929; however, following the creation of Moriches Inlet in 1931, plover numbers increased to 20 pairs along a two-mile stretch of beach by 1938. Wilcox added that Moriches Inlet moved one mile west between 1931 and 1956. In 1938, a hurricane opened Shinnecock Inlet and also flattened dunes along both bays. In 1941, plover numbers along the same 17-mile stretch of beach peaked at 64 pairs. Numbers then gradually decreased, a decline that Wilcox attributed to deposition of dredged sand to rebuild dunes, planting of beach grass, and construction of roads and summer homes. Analysis of aerial photographs of Fire Island, immediately west of Wilcox' study area, by Leatherman and Allen (1985), showed that during the same time period as Wilcox' study, coverage of Fire Island by overwash declined from 26% in 1938 to 11% in 1954 and 2% in 1960.

A study of nest site selection on the central barrier islands of southern Long Island, New York (Elias-Gerken 1994) found that beach segments where piping plover broods had access to ephemeral pools or bayside foraging areas were strongly selected by nesting plovers. The creation of a new inlet and a large overwash zone in Elias-Gerken's study area by a December 1992 storm coincided with colonization of these areas by nesting plovers the following season. On beaches without ephemeral pools or access to bayside mudflats, the probability of plover nesting increased with increasing width of "open vegetation," which she characterized as a "storm-maintained, early successional habitat."

Habitat availability for nest site selection is decreased where blowouts or gaps in the foredune are "plugged," increasing the foredune slope. An investigation into effects of foredune slope on nest site selection by piping plovers was conducted by Strauss (1990), using collected data on nest sites of piping plovers at Sandy Neck in Barnstable County, Massachusetts from 1984-87. Strauss' study area included a flat, sparsely vegetated sandspit; steep, mature, vegetated foredunes; and blowouts or gaps in the foredune caused by wind or wave action. Although mature foredunes, including many areas where former or incipient blowouts had been deliberately plugged with discarded Christmas trees and/or snowfences, constituted 83% of the beachfront, none of 80 plover nest attempts occurred seaward of the steep foredunes. Furthermore, foredune profiles of blowout (n=26) and sandspit nests (n=34) were significantly less steep than those of 40 random profiles.

On some beaches, artificial or stabilized dunes and vegetation may also impair piping plover nest site selection and/or chick survival by blocking access to bayside feeding areas. Loegering and Fraser (1995) found that those flightless plover chicks on Assateague Island, Maryland able to reach bay beaches and the island interior had significantly higher survival rates than those which foraged solely on the ocean beaches. Their management recommendations stressed the importance of sparsely vegetated access routes to bayside beaches maintained by overwash (see footnote 2, page 6). Overwash was also cited as an important component of interior habitat maintenance, and Loegering and Fraser expressly discouraged deposition of dredged material and artificial dune building. Piping plover broods on some portions of the barrier beach on Chappaquiddick Island, Martha's Vineyard, Massachusetts, have been observed walking across a gently sloped barrier beach from ocean to bayside feeding areas with the turning of almost every tide (T. Chase, The Trustees of Reservations, pers. comm. 1992), and concern has been expressed that installation of snowfences to build dunes on this beach will degrade piping plover and least tern habitat (P. Huckery, Massachusetts Division of Fisheries and Wildlife, *in litt.* 1994).

DISTURBANCE OF BREEDING PLOVERS BY HUMANS AND PETS

The increasing intensity of human recreation dating from the end of World War II on Atlantic Coast piping plover breeding sites was a major threat cited in the 1986 listing of the piping plover. The Coastal Barriers Task Force (1983) states, "In the thirty-five years following World War II, many factors have combined to produce an explosion in the demand for the kinds of recreational opportunities that coastal barriers provide." Factors contributing to this "explosion" include a 47% growth in the populations of the 19 States bordering the Atlantic Ocean and Gulf Coast between 1950 and 1980; increasing affluence and leisure time; increasing use of motor vehicles, bringing coastal barriers within easy access to more people; and an increasing diversity of recreational demands. Many examples serve to illustrate the role of beach recreation in the post-1950 decline of the piping plover and the need to continue and (in some locations) intensify efforts to protect piping plovers from human disturbance:

- Few vehicles were observed in 1950 at Sandy Neck, in Barnstable, Massachusetts. By 1981, 2,234 permits were given for off-road vehicles at this same beach, and in 1989, 4,000 off-road vehicle permits were issued (Blodget 1990). Between 1984 and 1989, the piping plover population on the same beach declined from 14 pairs to five pairs, and productivity between 1984 and 1988 was extremely low (0.33 chicks per pair), although it improved substantially after the core of the nesting area was closed to vehicles starting in 1989 (Strauss 1990; E. Strauss, University of Massachusetts, Boston, pers. comm. 1991). Further vehicle restrictions to prevent crushing of nests and chicks were instituted in 1990, and the population increased to 18 pairs with a productivity of 2.1 chicks per pair by 1994 (S.M. Melvin *in litt.* 1994).

- Visitation to Cape Cod National Seashore increased from 2,830,000 visits in 1966 to 4,979,000 visits in 1981; during that same period, annual visits to Cape Hatteras National Seashore increased from 1,133,000 to 1,635,000 (Coastal Barriers Task Force 1983). By 1987-1993, average annual visitation at Cape Hattaras National Seashore had increased to 2,125,000 (D. Avrin, National Park Service, pers. comm. 1994). Another national seashore, Fire Island, saw an increase in average annual visitation from 449,000 visits in 1967-1976 to 815,000 visits in 1988-1993 (D. Avrin pers. comm. 1994).

- Cape Henlopen State Park in Delaware was first opened to off-road vehicle use in 1978 (Delaware Department of Natural Resources and Environmental Control 1993). Piping plover counts on that site dropped from eight (adults) in 1979 (J. Thomas *in litt.* 1986) to none in 1988. In 1990, Delaware State Parks implemented restrictions on vehicles in the vicinity of plovers, and there are now tenuous signs that plovers may reestablish at Cape Henlopen (L. Gelvin-Innvaer, Delaware Division of Fish and Wildlife, *in litt.* 1994).

- Vehicle use is prohibited on all beaches in New Brunswick (R. Chaisson, Atlantic Piping Plover Working Group, *in litt.* 1993) and Prince Edward Island (McAskill *et al.* in CWS 1994) and on Province-owned beaches in Nova Scotia. However, remote locations of many small nesting beaches makes enforcement extremely difficult, and plover censusers frequently report vehicles and tire tracks on beaches (Boates *et al.* 1994, CWS 1994, S. von Oettingen pers. comm. 1994).

Various management techniques, including fencing and posting of nesting sites and the exclusion of vehicles from areas where chicks are present, can mitigate impacts of beach recreation on piping plovers, but must be implemented annually as long as the demand for beach recreation continues.

Non-motorized Beach Activities

Non-motorized recreational activities can be a source of both direct mortality and harassment of piping plovers. Pedestrians on beaches may crush eggs (Burger 1987b, Hill 1988, Shaffer and Laporte 1992, Cape Cod National Seashore 1993, Collazo *et al.* 1994). Unleashed dogs may chase plovers (McConnaughey *et al.* 1990), destroy nests (Hoopes *et al.* 1992), and kill chicks (Cairns and McLaren 1980; Z. Boyagian, Massachusetts Audubon Society, pers. comm. 1994).

Concentrations of pedestrians may deter piping plovers from using otherwise suitable habitat. Ninety-five percent of Massachusetts plovers (n = 209) observed by Hoopes (1993) were found in areas that contained less than one person per 8100 m^2 of beach. Elias-Gerken (1994) found that piping plovers on Jones Beach Island, New York selected beachfront that had less pedestrian disturbance than beachfront where plovers did not nest. Sections of beach at Trustom Pond NWR in Rhode Island were colonized by piping plovers within two seasons of their closure to heavy pedestrian recreation (C. Blair and J. Kurth, U.S. Fish and Wildlife Service, pers. comm. 1988 and 1990, respectively). Burger (1991, 1994) found that presence of people at several New Jersey sites caused plovers to shift their habitat use away from the ocean front to interior and bayside habitats; the time plovers devoted to foraging decreased and the time spent alert increased when more people were present. Burger (1991) also found that when plover chicks and adults were exposed to the same number of people, the chicks spent less time foraging and more time crouching, running away from people, and being alert than did the adults.

Pedestrians may flush incubating plovers from nests (see Table 3, page 12), exposing eggs to avian predators or excessive temperatures. Repeated exposure of shorebird eggs on hot days may cause overheating, killing the embryos (Bergstrom 1991), while excessive cooling may kill embryos or retard their development, delaying hatching dates (Welty 1982). Pedestrians can also displace unfledged chicks (Strauss 1990, Burger 1991, Hoopes *et al.* 1992, Loegering 1992, Goldin 1993b), forcing them out of preferred habitats, decreasing available foraging time, and causing expenditure of energy.

Fireworks are highly disturbing to piping plovers (Howard *et al.* 1993). Plovers are also intolerant of kites, particularly as compared to pedestrians, dogs, and vehicles; biologists believe this may be because plovers perceive kites as potential avian predators (Hoopes *et al.* 1992).

Motorized Vehicles

Unrestricted use of motorized vehicles on beaches is a serious threat to piping plovers and their habitats. The magnitude of this threat is particularly significant because vehicles extend impacts to remote stretches of beach where human disturbance would be very slight if access were limited to pedestrians. For example, approximately 0.5 mile of life-guarded beach at Race Point Beach on the Cape Cod National Seashore received an average of 334,000 visits in 1989 and 1990 (I. Tubbs, National Park Service, pers. comm. 1990). In addition, 2,338 off-road vehicle season permits and 290 permits for self-contained camping vehicles were sold at Cape Cod National Seashore in 1989; off-road vehicle permittees (most of whom made multiple trips on their permits) extended impacts to an additional 8.1 miles of beach that receive only light use by pedestrians walking beyond the 0.5 miles of life-guarded beach (K. Jones, National Park Service, pers. comm. 1991).

Vehicles can crush eggs (Wilcox 1959; Tull 1984; Burger 1987b; Patterson *et al.* 1991; United States of America v. Breezy Point Cooperative, Inc., U.S. District Court, Eastern District of New York, Civil Action No. CV-90-2542, 1991; Shaffer and Laporte 1992) as well as adults and chicks. In Massachusetts and New York, biologists documented 14 incidents in which 18 chicks and two adults were killed by vehicles between 1989 and 1993 (Melvin *et al.* 1994). Goldin (1993b) compiled records of 34 chick mortalities (30 on the Atlantic Coast and four on the Northern Great Plains) due to vehicles. Biologists that monitor and manage piping plovers believe that many more chicks are killed by vehicles than are found and reported (Melvin *et al.* 1994). Beaches used by vehicles during nesting and brood-rearing periods generally have fewer breeding plovers than available nesting and feeding habitat can support. In contrast, plover abundance and productivity has increased on beaches where vehicle restrictions during chick-rearing periods have been combined with protection of nests from predators (Goldin 1993b, S.M. Melvin pers. obs.).

Typical behaviors of piping plover chicks increase their vulnerability to vehicles. Chicks frequently move between the upper berm or foredune and feeding habitats in the wrack line and intertidal zone. These movements place chicks in the paths of vehicles driving along the berm or through the intertidal zone. Chicks stand in, walk, and run along tire ruts, and sometimes have difficulty crossing deep ruts or climbing out of them (Eddings *et al.* 1990, Strauss 1990, Howard *et al.* 1993). Chicks sometimes stand motionless or crouch as vehicles pass by, or do not move quickly enough to get out of the way (Tull 1984, Hoopes *et al.* 1992, Goldin 1993b). Wire fencing placed around nests to deter predators (Rimmer and Deblinger 1990, Melvin *et al.* 1992) is ineffective in protecting chicks from vehicles because chicks typically leave the nest within a day after hatching and move extensively along the beach to feed (see Table 1, page 9).

Vehicles also significantly degrade piping plover habitat or disrupt normal behavior patterns. They may harm or harass plovers by crushing wrack into the sand and making it unavailable as cover or a foraging substrate (Hoopes *et al.* 1992, Goldin 1993b), by creating ruts that can trap or impede movements of chicks (J. Jacobs, U. S. Fish and Wildlife Service, *in litt.* 1988), and by preventing plovers from using habitat that is otherwise suitable (MacIvor 1990, Strauss 1990, Hoopes *et al.* 1992, Goldin 1993b, Hoopes 1994). Vehicles that drive too close to the toe of the dune may destroy "open vegetation" that may also furnish important piping plover habitat (Elias-Gerken 1994).

Beach-cleaning

While removal of human-created trash on the beach is desirable to reduce predation threats, the indiscriminate nature of mechanized beach-cleaning adversely affects piping plovers and their habitat. In addition to the danger of directly crushing piping plover nests and chicks and the prolonged disturbance from the machine's noise, this method of beach-cleaning removes the birds' natural wrackline feeding habitat (Eddings and Melvin 1991, Howard *et al.* 1993).

PREDATION

Predation has been identified as a major factor limiting piping plover reproductive success at many Atlantic Coast sites (Burger 1987a, MacIvor 1990, Patterson *et al.* 1991, Cross 1991, Elias-Gerken 1994). As with other limiting factors, the nature and severity of predation is highly site-specific. Predators of piping plover eggs and chicks include red foxes, striped skunks, raccoons, Norway rats, opossums, crows, ravens, gulls, common grackles, American kestrels, domestic and feral dogs and cats, and ghost crabs.

Substantial evidence exists that human activities are affecting types, numbers, and activity patterns of predators, thereby exacerbating natural predation. Non-native species such as feral cats and Norway rats are considered significant predators on some sites (Goldin *et al.* 1990, Post 1991; see also Appendix C). At other locations, the introduction of predator species to islands has resulted in increased predation pressure on piping plovers and their young. For example, skunks have been introduced to Martha's Vineyard in Massachusetts (T. French, Massachusetts Division of Fish and Wildlife, pers. comm. 1989). Humans have also indirectly influenced predator populations; for instance, human activities have abetted the expansions in the populations and/or range of other species such as gulls (Erwin 1979, Drury 1973) and opossum (Gardner 1982). The availability of trash at summer beach homes increases local populations of skunks and raccoons (Raithel 1984). Strauss (1990) found that the density of fox tracks on a beach area was higher during periods of more intensive human use.

In addition to direct predation on piping plovers, herring, great black-backed, and ring-billed gulls compete with plovers for space and may cause piping plovers to abandon former nesting areas. Raithel (1984) noted that piping plovers no longer nest on the northern tip of Block Island, Rhode Island, where a large gull colony now occurs. Nesting pairs of piping plovers declined at Monomoy NWR in Massachusetts as a large gull colony grew rapidly during the 1960's and 1970's (USFWS 1988c). Cross (1988) attributed the absence of breeding plovers on South Metompkin Island (contrasted with 30 and five pairs, respectively, on islands immediately to the north and south) to intimidation and nest site competition from 2,000+ pairs of herring gulls. Cartar (1976) suggested that invading gulls were a major factor in plover nest destruction at Long Point, Ontario. The USFWS believes that nesting gulls pose a substantial threat to piping plovers and other nesting shorebirds at Breezy Point, New York and, consequently, has encouraged the National Park Service to eliminate the gull colony (N. Kaufman and P. Nickerson, U.S. Fish and Wildlife Service, *in litt.* 1992 and 1994, respectively).

Increased depredation by crows may be an indirect adverse impact of woody vegetation plantings. Elias-Gerken (1994) observed these avian predators perching and nesting in exotic Japanese black pines along the Ocean Parkway on Jones Island, New York and hypothesized that this vegetation and other artificial perches exacerbated depredation by crows there.

Migrating peregrine falcons are transitory inhabitants of most Atlantic Coast plover breeding sites (and nest on a few artificial sites in Virginia, Maryland, and New Jersey) and are incidental predators of piping plovers. In response to recovery efforts for that species, peregrine numbers are now increasing. Incidents of piping plover depredation by peregrines may be increasing relative to the 1950's and 1960's when the latter species' numbers were very depressed, but even at full recovery levels there is no reason to believe that peregrines will become a significant piping plover predator (P. Nickerson pers. comm. 1994).

THREATS TO WINTERING PIPING PLOVERS

Overall winter habitat loss is difficult to document, but some historical accounts indicate that degradation has occurred along the Atlantic Coast (Stevenson 1960). A variety of anthropogenic disturbance factors has been noted that may affect plover survival or utilization of wintering habitat (Nicholls and Baldassarre 1990a, Haig and Plissner 1993). These factors include recreational activities (motorized and pedestrian), inlet and shoreline stabilization, dredging of inlets, beach maintenance and renourishment, and pollution (e.g., oil spills) (Nicholls and Baldassarre 1990a, Haig and Oring 1985, Haig and Plissner 1993).

Wintering habitat, like Atlantic Coast breeding habitat, is dependent on natural forces of creation and renewal. Man-made structures along the shoreline or manipulation of natural inlets can upset this dynamic process and result in habitat loss or degradation (Melvin *et al.* 1991). For example, dredging of inlets can affect spit formation adjacent to inlets, while jetties can cause widening of islands and subsequent growth of vegetation on inlet shores. Over time, both result in loss of plover habitat. Additional investigation is warranted to determine the extent to which these disturbance factors affect wintering plovers (Melvin *et al.* 1991). This is a particularly pressing problem in Texas because of several major U.S. Army Corps of Engineers projects (Corps), which could affect plover wintering habitat (Haig and Plissner 1993).

Nicholls (1989) found higher densities of both people and off-road vehicles on those wintering sites where piping plovers were absent than those where they were present. Although these differences were not statistically significant, she cited the need for further investigation of recreational impacts on wintering plovers (J. Nicholls *in litt.* 1989).

Severe cold weather and storms are believed to take their toll on wintering plovers. After an intense snowstorm swept the entire North Carolina Coast in late December 1989, high mortality of many coastal bird species was noted (Fussell 1990). Piping plover numbers decreased significantly from approximately 30-40 to 15 birds. While no dead piping plovers were found, circumstantial evidence suggests that much of the decrease was mortality (Fussell 1990). Hurricanes may also result in direct mortality or habitat loss, and if piping plover numbers are low enough or if total remaining habitat is very sparse relative to historical levels, population responses may be impaired with even short-term habitat losses. Wilkinson and Spinks (1994) suggest that, in addition to the unusually harsh December 1989 weather, low plover numbers seen in South Carolina in January 1990 (11 birds, compared with more than 50 during the same time period in 1991-1993) may have been influenced by effects on habitat and food availability caused by Hurricane Hugo, which came ashore there in September 1989. Hurricane Elena struck the Alabama Coast in September 1985, and subsequent surveys noted a reduction of foraging intertidal habitat on Dauphin and Little Dauphin Islands (Johnson and Baldassarre 1988). Birds were observed foraging at Sand Island, a site that was previously little used prior to the hurricane.

OIL SPILLS AND OTHER CONTAMINANTS

Oil spills pose a threat to piping plovers throughout their life cycle. Oiled plovers have been reported from Breezy Point, New York; Sandy Hook and Mantoloking, New Jersey; Trustom Pond, Rhode Island; Horseneck Beach, Massachusetts; and Matagorda Island NWR, Texas (USFWS files).

Fourteen abandoned plover eggs from five New Jersey sites were analyzed for presence of organochlorine and heavy metal burdens in 1990 (USFWS 1991a). Although DDE, PCB's, and chlordane metabolites were detected in all samples, levels did not appear to threaten reproduction. Mercury concentrations ranged from 0.077 to 1.07 ppm wet weight; with the exception of 1.07 ppm wet weight mercury in eggs from Brick Township, New Jersey, mercury residues in that study appeared below those thought causative of avian reproductive anomalies.

IMPLICATIONS FOR THE BEACH ECOSYSTEM

The plight of the piping plover is an indicator of an entire ecosystem in very serious trouble. Since the the piping plover's 1986 listing, the roseate tern (*Sterna dougallii*) has been listed as endangered in the range of its northeastern population (USFWS 1987a), and two other beach-dwelling species native to the Atlantic Coast -- the northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*) (USFWS 1990a) and the seabeach amaranth (*Amaranthus pumilus*) (USFWS 1993a) -- have been listed under the Endangered Species Act as threatened species. Loggerhead sea turtles, listed as threatened since 1978, nest on 10 current or potential plover nesting beaches in North Carolina. Eighty-two percent of the 181 current and potential U.S. breeding sites listed in Appendix B support other Federal- or State-listed species or have historical records of species that are now Federally listed; for instance, seabeach amaranth currently coincides with nesting piping plovers on most beaches in North Carolina and on the south coast of Long Island, New York, but it is now extirpated from southern Massachusetts, Rhode Island, New Jersey, Delaware, Maryland, and Virginia (Weakley and Bucher 1992). Likewise, the only extant ocean beach populations of northeastern beach tiger beetle (this species is also found on the Chesapeake Bay shoreline) occur on two Massachusetts sites that are also used by piping plovers, although this insect was once considered abundant on ocean beaches from Massachusetts to New Jersey (USFWS 1994d). Unlike many endangered or threatened species, none of the Atlantic beach species mentioned above is an endemic species; thus, their status indicates widespread ecological problems.

These threatened and endangered beach species that breed along the Atlantic Coast have many threats in common with the piping plover. Habitat loss and degradation due to shoreline development and beach stabilization and crushing by off-road vehicles are cited as major factors contributing to the listing of the northeastern beach tiger beetle (USFWS 1990a) and seabeach amaranth (USFWS 1993a). The most prominent threat to the endangered roseate tern is the loss of nesting sites to expanding numbers of nesting herring and great black-backed gulls (USFWS 1987a), also a significant cause of reduced piping plover numbers and productivity at some Atlantic Coast nesting beaches.

If the precarious status of these species is a symptom of an embattled ecosystem, then remedial efforts aimed at the restoration of the natural processes that maintain this system, rather than single-species "fixes," are likely to have the greatest long-term benefits. Important components of ecologically sound barrier beach management include perpetuation of natural dynamic coastal formation processes; management of human recreation to prevent or minimize adverse impacts on dune formation, vegetation, and the invertebrate and vertebrate fauna; and efforts to counter the effects of human-induced changes in the types, distribution, numbers, and activity patterns of predators.

No piping plover recovery efforts implemented to date have been detrimental to the natural functions of the beach ecosystem. Furthermore, many protection efforts for piping plovers have also benefitted other sensitive beach species such as least terns and seabeach amaranth, and the reverse (benefits to piping plovers from protection efforts targeted at other species, such as least terns) has also occurred. However, some piping plovers protection measures have been tailored to the specific needs of this species in ways that limit benefits to the beach ecosystem as a whole. For example, in an effort to reduce conflicts with beach users, off-road vehicle management recommendations in Appendix G seek to minimize the size and duration of vehicle closures. While these short-duration closures prevent mortality and harassment of piping plovers and provide some benefits to other beach-nesting birds, they amount to insufficient protection for northeastern beach tiger beetles. An extreme example of single-species protection is the use of predator exclosures to reduce depredation of plover eggs; nonetheless, in many situations, exclosures provide by far the most effective and efficient protection against prolific entrenched predators, where reductions in predator numbers would be very difficult to achieve and very temporary. Implementation of more ecosystem-oriented approaches to piping plover protection would provide important benefits to other rare species and merit serious consideration, but it should be recognized that, in many cases, these approaches would entail significantly higher costs and/or cause more conflicts with human beach users.

CURRENT CONSERVATION EFFORTS

Piping plover protection efforts along the Atlantic Coast have accelerated rapidly since 1985. Many ongoing activities are discussed in the Recovery Tasks section of this plan.

REGULATORY PROTECTION

Section 9 of the Endangered Species Act prohibits any person subject to the jurisdiction of the United States from taking (i.e., harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting) listed wildlife species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the ESA (50 CFR 17.3) further define "harm" to include significant habitat modification or degradation that results in the killing or injury of wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. Appendix G, Guidelines for Managing Recreational Activities in Piping Plover Habitat on the U.S. Atlantic Coast to Avoid Take Under Section 9 of the ESA, contains recommendations to beach managers and property owners.

Section 10 of the ESA and related regulations provide for permits that may be granted to authorize activities otherwise prohibited under Section 9, for scientific purposes or to enhance the propagation or survival of a listed species. States that have cooperative agreements under Section 6 of the ESA may provide written authorization for take that occurs in the course of implementing conservation programs. For example, State agencies have authorized certain biologists to construct predator exclosures for piping plovers. It is also legal for employees or designated agents of certain Federal or State agencies to take listed species without a permit if the action is necessary to aid sick, injured, or orphaned animals or to salvage or dispose of a dead specimen.

Section 10 also allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity" if the USFWS determines that certain conditions have been met. An applicant for an incidental take permit must prepare a conservation plan that specifies the impacts of the take, the steps the applicant will take to minimize and mitigate the impacts, funding that will be available to implement these steps, the alternative actions to the take that the applicant considered, and the reasons why such alternatives are not being utilized. Appendix H contains guidelines for the preparation and evaluation of conservation plans for Atlantic Coast piping plovers pursuant to Section 10(a)(1)(B) and 10(a)(2) of the ESA.

Section 7 of the ESA requires Federal agencies to consult with the USFWS prior to authorizing, funding, or carrying out activities that may affect listed species. Section 7 also requires that these agencies use their authorities to further the conservation of listed species. Section 7 obligations have caused Federal land management agencies to implement piping plover protection measures that go beyond those required to avoid take, for example, by conducting research on threats to piping plovers. Other examples of Federal activities that may affect piping plovers along the Atlantic Coast, thereby triggering Section 7(b) consultation, include permits for beach nourishment or disposal of dredged material (U.S. Army Corps of Engineers) and funding of beach restoration projects (Federal Emergency Management Authority).

In September 1994, fourteen Federal agencies, including the U.S. Fish and Wildlife Service, National Park Service, U.S. Coast Guard, U.S. Army Corps of Engineers, and Department of Defense, signed a Memorandum of Understanding affirming their commitments to carry out programs for the conservation of species listed under the ESA and the ecosystems upon which they depend, including implementing appropriate recovery actions that are identified in recovery plans.

Executive Order 11644, Use of Off-Road Vehicles on the Public Lands, and Executive Order 11989, Off-Road Vehicles on Public Lands, pertain to lands under custody of the Secretaries of Agriculture, Defense, and Interior (except for Native American Tribal lands). Executive Order 11644 requires administrative designation of areas and trails where off-road vehicles may be permitted. Executive Order 11989 states that "... the respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, *wildlife, wildlife habitat* ... immediately close such areas or trails to the type of off-road vehicles causing such effects, until such time as he determines that such effects have been eliminated and that measures have been implemented to prevent future recurrence" (emphasis added).

Piping plovers are also protected under the Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712). Prohibited acts include pursuing, hunting, shooting, wounding, killing, trapping, capturing, collecting, or attempting such conduct.

The Coastal Barriers Resource Protection Act of 1982 (CBRA), as amended by the Coastal Barrier Improvement Act of 1990 (P.L. 101-591), provides certain protections to designated units of the Coastal Barrier Resources System (System), including many sites where piping plovers breed or winter on the Atlantic Coast. Except for a few specified exemptions, Section 6 of CBRA bans all Federal expenditures within units of the System. Section 6 also requires that Federal agencies consult with the USFWS prior to committing funds for any exempted activities.

Almost all States within the breeding range of the Atlantic Coast piping plover list the species as State-threatened or -endangered (Northeast Nongame Technical Committee 1993), and many State endangered species laws and regulations prohibit take of State-listed species. As a further protection, the Maine Department of Inland Fisheries and Game (1995) has designated nine sites as Essential Habitat for piping plovers and least terns; this designation prohibits significant alteration or unreasonable harm to the Essential Habitat from projects requiring a permit or license from, or to be funded or carried out by, a State agency or municipal government.

Other State regulations also protect piping plovers and/or their habitat. For example, the Massachusetts Wetlands Protection Act (Massachusetts General Laws Chapter 131, Section 140) requires that proposed projects that occur in wetlands (including beaches) be designed to avoid short-term or long-term adverse effects on the habitat of any rare species of wildlife (Melvin and Roble 1990). Opinions, based on this law, provided by the Massachusetts Division of Fisheries and Wildlife on the impacts of proposed dredging have recommended restrictions on the timing or location of beach nourishment in order to prevent adverse effects on piping plover habitat (S.M. Melvin pers. comm. 1990). In New York, compliance with the New York Tidal Wetlands Act and the New York State Environmental Quality Review Act usually results in conditions on dredging permits that restrict the season or location of operation; these restrictions are designed to protect piping plovers and other State-listed wildlife (S. Sanford, New York State Department of Environmental Conservation, pers. comm. 1990). It should be noted, however, that revisions in the New York Tidal Wetlands Act are currently under discussion, and that potential changes lessening or eliminating jurisdiction over shoals, mudflats areas and areas adjacent to tidal wetlands could result in decreased protection of these habitats in the future (USFWS 1995b).

In some cases, piping plovers benefit from State regulations intended to protect other natural resources. For instance, the Connecticut Coastal Resources Management Division prohibits most dredging projects in that State between May 30 and September 30 to avoid impacts to shellfish beds (R. Rozsa, Connecticut Coastal Resources Management Division, pers. comm. 1989).

PROTECTION AND MANAGEMENT ON BREEDING SITES

Current breeding site protection efforts are documented in Appendix C (Summary of Current and Needed Breeding Site Management Activities). Most common management strategies include protection of nests with predator exclosures (see Appendix F); signing and symbolic fencing of nesting areas; restrictions on motorized vehicles in the vicinity of flightless chicks; wardening of nesting areas, especially in areas where public use is heavy; and public information and education.

The magnitude of the piping plover protection effort on the breeding grounds may be gauged from information in Appendix J (Estimated Cost of U.S. Atlantic Coast Piping Plover Protection Activities during the 1993 Breeding Season). Estimates compiled by the State wildlife agencies show that approximately $1.8 million was spent to protect 875 pairs of plovers that nested on the U.S. portion of the range in 1993. This figure includes more than 85,000 person-hours by paid staff, but does not reflect approximately 32,750 hours of volunteer labor. Comprehensive estimates of protection costs in Atlantic Canada are unavailable, but a substantial effort is also being exerted to protect piping plovers there. Report #3 prepared by Recovery of Nationally Endangered Wildlife (RENEW 1993) reported expenditures of more than $154,000 (Canadian) and 6.5 person-years of effort (cost not included in the expenditures figure) to protect Atlantic plovers in the year ending March 31, 1993. The 1992 efforts reported by RENEW were supplemented by 84 volunteers who provided wardening through the Piping Plover Guardian Program on 20 beaches in Nova Scotia and on Prince Edward Island (Atlantic Canada Piping Plover Recovery Team 1992); in 1993, the Guardian Program expanded to include beaches in Newfoundland and New Brunswick and a full-time paid coordinator (Atlantic Canada Piping Plover Recovery Team 1993). RENEW (1994) reported increases in expenditures for protection of Atlantic Coast piping plovers to $205,000 (Canadian) during the 1993 breeding season, not including unquantified paid and volunteer time.

Although a few piping plover recovery expenditures represent investments in basic research with broad applicability to piping plover management, the vast majority of the piping plover protection effort involves labor-intensive, on-site efforts such as the posting and fencing of nesting areas, wardening, and construction of predator exclosures. Such efforts can effectively reduce impacts to piping plovers, but they do not remove the root causes of threats such as intensive recreational use and elevated predation pressure. These protection efforts will have to be continued each season in perpetuity if the piping plover population is to be recovered and maintained.

PROTECTION AND MANAGEMENT ON WINTERING SITES

Efforts to protect piping plover wintering habitat on the Atlantic Coast have focused primarily on:

(1) Surveys to identify wintering sites. In addition to the 1991 International Census of wintering sites, several State nongame programs have conducted surveys to further identify specific wintering sites.

(2) Recommendations to prevent habitat degradation made through the Section 7 consultation process on a project-by-project basis. A 1991 workshop was held in North Carolina specifically for representatives of State and Federal regulatory agencies to inform them of the plover's habitat needs and ecology, and requirements to protect and consult on this species.

(3) Acquisition and recognition of a few key sites. The Nature Conservancy (TNC) recently purchased Little Tybee Island in Georgia and turned the site over to the State for conservation purposes. The National Key Deer Refuge, including two plover wintering sites, was recently recognized as a part of the Western Hemispheric Shorebird Reserve Network (WHSRN). The WHSRN also has recently developed a Piping Plover Registry Program, which seeks to promote international recognition of landowner efforts to preserve piping plovers (J. Sibbing, Western Hemispheric Shorebird Reserve Network, *in litt.* 1993).

ROLE OF FEDERAL LANDS IN RECOVERY EFFORTS

Federal lands administered by the NPS, USFWS, National Aeronautics and Space Administration (NASA), U.S. Coast Guard, U.S. Army Corps of Engineers, and U.S. Air Force supported approximately 370 nesting pairs of piping plovers in 1995. These 370 pairs constituted 32% of the U.S. Atlantic Coast population and 27% of the entire breeding population, including Atlantic Canada. The carrying capacity of Federal lands as estimated in 1993 was 635 pairs, approximately 33% of the estimated capacity of all U.S. breeding sites.

Most Federally administered breeding sites are very intensively managed. Consistent with National Wildlife Refuge System Administration Act and Refuge Recreation Act requirements regarding compatibility of refuge activities, plover habitat within most national wildlife refuges is closed to public use during the breeding season. Cape Cod, Fire Island, and Assateague National Seashores and the Gateway National Recreation Area have written plans detailing how piping plovers will be protected. Nesting areas on NASA's Wallops Island are also closed to public entry during the breeding season.

Protection of piping plovers and their habitat on Federal lands is important not only because of the direct benefits to plovers that use these areas, but because plover protection programs on Federal lands serve as examples to non-Federal landowners.

COORDINATION AND PARTICIPATION

Recovery efforts at the State level are coordinated by the State wildlife agencies; population-wide coordination is supplied by the recovery team with oversight by the USFWS. Since 1988, the USFWS has prepared and distributed annual status updates on the Atlantic Coast piping plover population. These are widely requested and provide biologists, beach managers, user groups, and other interested parties with timely information about progress towards recovery. Periodic rangewide wintering censuses (e.g., the 1991 and 1996 International Censuses) provide important information on the plover's status and stimulate awareness of important wintering sites. Bi-annual meetings of biologists involved in plover conservation within the Atlantic Coast breeding range afford opportunities for exchange of important information about plover ecology and management techniques. Similar but less frequent meetings have focused on protection of wintering plovers and their habitat. The U.S. Atlantic Coast, Atlantic Canada, and Great Lakes/Northern Great Plains recovery teams maintain communication and frequently exchange observers at team meetings. These meetings and other communications among the recovery teams and State plover coordinators assure prompt evaluation and distribution of new information. For example, dissemination of information about design and use of predator exclosures has required a significant effort over the last eight years; experts have traveled to various States and to Canada to help resolve difficulties with exclosures.

Participation of affected agencies, organizations, and user groups in planning and implementing U.S. recovery efforts has been fostered primarily at the State level. Various working groups provide continuing forums for discussion and adjustment of recovery efforts. Examples include the Massachusetts Barrier Beach Task Force, formed in 1992 under the auspices of

Massachusetts Coastal Zone Management Office with members from four State agencies, as well as user groups, municipal governments, conservation groups, and the USFWS (Massachusetts Barrier Beach Task Force 1994). Coordination of plover survey efforts and threat assessment in New York has been facilitated by the Long Island Colonial Waterbird Association since before the listing of the plover under the ESA; in March 1995, the New York State Department of Environmental Conservation, Division of Fish and Wildlife, formed a Regional Piping Plover Management Coordination Group comprising State, Federal, and local government agencies and private organizations to intensify piping plover recovery efforts on Long Island (K.J. Meskill and C.T. Hamilton, New York State Department of Environmental Conservation, *in litt.* 1995). In Delaware, multi-agency participation in piping plover protection has been implemented through the Delaware Beach Issues Group, an ongoing working group of State agencies; participating agencies also maintain communication with interested and affected private organizations and groups and with Federal agencies (L. Gelvin-Innvaer pers. com.).

RECOVERY STRATEGY

The original recovery objective for the Atlantic Coast piping plover, established in the 1988 recovery plan, was to "increase the Atlantic Coast population of the piping plover (U.S. and Canada) to a self-sustaining population of 1,200 breeding pairs, while maintaining the current distribution" (USFWS 1988e). As stated in that plan, this objective represented "a compromise between a complete recovery from the 50-80% population decline over the preceding 50 years, versus what [the recovery team believed] could realistically be achieved in the face of continuing loss (both physical and functional) of habitat from increasing human recreation and development pressures." This recovery objective, formulated in the initial stages of the recovery effort, reflected the best judgment at that time of the most knowledgeable piping plover specialists.

Since 1988, recovery efforts have produced additional information to test whether the original objective provides for a "self-sustaining population." In particular:

- Experience gained in New England, where piping plover numbers doubled between 1988 and 1993 while maintaining high levels of productivity, has expanded the definition of suitable habitat and shown that populations can grow very rapidly where they are intensively managed to reduce impacts of human-induced mortality, human disturbance, and predation. As a result, biologists have greatly increased their estimates of habitat carrying capacity. Current estimates of carrying capacity of known and potential U.S. breeding sites are provided in Appendix B; the U.S. Fish and Wildlife Service believes these estimates remain very conservative, especially for the southern portion of the range (see discussion on page 30).

- Information about movements of piping plovers and gene flow, while limited, is substantially improved since 1988. It suggests that movements are probably sufficient to maintain gene flow within the Atlantic Coast population. However, observations have shown that the vast majority of marked birds select breeding sites in the same (or adjacent) State as their natal beaches and return to the same or adjacent States in ensuing breeding seasons. This pattern of fidelity to the natal region is supported by the close correlation between productivity rates and subsequent population trends.

- New data on survival and fecundity rates have facilitated computer modeling of long-term population viability under varying scenarios. The PVA for the Atlantic Coast piping plover (Appendix E, Melvin and Gibbs 1994) incorporated productivity data from the entire U.S. portion of the Atlantic Coast range and estimated survival rates for plovers that breed on outer Cape Cod. Results were examined to determine the sensitivity of population persistence to each factor.

As a result of this new information, the recovery team has conducted a detailed re-evaluation of the original recovery objective, resulting in substantial revisions and refinements.

The following principles will guide future recovery efforts for the Atlantic Coast piping plover population:

1. **Sufficiency of population size and productivity will be based on a >95% probability of persistence for 100 years.** All populations face varying probabilities of extinction due to stochastic events that affect survival and productivity. At given average rates of survival and productivity, and variability around these averages, large populations have lower probabilities of extinction than small ones. Population viability analysis is a form of risk analysis applied to the issue of population extinction. It is a structured and systematic analysis of the interacting factors, including abundance, rates of survival and productivity, demographic and environmental stochasticity, and catastrophes, that determine a population's risk of extinction. In recent years, PVA's have been used as tools in establishing recovery goals for threatened and endangered species such as the northern spotted owl and the desert tortoise. Information about the Atlantic Coast piping plover PVA is provided in Appendix

E. Modeling was conducted to estimate probabilities of extinction, as well as probabilities that the population would fall below thresholds of 50, 100, and 500 pairs. The results of this modeling are the basis for the revised quantitative delisting objectives.

2. Population increases should be evenly distributed throughout the plover's Atlantic Coast range. This principle was reflected in the 1988 recovery objective stipulation that the population increase had to be achieved "while maintaining the current distribution." Dispersal of the population across its breeding range serves as a hedge against catastrophes, such as hurricanes, oil spills, or disease that might depress regional survival and/or productivity. Maintaining robust, well-distributed subpopulations should reduce variance in survival and productivity of the Atlantic Coast population as a whole, facilitate interchange of genetic material between subpopulations, and promote recolonization of any sites that experience declines or local extirpations due to low productivity and/or temporary habitat succession.

To facilitate an even distribution of the population, the recovery team has delineated four recovery units -- Atlantic Canada, New England, New York-New Jersey, and Southern -- and assigned a portion of the population target to each. These units are large enough that their overall carrying capacity should be buffered from changes due to natural habitat formation processes at individual nesting sites, while still assuring a geographically well-distributed population.

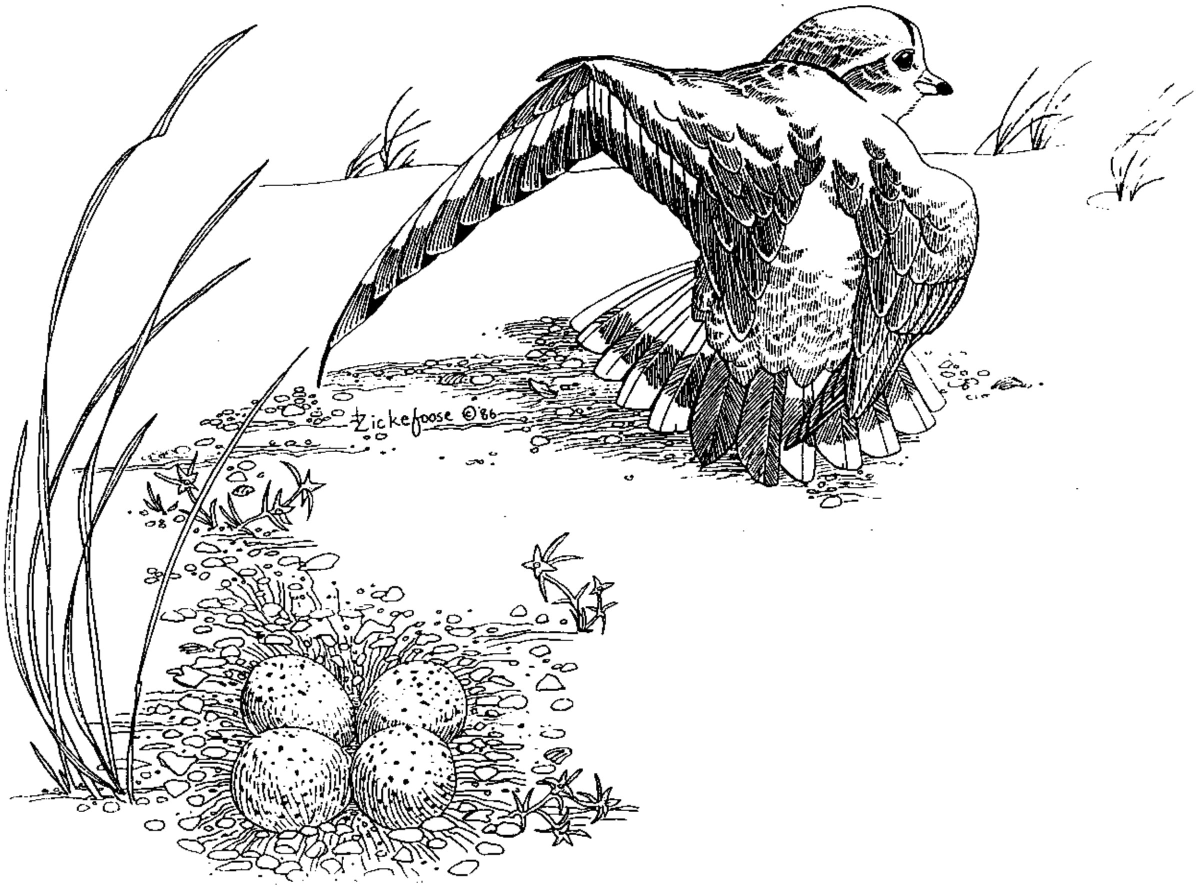
Current information indicates that most Atlantic Coast piping plovers nest within their natal region, that regional population trends are related to regional productivity, and that intensive regional protection efforts contribute to increases in regional piping plover numbers (see Breeding Site Fidelity and Dispersal, page 28). However, at least low levels of dispersal are ongoing within the Atlantic Coast piping plover population, and recovery units do not represent biologically distinct population segments as defined in the USFWS policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act (USFWS 1996a).

A premise of this plan is that the overall security of the Atlantic Coast piping plover population is profoundly dependent upon attainment and maintenance of the minimum population levels for the four recovery units. Any appreciable reduction in the likelihood of survival of a recovery unit will also reduce the probability of persistence of the entire population.

3. **Measures should be taken to prevent loss of genetic diversity over the long term.** Small populations risk loss of genetic diversity through inbreeding and random genetic drift. In the short term, such a loss may reduce individual fitness and productivity. Over the long term, loss of genetic diversity may erode the evolutionary potential of a population or species, reducing its ability to adapt to changes in its environment, and thereby increasing its risk of extinction. An N_e of 500 was cited by Franklin (1980) and Frankel and Soulé (1981) as the *minimum* effective population size necessary to maintain long-term genetic fitness and evolutionary potential. Since no formal estimates of N_e/N are currently available for piping plovers, and because the species' sparse distribution results in highly non-random breeding that may pose a barrier to gene flow, the revised delisting criteria require the USFWS to verify that the target population is sufficiently large to maintain long-term genetic fitness.

4. **Mechanisms should be provided to prevent a reversal of population increases following delisting under the ESA.** All of the piping plover protection mechanisms devised to date are labor-intensive activities that are effective only if implemented annually. While increasing piping plover numbers will reduce the probability of extinction, these gains will be quickly eroded if actions to mitigate threats from predation and human-caused mortality, disturbance, and habitat degradation are not continued. The PVA shows that even a population that is several-fold times that provided in the 1988 recovery objective must sustain high productivity and survival and low variance in those parameters in order to persist over the long term. This will require continued intensive management to ensure high productivity and maintenance of wintering and breeding habitat quantity and quality.

While protection of piping plovers and their habitat will require a significant long-term commitment, the benefits go beyond survival of this one species. Protection of piping plovers and their habitat responds to the stated purposes of the ESA (Section 2(b)), by "provid[ing] a means whereby the ecosystems on which endangered species and threatened species depend may be conserved." Since 1988, two more species that share the piping plover's beach habitat over parts of its range, the northeastern beach tiger beetle and seabeach amaranth, have been added to the list of threatened species. This and the observed response of other beach-nesting birds to piping plover protection efforts has increased biologists' awareness of the piping plover as an indicator of the health of the fragile beach ecosystem.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