CONSERVATION PLAN FOR DUNLIN WITH BREEDING POPULATIONS IN NORTH AMERICA (*CALIDRIS ALPINA ARCTICOLA*, *C. A. PACIFICA*, AND *C. A. HUDSONIA*)

Version 1.0

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WHSRN
WESTERN HEMISPHERE SHOREBIRD RESERVE NETWORK

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Dunlin (*Calidris alpina pacifica*) roosting at Port Susan Bay, Snohomish, Washington, USA. Photo by Steve Mlodinow.

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EXECUTIVE SUMMARY

The Dunlin (*Calidris alpina*) is one of the more abundant migratory shorebirds of the Northern Hemisphere, and has an almost circumpolar distribution of breeding populations. Unlike most other shorebirds, the Dunlin shows considerable phenotypic and genotypic variation over its range, with up to 11 subspecies recognized. Three subspecies are known to occur in North America: *C. a. arcticola*, *C. a. pacifica*, and *C. a. hudsonia*, with population estimates of 750,000, 550,000, and 225,000, respectively. Despite their large population estimates, the U.S. Shorebird Conservation Plan lists the Dunlin (*C. a. arcticola* and *C. a. pacifica*) as a Species of High Concern (Brown *et al.* 2001), while the Canadian Shorebird Conservation Plan considers it a Species of Moderate Concern with known or potential threats (Donaldson *et al.* 2000). The Dunlin warrants conservation planning due to 1) recent rates of habitat loss in the nonbreeding range where the species tends to aggregate; 2) gaps in knowledge regarding factors limiting the populations; 3) the species' vulnerability to a variety of impacts, given its strong tendency to aggregate; and 4) inadequate monitoring data for determining population trends, coupled with suspected declines in parts of its range.

C. a. arcticola breeds in northern Alaska (and possibly Canada), and spends the nonbreeding season distributed from Japan to the People's Republic of China. *C. a. pacifica* breeds in coastal western Alaska, and its primary nonbreeding distribution is the Pacific coast from southern British Columbia, Canada, to northwestern Mexico. *C. a. hudsonia* breeds in northern Canada and spends the nonbreeding season commonly on the Atlantic and Gulf coasts from Massachusetts to Mexico. All three subspecies use similar habitats during migration and nonbreeding. Dunlin are common at estuarine mudflats, but they can move among a variety of available habitats, from freshwater to brackish wetlands. Dunlin also are found in coastal and adjacent agricultural habitats, and some individuals spend part or all of the season inland in freshwater wetlands and agricultural habitats.

Each subspecies uses a substantial number of sites throughout its annual range, and some sites support very large numbers of birds. Although some of the most important sites are protected, many others are on unprotected lands. Important migratory and nonbreeding sites for *C. a. arcticola* include:

- ***Alaska, USA***: Yukon-Kuskokwim Delta, Shishmaref Inlet, and Kasegaluk Lagoon (southward migration);

- ***People's Republic of China***: Yancheng National Nature Reserve (migration), and Yalu Jiang National Nature Reserve (northward migration);
- ***Republic of Korea*** *[South Korea]*: Saemangeum Estuary, Mangyeung Gang Hagu, and Tongjin Gang Hagu (migration).

It is noteworthy that the nonbreeding range of *C. a. arcticola* overlaps that of three other Dunlin subspecies (*actites, sakhalina*, and *kistchinski*) in the East Asian-Australian Flyway. This mixing of subspecies has complicated and, to date, prevented the establishment of a reliable population estimate for and identification of important sites used by *C. a. arcticola* during the migration and nonbreeding periods.

Important migratory and nonbreeding sites [per country/state] for *C. a. pacifica* include:

- ***British Columbia, Canada***: Mud Bay and Fraser River Delta (nonbreeding);
- ***Alaska, USA***: Yukon-Kuskokwim Delta, Nelson Lagoon-Mud Bay, Egegik Bay, Port Heiden, and Shishmaref Inlet (southward migration), and Copper River Delta, Yakutat Foreland, and Cook Inlet (northward migration);
- ***Washington, USA***: Grays Harbor, Willapa Bay, and Puget Sound (migration and nonbreeding), and coastal beaches adjacent to the latter two sites (migration and nonbreeding);
- ***Oregon, USA***: Columbia River Estuary [*shared with Washington*] (nonbreeding and northward migration), and the Willamette Valley (nonbreeding);
- ***California, USA***: Central Valley (migration and nonbreeding), Sacramento Valley (nonbreeding), and San Francisco Bay and Humboldt Bay (nonbreeding and northward migration);
- ***Baja California Sur, Mexico***: Laguna Ojo de Liebre–Guerrero Negro (nonbreeding).

Important migratory and nonbreeding sites [per state] for *C. a. hudsonia* include:

- ***North Dakota, USA***: Minnewaukan Flats–Devil's Lake (northward migration);
- ***Michigan, USA***: Shiawassee National Wildlife Refuge (northward migration);
- ***Ohio, USA***: Ottawa National Wildlife Refuge (northward migration).
- ***New Jersey, USA***: Edwin B. Forsythe National Wildlife Refuge (southward migration);
- ***Virginia, USA***: Chincoteague National Wildlife Refuge (southward migration);
- ***Texas, USA / Tamaulipas, Mexico***: Laguna Madre (nonbreeding);

Conservation threats to the three subspecies and the proposed solutions are similar. At migratory and nonbreeding sites, potential or actual threats include habitat loss and degradation, human disturbance, oil spills, and contaminants. Sources of habitat alteration are related to reclamation of intertidal areas for food production, shrimp farms, changes in water hydrology (i.e., dams) and agricultural practices, restoration of salt marshes, and invasive species (e.g., *Spartina*). There are still major gaps in the underlying factors that have the greatest influence on Dunlin populations and demographic rates.

Overall, the highest-priority conservation action identified within each subspecies' range is habitat protection, particularly during migration and at nonbreeding sites. For *C. a. arcticola*, it is critical to evaluate and curtail changes in nonbreeding sites, especially in the Yangtze River floodplain and along the Fujian coast. For *C. a. pacifica*, it is critical to reconsider plans to restore salt pond habitat to tidal marsh habitat, especially in California; the needs of Dunlin should be carefully balanced with those for other species. The control of *Spartina* also is a high priority. Important sites should be properly recognized at local, regional and international scales, either as new protected areas or as WHSRN, Ramsar Convention, or Important Bird Area designations. An education and outreach program would be valuable to increase awareness of migratory shorebird ecology and the importance of protecting wetlands. The conservation-related research needs include studies on migratory connectivity, density-dependent effects of habitat loss, and factors affecting survival and population dynamics. The monitoring needs include an adequate population monitoring program(s) to determine population trends and counts of birds in natural and manmade habitats.

PURPOSE

The Dunlin (*Calidris alpina*) is one of the more abundant migrants of the Northern Hemisphere and has a near circumpolar distribution of breeding populations. Unlike most shorebirds, the Dunlin shows considerable phenotypic and genotypic variation over its range, with up to 11 subspecies recognized (Greenwood 1986, Nechaev and Tomkovich 1988, Browning 1991, Wennerberg *et al*. 1999, Wennerberg 2001). Despite its large population numbers, various issues of concern have been identified, which prompted the development of this conservation plan. The issues of concern include: 1) recent rates of habitat loss due to reclamation for industrial development and agriculture, dam construction, coastal development, and aquaculture management in the nonbreeding range where the species tends to aggregate in spatially constrained or otherwise limited areas; 2) gaps in knowledge regarding factors limiting the populations; 3) suspected declines in number; and 4) inadequate monitoring data for determining population trends, coupled with suspected declines in parts of its range. These concerns have prompted a number of organizations and agencies to assign special conservation status to the Dunlin. For example, the U.S. Shorebird Conservation Plan lists the Dunlin (*C. a. arcticola* and *C. a. pacifica*) as a Species of High Concern (Brown *et al*. 2001), while the Canadian Shorebird Conservation Plan considers it a Species of Moderate Concern with known or potential threats (Donaldson *et al*. 2000). This conservation plan is the first step in a process to develop a multi-faceted conservation strategy for Dunlin that breed in the Western Hemisphere.

In this conservation plan we provide information that will help a variety of audiences to understand Dunlin ecology and behavior, as well as the various conservation issues important to achieving population goals set forth in the U.S. Shorebird Conservation Plan (Brown *et al*. 2001). Specifically, we provide a brief overview of each subspecies' ecology and status in North America (*C. a. arcticola, C. a. pacifica*, and *C. a. hudsonia*), identify important sites used by at least 1% of each subspecies, and describe major conservation threats and conservation actions needed at those sites. To develop the plan, we summarized information from published literature, unpublished data, and personal communications with shorebird scientists, resource managers, and amateur field ornithologists with special interest in and experience with shorebirds. To the extent possible, the scope of this plan includes the entire range and full annual cycle for each of the three subspecies that breed in North America. In each section of the plan, for consistency and comparison, information about *C. a. arcticola* and *C. a. pacifica*—both of which breed in Alaska—is presented first, followed by the relatively more eastern-breeding *C. a. hudsonia.* Site information includes high counts of Dunlin, habitats used, factors that impact or potentially impact each site, and conservation actions needed to diminish or offset threats.

This plan was written in accordance with the United States and Canadian shorebird conservation plans (Brown *et al*. 2001, Donaldson *et al*. 2000) and the Action Plan for the Conservation of Migratory Shorebirds in the East Asian-Australasian Flyway (Asian-Pacific Migratory Conservation Committee 2001). In addition, we used regional shorebird plans to identify research and education/outreach needs that pertain to Dunlin in the following planning regions: Asia (Wetlands International – Oceania 2004); Alaska (Alaska Shorebird Working Group 2000); Northern Pacific (Drut and Buchanan 2000); Southern Pacific (Hickey *et al*. 2003); Prairie Potholes (Skagen 2000); Central Plains/Playa Lakes (Fellows *et al*. 2001); Northern Atlantic (Clark and Niles 2000); Southeastern Coastal Plains (Hunter *et al*. 2000); and Western Gulf Coast (Elliott and McKnight 2000) planning regions. Our goal is to provide natural resource managers, funding agencies, scientists, and other interested parties with the information necessary to maintain or increase Dunlin populations throughout their ranges.

NATURAL HISTORY AND STATUS

Dunlin are one of the better studied shorebirds in North America with numerous studies done at breeding grounds and at nonbreeding sites; however, considerable gaps remain, especially with respect to population trends and factors involved in these trends.

MORPHOLOGY

The Dunlin (*Calidris alpina*) is a medium-size (33–85 grams) sandpiper that is distinguished from most other Calidrid sandpipers in the Western Hemisphere by its relatively long and slightly curved bill (Paulson 2005). Dunlin in breeding plumage are very different in appearance than those in nonbreeding plumage. In breeding, or alternate plumage, Dunlin have a black belly, reddish cap, and a bright reddish-brown back, hence its former name of Red-backed Sandpiper. Dunlin in juvenal plumage are seldom seen except on or adjacent to breeding areas, and have a reddish-brown back and brownish-black splotches on the belly (see photo in Paulson 2003). In nonbreeding, or basic plumage, Dunlin have overall light brownish-grey coloration with diffuse brownish bands of streaking on upper breast, and white under parts (Warnock and Gill 1996). Females on average are larger and have longer wings and bills than males (Warnock and Gill 1996).

TAXONOMY

Unlike most other shorebirds, the Dunlin shows considerable phenotypic and genotypic variation over its range. Nine to eleven races are recognized (Greenwood 1986, Nechaev and Tomkovich 1988, Browning 1991, Piersma 1996, Engelmoer and Roselaar 1998) in five phylogenetic lineages (Wenink *et al*. 1996, Wennerberg et el. 1999, Wennerberg 2001). Subspecies differ mainly in size (mass and length of bill and wing) and in subtle differences in mostly breeding plumage (Engelmoer and Roselaar 1998, Paulson 2005). Three subspecies breed in North America: *C. a. arcticola, C. a. pacifica*, and *C. a. hudsonia* (Warnock and Gill 1996). *C. a. pacifica* and *C. a. hudsonia* are larger and dorsally brighter than *C. a. arcticola* (Warnock and Gill 1996, Paulson 2005). The antiquity of North American subspecies dates to the late Pleistocene, with *C. a. hudsonia* being ancestral (Wenink *et al*. 1993).

POPULATION ESTIMATE AND TREND

The Dunlin is one of the most abundant shorebird species in the Western Hemisphere, with an estimated North American population of 1,525,000 birds (Table 1). The confidence of population estimates for the three North American subspecies are considered “low” (Brown *et al*. 2001). Although comprehensive trend data for Dunlin populations are generally lacking, all three North American subspecies are thought to be declining (Brown *et al*. 2001, U.S. Shorebird Conservation Plan 2004).

Table 1. Population estimates for three subspecies of Dunlin that breed in North America.

Subspecies	Estimated population	Range of estimate	Reference
C. a. arcticola	750,000[a]	200,000 – 750,000	Morrison *et al*. (2001, 2006)
C. a. pacifica	550,000	500,000 – 600,000	Page and Gill (1994), Bishop *et al*. (2000), Morrison *et al*. (2006)
C. a. hudsonia	225,000	150,000 – 300,000	Morrison *et al*. (2001, 2006)

[a] Based on extrapolations of breeding densities.

C. a. arcticola

Although Morrison *et al*. (2006) retained the current estimate of 750,000 as the population size for *C. a. arcticola*, data from recent surveys suggest this number is too high. Brown *et al*. (2007) estimated 10,506 (± 4,112 SE) Dunlin reside in the Arctic National Wildlife Refuge, which represents only a small portion of the species' range on its eastern edge. A more recent estimate by Declan Troy (in litt., cited by M. Barter, unpubl. paper) gives a figure of 640,000, while R. Gill (in litt.) suggests that between 200,000 and 300,000 are likely to exist based on data from Gill and Handel (1990). Surveys in the People's Republic of China and other East Asian countries have located only 703,000 Dunlin (Barter and Cao 2007). This estimate includes four subspecies (*C. a. actities, arcticola, kistchinski,* and *sakhalina*), further supporting the notion that the estimate of 750,000 *arcticola* Dunlin is too high.

C. a. arcticola was the only shorebird species at the Prudhoe Bay Oil Field between 1981 and 1992 that exhibited a persistent downward trend in abundance, although no significant trend in nest density was detected (Troy Ecological Research Associates 1993). Decreases in nest densities of Dunlin at Barrow since the 1970s (D. Norton, pers. comm., cited in Troy 2000) suggest a widespread decline in this subspecies. At present, nonbreeding areas for *C. a. arcticola* are only generally defined, and it is likely the subspecies mixes with other East Asian subspecies. Thus it is difficult to assess population sizes and trends from the nonbreeding range.

C. a. pacifica

The available data for this subspecies reveal variation in population trends depending on location. Data from Christmas Bird Counts (CBC) in the Lower Mainland, British Columbia, suggest a stable population over the last 25 years (1974–2000) (Shepherd 2001a). In the United

States, CBC data from Washington (Figure 1) and Oregon (Figure 2) show substantial annual variability but no obvious trend between 1979–80 and 2005–06. In California, however, there appears to be a curvilinear trend in Dunlin abundance in CBC locations since 1979–80, with a strongly downward trend since 1989–90 (Figure 3 and 4). These data are consistent with counts at Bolinas Lagoon, an estuary in California for which a 30-year data set shows a significant decline in numbers of nonbreeding Dunlin, especially since 1993 (PRBO 2007). Comprehensive data from the breeding grounds are not available for evaluating population trends. Future efforts to evaluate population trends on the breeding grounds should include a 20-year data set from the Yukon-Kuskokwim Delta that focuses on presence/absence status over an extensive system of randomized plots maintained by the Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage, Alaska.

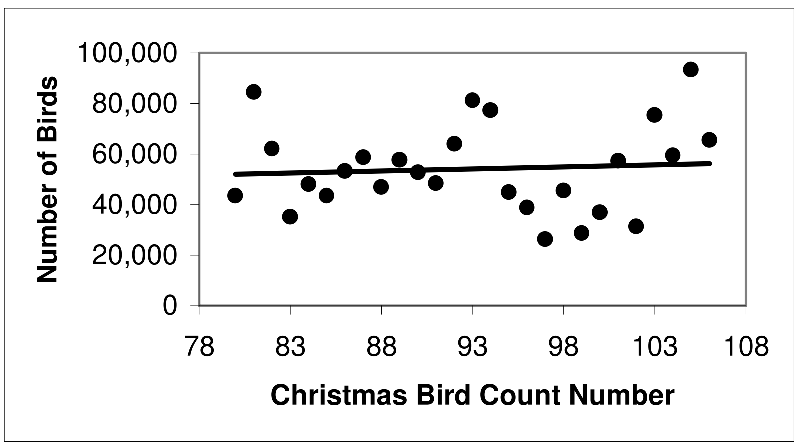

Figure 1. Trend in annual abundance of Dunlin (*C. a. pacifica*) at seven Christmas Bird Count locations in Washington (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) ($r^2 = 0.005, F = 0.135, P = 0.34$)**.** Sites included in the analysis were Bellingham Bay, Columbia River estuary, Grays Harbor, Leadbetter Point, Olympia, Padilla Bay, and Sequim-Dungeness.

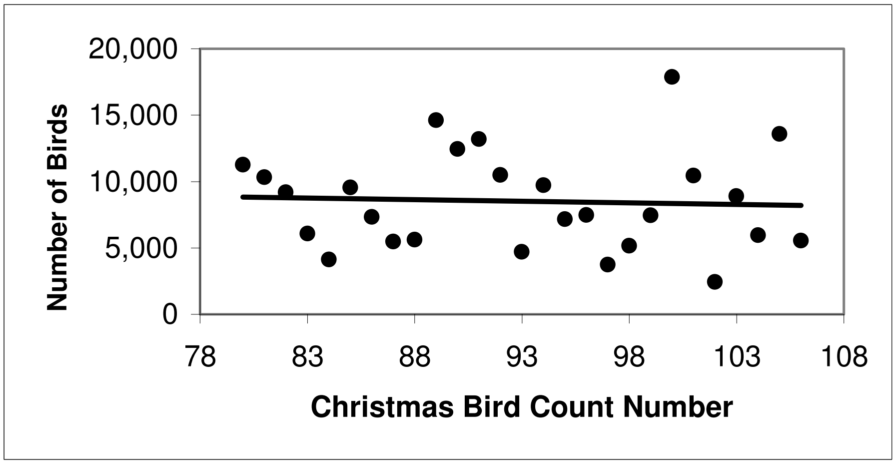

Figure 2. Trend in annual abundance of Dunlin (*C. a. pacifica*) at six Christmas Bird Count locations in Oregon (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) ($r^2 = 0.004, F = 0.087, P = 0.22$). Sites included in the analysis were Coos Bay, Corvallis, Eugene, Sauvie Island, Tillamook Bay, and Yaquina Bay.

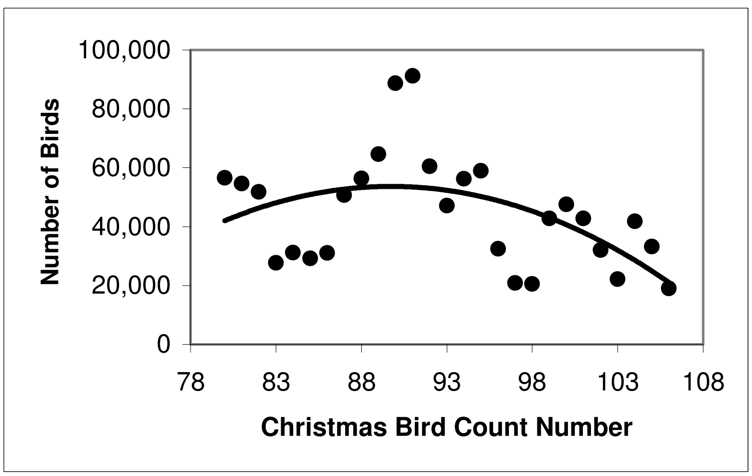

Figure 3. Trend in annual abundance of Dunlin (*C. a. pacifica*) at 30 Christmas Bird Count locations in California (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) (*polynomial model;* $r^2 = 0.245, F = 3.89, P = 0.034$). Sites included in the analysis were Bernicia, Centerville, Contra Costa, Del Norte County, Hayward-Fremont, Lancaster, Los Angeles, Los Banos, Malibu, Marin County (south), Mendocino, Morro Bay, Moss Landing, Oakland, Oceanside-Vista-Carlsbad, Orange County (coastal), Palo Alto, Palos Verdes Peninsula, Point Reyes Peninsula, Sacramento, Salton Sea (north), Salton Sea (south), San Diego, San Jose, Santa Barbara, Santa Rosa, Stockton, Thousand Oaks, Ventura, and Western Sonoma County.

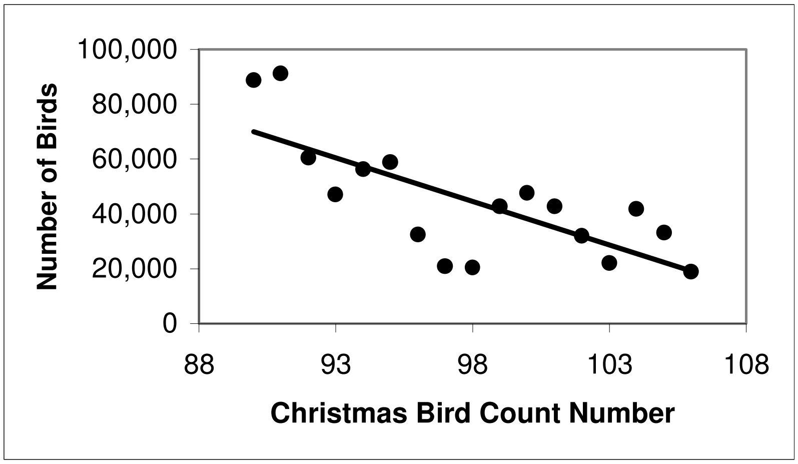

Figure 4. Trend in annual abundance of Dunlin (*C. a. pacifica*) at 30 Christmas Bird Count locations in California (USA) between 1989–90 and 2005–06 (see Appendix 1 for explanation) (r^2 = 0.55, *F*-ratio = 18.2, *P* = 0.0007). See Figure 3 for CBC locations used in the analysis.

C. a. hudsonia

Population trends of this subspecies are not clear. A qualitative assessment of shorebird populations breeding in the vicinity of Churchill, Manitoba (Canada) between the 1930s and the 1990s, indicated that Dunlin have decreased in the area (Jehl and Lin 2001). Based on the Maritimes Shorebird Survey (MSS) and the International Shorebird Survey (ISS), data from southbound migration between 1974 and 1998 indicate a non-significant downward trend for the North Atlantic Region (annual change: -2.5%), but a non-significant upward trend for the Midwest Region (annual change: +3.6%) (Bart *et al*. 2007). Although this is the only Dunlin subspecies that migrates through the interior (e.g. the Mississippi Flyway), the Atlantic Coast route is the most important flyway during migration (Warnock and Gill 1996). Based on Christmas Bird Count data from 1979–80 to 2005–06, annual population trends for each of three regions varied. Specifically, trends from New England and Mid-Atlantic States (Figure 5) and from Texas (Figure 6) suggested stable populations, whereas the trend for the southeast region indicated a slight decline followed by a slight increase (Figure 7).

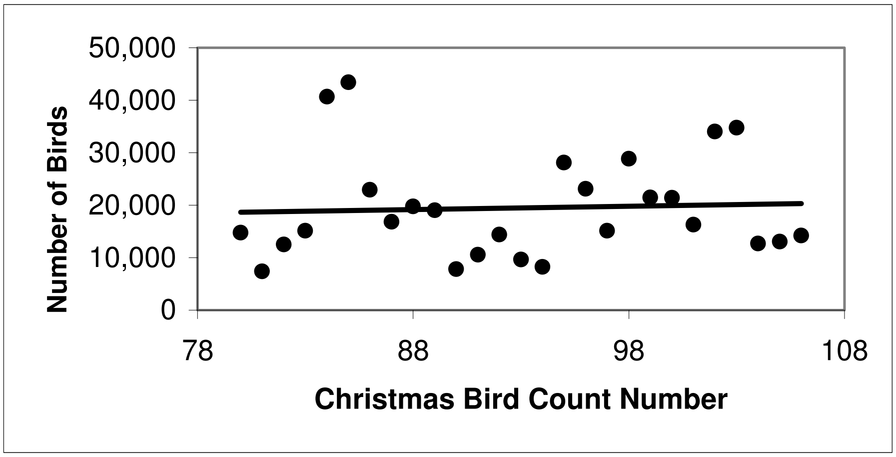

Figure 5. Trend in annual abundance of Dunlin (*C. a. hudsonia*) at 15 Christmas Bird Count locations in New England and the Mid-Atlantic States (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) ($r^2 = 0.003, F = 0.066, P = 0.56$). Sites included in the analysis were New Haven and New London (Connecticut); Bombay and Cape Henlopen (Delaware); Ocean City (Maryland); Cape Cod, Martha's Vineyard, mid-Cape Cod, New Bedford (Massachusetts); Cape May and Long Branch (New Jersey); Newport County (Rhode Island); and Back Bay, Chincoteague, and Newport News (Virginia).

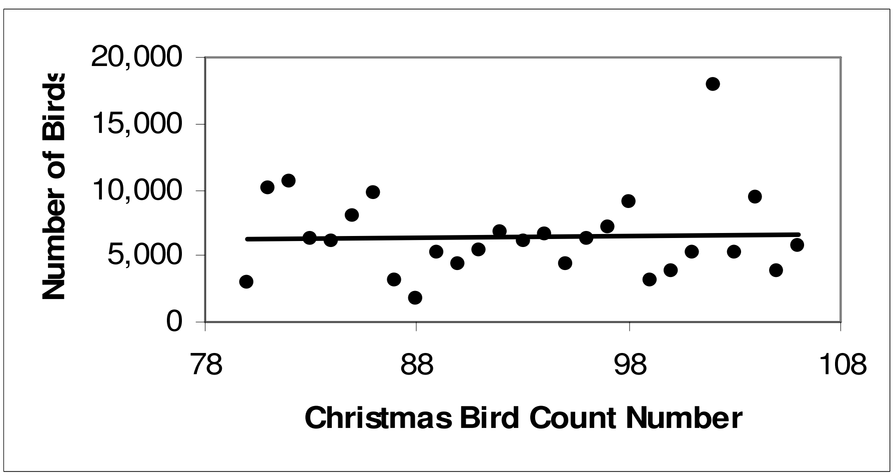

Figure 6. Trend in annual abundance of Dunlin (*C. a. hudsonia*) at 10 Christmas Bird Count locations in Texas (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) ($r^2 = 0.002, F = 0.049, P = 0.83$). Sites included in the analysis were Aransas, Bolivar Peninsula, Corpus Christi, Corpus Christi (Flour Bluff), Cypress Creek, Freeport, Galveston, Houston, Laguna Atascosa and Port Aransas.

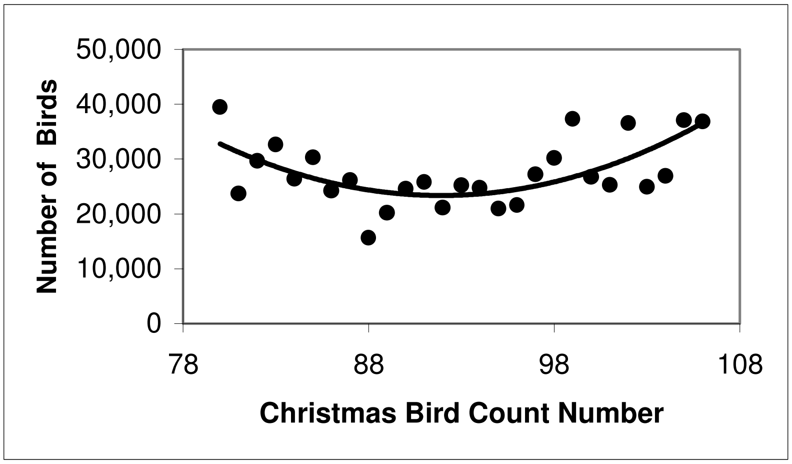

Figure 7. Trend in annual abundance of Dunlin (*C. a. hudsonia*) at 41 Christmas Bird Count locations in the Southeast region (USA) between 1979–80 and 2005–06 (see Appendix 1 for explanation) (*polynomial model;* $r^2 = 0.417$, $F = 8.57$, $P = 0.002$). Sites included in the analysis were Dauphin and Wheeler (Alabama); Bay County, Bradenton, Cedar Key, Cocoa, Coot Bay, Dade County, Ft. Myers, Jacksonville, Key Largo, Lower Keys, Merrit Island, Naples, North Pinellas, Pensacola, Port St. Joe, Sabine, Sanibel, Sarasota, St. Augustine, St. Marks, St. Petersburg, and Tampa Bay (Florida); Harris Neck and Sapelo (Georgia); Bodie, Cape Hatteras, Mattamuskeet National Wildlife Refuge, and Ocracoke (North Carolina); and Charleston, Hilton Head, and Litchfield (South Carolina).

DISTRIBUTION

Globally, the Dunlin has a vast breeding and nonbreeding distribution (Piersma 1996, Engelmoer and Roselaar 1998). It has a circumpolar breeding range, nesting in most arctic regions (absent only from high Arctic islands of Asia and North America, western Greenland, and eastern Canada). In migration, the species is associated with marine and estuarine environments and interior wetlands, and during the nonbreeding season is found in or near coastal areas throughout much of the Northern Hemisphere (Figure 8).

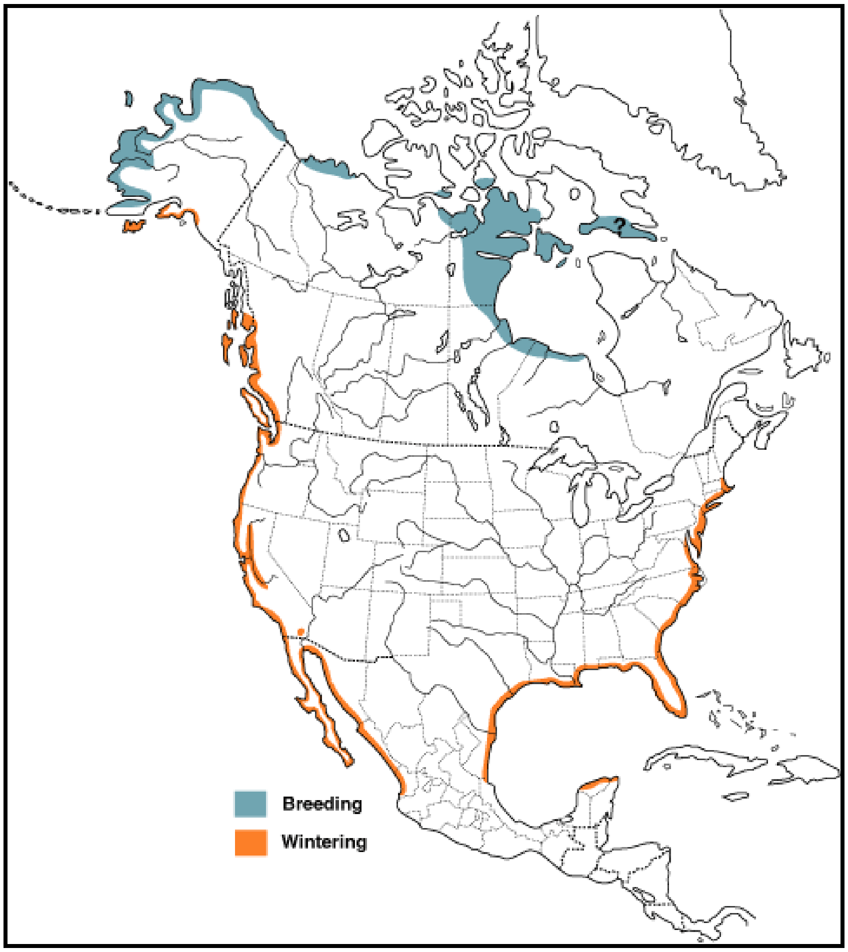

Figure 8. Breeding and nonbreeding (wintering) distribution of Dunlin in North America (Warnock and Gill 1996). Blue areas indicate known breeding locations: northern Alaska for *C. a. arcticola*, western Alaska for *C. a. pacifica*, and northern Canada for *C. a. hudsonia*. Orange areas signify nonbreeding areas: Pacific Coast for *C. a. pacifica*, and Atlantic Coast for *C. a. hudsonia*.

C. a. arcticola

This subspecies breeds in northern Alaska, north of Lisburne Peninsula east to Camden Bay, and is most common between Point Barrow and Prudhoe Bay (Johnson and Herter 1989, Warnock and Gill 1996, Johnson *et al*. 2007) (Figure 9). During intensive surveys of the North Slope of Alaska, the subspecies was entirely absent from the Brooks Range Foothills, but found on the majority of coastal plots within the National Petroleum Reserve–Alaska, and in the north-central portions of the Coastal Plain (Johnson *et al*. 2007). It is unclear whether Dunlin breeding near Cape Bathurst, Canada, represents an eastward extension of *C. a. arcticola* or a westward extension of *C. a. hudsonia* (Figure 9). After migrating to Asia, the population is thought to spend the nonbreeding season mainly along the coast from Japan south to the Republic of China

[Taiwan] (see map at http://alaska.usgs.gov/science/biology/avian_influenza/species/species.php?code=DUNL). Color-marked birds have been reported migrating between Alaska and Japan, the Republic of Korea [South Korea], the Republic of China, and the People's Republic of China (Rogers *et al*. 2006, M. Barter and R. Lanctot, unpubl. data) (Figure 9).

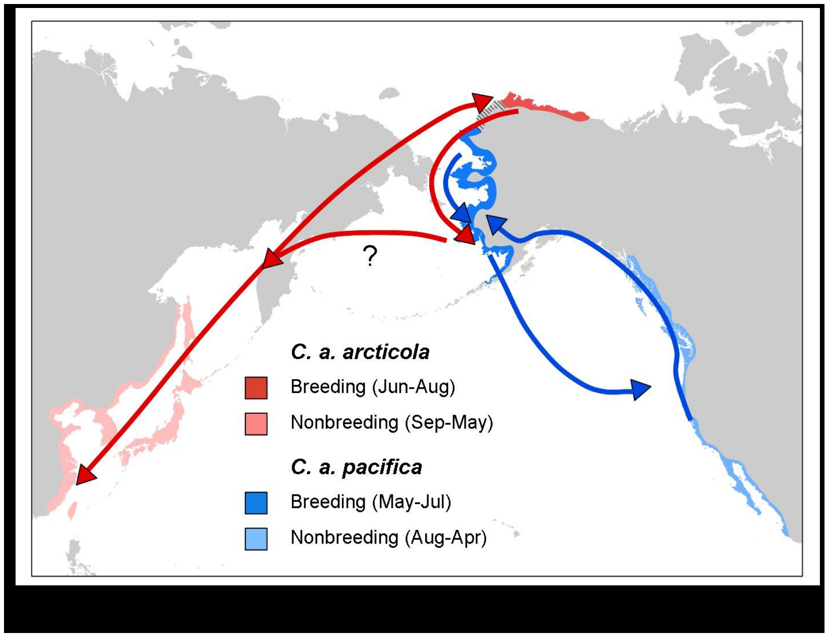

Figure 9. Seasonal occurrence and migration pathways for *C. a. arcticola* and *C. a. pacifica*. (R. Gill)

C. a. pacifica

This subspecies breeds in coastal western Alaska from the tip of the Alaska Peninsula north to at least Point Hope (Gabrielson and Lincoln 1959, Warnock and Gill 1996); it occurs extralimitally to the Cooper River Delta (Mickelson *et al*. 1981, Murphy 1981). Its primary breeding areas include Norton Sound and the Yukon-Kuskokwim Delta, and coastal meadows along the north side of the Alaska Peninsula (Gill and Jorgensen 1979, Warnock and Gill 1996, R. Gill, unpubl. data) (Figure 8). The northern extent of its breeding range is unclear, but likely occurs between Point Hope and Barrow and may overlap with *C. a. arcticola* (Figure 9).

With the exception of the Rock Sandpiper (*Calidris ptilocnemis*), *C. a. pacifica* has the northernmost nonbreeding distribution of any Calidrid on the Pacific coast of North America. Its primary nonbreeding distribution extends from southern Alaska to northwestern Mexico, including the Baja California Peninsula, and the States of Sonora, Sinaloa, and Nayarit (Warnock and Gill 1996). It occurs in coastal areas and also in agricultural areas away from the immediate coast, including the Willamette Valley in Oregon (Warnock 2003) and the Central Valley in California (Shuford *et al*. 1998) (Figure 8).

It appears that a certain amount of population segregation occurs during the nonbreeding season. Dunlin staging on the Yukon-Kuskokwim Delta in the fall are more likely to migrate to and spend the nonbreeding season in coastal British Columbia, Canada, and coastal Washington and Oregon, while Dunlin staging on the Alaska Peninsula in the fall are more likely to migrate to and spend the nonbreeding season in California (Gill 1996, Warnock and Gill 1996, R. Gill, unpubl. data) (Figure 8).

C. a. hudsonia

This subspecies breeds in northern Canada, from the Northwest Territories to the west sides of Hudson and James Bays (Godfrey 1986); there are also confirmed breeding records as far east as southwest Baffin Island (Martin *et al*. 1988) and along the eastern shore of Hudson Bay at the Ungava Peninsula, Quebec (Andres 2006). This subspecies spends the nonbreeding season commonly on the Atlantic and Gulf Coasts from Massachusetts to Mexico, with birds occasionally reported from coastal western Yucatan Peninsula (Warnock and Gill 1996). Within the nonbreeding range it appears to be most abundant on the Texas coast (Eubanks 2006), and less abundant in the Atlantic Coast states (less than 7,000 birds in Florida) (Sprandel *et al*. 2000). In Mexico, the subspecies spends the nonbreeding season south along the coast from Tamaulipas to northern Veracruz and on the northern coast of Yucatan Peninsula (Howell and Webb 1995) (Figure 8).

MIGRATION

Depending on the subspecies, Dunlin migrate variable distances from breeding to nonbreeding areas, but usually do not exceeded about 8,000 kilometers. *C. a. arcticola* likely migrates the farthest, with marked individuals known to travel a minimum of 7,300 kilometers between the North Slope of Alaska and the Republic of China. All three subspecies have similar migration timing during the northward migration, but there are differences in timing during the southward migration, with *C. a. arcticola* and *C. a. hudsonia* migrating earlier than *C. a. pacifica* (Warnock and Gill 1996). Prior to southward migration, the *C. a. pacifica* subspecies undergoes pre-basic molt while on staging areas that are usually adjacent to the breeding grounds. The duration of this molt—into September—has been cited as a reason for this taxon's unusually late departure on the southbound migration (Holmes 1971, Greenwood 1986).

C. a. arcticola

Northward migration of this subspecies is similar to the timing shown by *C. a. pacifica*. The passage of migrant Dunlin in the Republic of Korea and the People's Republic of China is from March to May, with a peak in mid-May at Saemangeum Estuary (Rogers *et al*. 2006). The peak of northward migration occurs between mid and late May (or even early June) at regions between Sakhalin and Magadan in far eastern Russia (Gerasimov and Huettmann 2006). Birds arrive on the breeding grounds between late May and early June (Warnock and Gill 1996, Barter 2002, R. Lanctot, unpubl. data). The route from nonbreeding areas to breeding areas is unknown, but presumed to be coastal over the Sea of Okhotsk and the western Bering Sea (Warnock and Gill 1996). Following nesting, birds move to coastal areas in northern Alaska between July and September, with a peak migration occurring in mid to late August (Andres 1989, Johnson and Herter 1989). After staging on the north coast of Alaska, an as yet un-quantified portion of the post-breeding populations moves south to the Yukon-Kuskokwim Delta where birds mix with *C. a. pacifica* Dunlin before they migrate to the coast of central East Asia in September or October (Gill and Handel 1981, Gill 1996, Warnock and Gill 1996). It is possible that some birds move directly to the nonbreeding grounds (Norton 1971), although this has not been confirmed. Dunlin using the East Asian-Australasian Flyway begin arriving in Japan and the Republic of Korea as early as late July (Barter *et al*. 2005), with peak arrival occurring in mid-September to late October (Brazil 2008). The early-arriving birds likely are not *C. a. arcticola* since *arcticola* seem to undergo at least a partial pre-basic molt while on or near the breeding grounds that lasts into August (R. Lanctot, unpubl. data). Much work remains to discern migration routes and timing in the East Asian-Australasian Flyway following the subspecies' departure from Alaska (Figure 9).

C. a. pacifica

Northward migration is suspected to begin in southern nonbreeding grounds in late March. The peak of migration in western North America occurs in late April and early May (Warnock and Gill 1996). Few migrants remain in coastal areas south of Alaska after mid-May

(Warnock and Gill 1996, Paulson 1993). Once the migration has begun, birds move along the Pacific coast or, in smaller numbers, through interior areas like the Central Valley in California, and Willamette Valley in Oregon (Strauch 1967, Warnock *et al*. 2004). Migrant Dunlin stop for short periods at various sites along the way as they migrate to the breeding grounds; length of stay at migratory stopover sites typically ranges between 1 and 4 days (Warnock *et al*. 2004). Depending on location, Dunlin migrating north towards Alaska from southern, coastal North American sites travel quickly, on average up to 826 ± 474 kilometers per day of active flight (Warnock *et al*. 2004).

After the breeding season, birds move from breeding grounds to coastal staging sites in western Alaska (Holmes 1971, Gill and Jorgensen 1979, Handel and Gill 1992). Southward migration begins after a complete pre-basic molt on the staging grounds that lasts into August or September with peak movements from Alaska between late September and mid-October; some juveniles occasionally remain into early November (Handel and Gill 1992, R. Gill, unpubl. data). Although a few birds arrive along the Pacific coast in later summer months, the vast majority of birds arrive there after mid to late October (Page 1974, Butler and Campbell 1987, Paulson 1993) (Figure 10). Occasional peaks in abundance in late November in Washington suggest that some movement continues at this latitude into early winter (Buchanan 1988) (Figure 9).

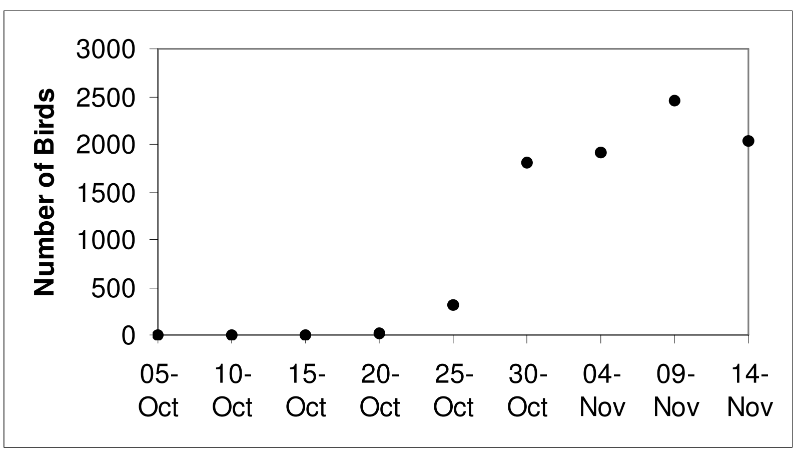

Figure 10. Median annual abundance (1999–2006) of Dunlin at Totten Inlet, Washington (USA), from early October to mid-November (J.B. Buchanan, unpubl data). Substantial numbers of birds typically arrive during the 5-day period from 28 October to 1 November. Dates shown are midpoints in each 5-day interval.

C. a. hudsonia

The northward migration of *C. a. hudsonia* involves two flyways, one along the Atlantic Coast and the other through the Great Plains (Warnock and Gill 1996, Skagen *et al*. 1999). This is the only subspecies of Dunlin that crosses the interior plains of North America, especially during the northward migration (Warnock and Gill 1996, Skagen *et al*. 1999). In the interior, northward migration is from March to May (Skagen *et al*. 1999). The limited numbers recorded in the mid-continent (Jorgensen 2004), except the Dakotas, suggest that birds migrating through the interior may fly directly from Gulf Coast nonbreeding sites to the Prairie Potholes, peaking in mid-May, before their final flight to the breeding grounds (Warnock and Gill 1996, Skagen *et al*. 1999). However, in the coast of Texas, Dunlin use inland sites more frequently during the southward migration versus northward migration (Lockwood and Freeman 2004). The timing of northward migration is similar in the Gulf and Atlantic coastal regions. Southward migration is later than for some other Calidrid species, but is earlier than for *C. a. pacifica*. The migration period extends from late August to November in both interior and coastal areas, with a peak passage in October (Warnock and Gill 1996, Skagen *et al*. 1999).

MAJOR HABITATS

Breeding

Dunlin use a wide variety of breeding habitats found in northern sub-arctic and some arctic areas. On the North Slope of Alaska, *C. a. arcticola* breed in moist-wet tundra, often in areas with ponds, polygons, and strangmoor landforms (Warnock and Gill 1996). Birds of this subspecies are more common in coastal tundra than interior tundra (Johnson and Herter 1989). *C. a. pacifica* on the Yukon-Kuskokwim Delta, Alaska, breed in coastal sedge graminoid meadows with numerous shallow ponds and tidal distributaries (Holmes 1970, Warnock and Gill 1996). On the Seward Peninsula, Alaska, *C. a. pacifica* are found breeding in highest densities where wet meadow habitat is mixed with drier sites of dwarf shrub meadow (Kessel 1989). *C. a. hudsonia* in northern Ontario breeds in wet tussock and peat-hummock tundra (Cadman *et al*. 1987), whereas in Manitoba they breed in wet tundra and wet sedge marshes (Jehl and Smith 1970).

Migration

All three subspecies use similar habitats during migration. Dunlin are common on mostly soft substrate littoral flats (mud, sand, consolidated material), but they also use, to a lesser extent, a wide variety of brackish and freshwater wetlands, both vegetated and unvegetated and both coastal and inland. They also use a variety of shallow, open-water habitats including flooded fields, sewage lagoons, and salt-works (Warnock and Gill 1996).

Nonbreeding

For all subspecies, habitat preferences during nonbreeding are similar to those during migration.

In the People's Republic of China, *C. a. arcticola* and other subspecies of Dunlin that breed in Asia are encountered in a wide variety of inland habitats including shallow water, muddy water edges, dry mud, and wet, lightly vegetated areas. Along the coast, Dunlin use intertidal areas both near and distant from the tide edge. Dunlin also feed in fish ponds and salt pans located inside of containment walls when high tides limit intertidal habitat (Barter and Cao 2007, R. Lanctot pers. obs.).

C. a. pacifica are able to forage in different microhabitats (Colwell 1993), and move among a variety of available habitats (Warnock *et al*. 1995, Shepherd and Lank 2004). During the nonbreeding season, Dunlin in some regions move between coastal and interior areas (Page 1974, Warnock *et al*. 1995, Shepherd and Lank 2004). Some Dunlin spend part or all of the season inland in freshwater wetlands and agricultural habitats (Shuford *et al*. 1998, Sanzenbacher and Haig 2002). This subspecies exhibits differential distribution patterns in which sex and age classes are spatially segregated, either latitudinally (Buchanan *et al*. 1986, Shepherd *et al*. 2001), or among habitats on a local scale (Ruiz *et al*. 1989, Warnock 1994, Shepherd and Lank 2004), or within feeding/roosting flocks (Kus 1985, Ruiz *et al*. 1989). *C. a. pacifica* males are more likely than females to make one-way movement from coastal estuaries to agricultural and wetland habitats up to 150 kilometers inland; these movements appear to be stimulated by rainfall and other weather variables (Warnock *et al*. 1995, Kelly *et al*. 2002). In the Fraser River Delta, British Columbia, this subspecies showed a significant preference for tidally influenced marine habitats, but most individuals (> 80%) also used terrestrial habitats, usually during high tide and primarily at night (Shepherd and Lank 2004). Based on stable isotope analysis, the agricultural habitat contributed approximately 38% of *C. a. pacifica* diet, and younger birds had a significantly higher terrestrial contribution to their diet (43%) than did adults (35%) (Evans Ogden *et al*. 2005). Dunlin regularly use agricultural areas near estuaries for diurnal and nocturnal roosting and foraging in Washington (Buchanan 2000). At Humboldt Bay, California, Dunlin make extensive use of upland pastures, especially for nocturnal roosting, from November to March (Conklin and Colwell 2007). Furthermore, Dunlin at the Willamette Valley, Oregon, exhibit a high degree of regional fidelity during the nonbreeding period (December–February). Individuals use extensive areas (seasonal home range is 258 ± 45 km^2), as well as numerous sites within the region, apparently to exploit the distribution and variability of local resources (Sanzenbacher and Haig 2002).

C. a. hudsonia is common on coastal estuaries, bays, interior seasonal wetlands, flooded fields and other agricultural lands, especially rice fields (Warnock and Gill 1996). In the coast of Texas, Dunlin make extensive use of managed and/or inland wetlands and agricultural fields (B. Ortego, pers. comm.).

CONSERVATION STATUS

The Canadian Shorebird Conservation Plan considers the Dunlin a Species of Moderate Concern (Donaldson *et al*. 2000). Brown *et al*. (2001) lists *C. a. arcticola* as highly imperiled, *C. a. pacifica* as high concern, and *C. a. hudsonia* as moderate concern. The U.S. Shorebird Conservation Plan (2004), based on the population trend and potential threats, lists the Dunlin as a Species of High Conservation Concern for *C. a. arcticola* and *C. a. pacifica*, and as a Species of Moderate Conservation Concern for *C. a. hudsonia*. The U.S. Fish and Wildlife Service includes *C. a. arcticola* as a Bird of Conservation Concern (U. S. Fish and Wildlife Service 2008). The American Bird Conservancy's Green List (2007) includes the Dunlin as a Moderately Abundant Species with Declines or High Threats. The IUCN Red List considers the Dunlin a Species of Least Concern (BirdLife International 2007), and NatureServe lists it as Globally Secure (NatureServe 2006). The Dunlin is not included in the Audubon WatchList 2002 or by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

POPULATION GOAL

Given the low confidence level in population estimates for the three North American subspecies (Brown *et al*. 2001), establishing a population goal will be deferred according to the following general schedule for each subspecies:

C. a. arcticola: Investigate status of subspecies, determine causes and extent of presumed decline, halt regional or rangewide declines, and then evaluate and establish population goals based on estimates of carrying capacity with and without habitat restoration efforts.

C. a. pacifica: Investigate status of subspecies, in particular to determine whether the apparent decline in abundance is limited to the population that spends the nonbreeding season south of Oregon; determine causes and extent of decline, if one is occurring; halt the decline, and then evaluate and establish population goals based on estimates of carrying capacity with and without habitat restoration efforts.

C. a. hudsonia: Investigate status of the subspecies to determine whether a population decline is occurring; determine causes and extent of decline, if one is occurring; then evaluate and establish population goals based on estimates of carrying capacity with and without habitat restoration efforts.

CONSERVATION SITES

BREEDING RANGE

It is difficult to identify particular sites on the breeding grounds because the density of birds is very low and spread out over a very large area. Thus the locations mentioned for each subspecies refer to general areas that can be quite large.

C. a. arcticola

This subspecies breeds primarily on the North Slope of Alaska between Cape Lisburne and Camden Bay (Johnson *et al*. 2007) (Figure 11). The highest concentrations occur in the National Petroleum Reserve–Alaska (particularly near Barrow and the Ikpikpuk River), Kuparuk and Prudhoe Bay Oil Fields, and areas east to the Canning River and Camden Bay in the Arctic

National Wildlife Refuge (Johnson *et al*. 2007). It is unclear whether populations breeding near Cape Bathurst in Northwest Territories belong to this subspecies.

C. a. pacifica

The core breeding area for this subspecies is the central Yukon-Kuskokwim Delta of western Alaska, but major breeding populations also occur at several sites on the Alaska Peninsula (R. Gill, unpubl. data, S. Savage, unpubl. data), in eastern Norton Sound, on the northern Seward Peninsula and eastern Kotzebue Sound (Kessel 1989, Warnock and Gill 1996).

C. a. hudsonia

The core breeding area for this subspecies in Canada appears to be centered in the lowlands of Nunavut Territory, especially in the Rasmussen Lowlands where more than 6,000 Dunlin are estimated to breed (Johnston *et al*. 2000). Other birds breed west to Southampton Island, along the shore of Hudson Bay in Manitoba and Ontario (Jehl and Smith 1970, Cadman *et al*. 1987), up to the Ungava Peninsula, Quebec (Andres 2006).

MIGRATION AND NONBREEDING RANGE

We identified important migration and nonbreeding areas that support at least 1% of the global population for each of the three subspecies of Dunlin (Tables 2–4). With the current population estimates being 750,000 for *C. a. arcticola*, 550,000 for *C. a. pacifica*, and 225,000 for *C. a. hudsonia* (Page and Gill 1994, Warnock and Gill 1996, Bishop *et al*. 2000, Morrison *et al*. 2001, 2006), we included all sites where high counts for any one season have been approximately 7,500 for *C. a. arcticola*, 5,500 for *C. a. pacifica*, and 2,250 for *C. a. hudsonia*.

It was fairly straightforward to define important sites that are comprised of a discrete wetland, bay, or intertidal flat where the 1% criterion occurs during a given season. In other cases, however, the process was more complicated. Factors that made it difficult to identify important nonbreeding sites included incompletely surveyed coastal and interior areas, and the unknown extent of movement by nonbreeding flocks. This includes movements among sites (and between roosting and foraging sites) that are affected at different times by the tide and by changing conditions as the nonbreeding season progresses. In addition, complexes of distinct sites in relatively close proximity to one another (such as at Cook Inlet in Alaska; the Greater

Puget Sound area in Washington; and Ojo de Liebre–Guerrero Negro in Mexico) collectively support large numbers of migrant or nonbreeding Dunlin. Although numerous individual sites in these complexes support only a few thousand birds each, the array of these "lesser" sites support many thousands of birds (Evenson and Buchanan 1997, Page *et al*. 1997).

Finally, our use of the 1% criterion generally required that we use single-day, high-count data from migration periods. Consequently, given the occurrence of turnover during migration, our migration count data are underestimates of abundance at the sites; other sites that may have met the 1% criterion, if turnover were taken into account, were not included in our tables.

C. a. arcticola

Twenty-two sites were identified as supporting at least 7,000 Dunlin (Table 2). Based on high counts, the Yukon-Kuskokwim Delta, Shishmaref Inlet, and Kasegaluk Lagoon (Alaska, USA), Yancheng National Nature Reserve and Yalu Jiang National Nature Reserve (People's Republic of China), and Saemangeum Estuary, Mangyeung Gang Hagu, and Tongjin Gang Hagu (Republic of Korea) are critical sites for *C. a. arcticola*. Numerous sites in Alaska, Republic of Korea, Republic of China, People's Republic of China, and Japan support between two and four Dunlin subspecies, making it difficult to understand the value of any particular site to a given subspecies during migration and nonbreeding (Table 2 and Figure 11). Given this uncertainty, it is noteworthy that several additional sites in the East Asian-Australasian Flyway have the potential to be important to *C. a. arcticola*. For example, over 500,000 shorebirds, including Dunlin, are known to use the Penzhina River mouth at the base of the Kamchatka Peninsula, and northwest Penzhina Bay supports over 100,000 shorebirds (Gerasimov and Huettmann 2006). Similarly, thousands of shorebirds use a number of sites around the Sea of Okhotsk (between Sakhalin Island, Kamchatka and Magadan in far eastern Russia), including Aniva Bay, Bolshoe Bay, Rekkiniky Bay and Tugursky Bay (Gerasimov and Huettmann 2006).

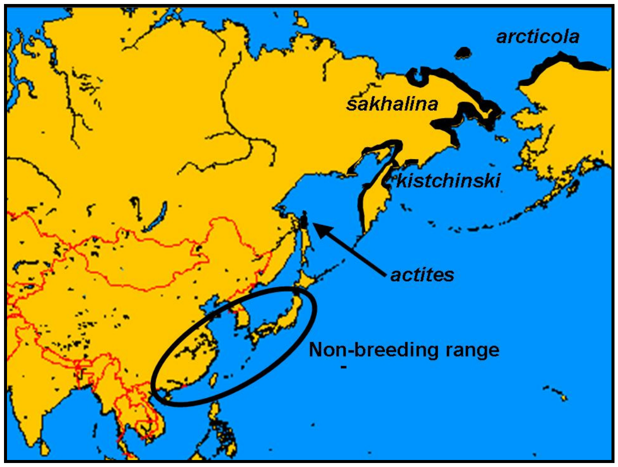

Figure 11. Breeding ranges of the four Dunlin subspecies (*C. a. arcticola*, *sakhalina*, *kistchinski* and *actites*) in the East Asian-Australasian Flyway and their combined core nonbreeding range.

Sixteen sites (73%) supported at least 7,000 Dunlin during the southward migration. The greatest numbers of birds were reported from the Yukon-Kuskokwim Delta, Shishmaref Inlet, and Kasegaluk Lagoon in Alaska (Table 2), however the proportion of *C. a. arcticola* present among *C. a. pacifica* on the Yukon-Kuskokwim Delta is as yet unknown.

Ten sites (45%) met our threshold criteria during the northward migration and the most important sites included the Yancheng National Nature Reserve and the Yalu Jiang National Nature Reserve in the People's Republic of China, and Saemangeum Estuary, Mangyeung Gang Hagu, and Tongjin Gang Hagu in Republic of Korea (Table 2).

Recent surveys of Dunlin (including *C. a. arcticola, sakhalina, kistchinski,* and *actites* subspecies) during the nonbreeding season in the People's Republic of China indicate a wide-spread coastal distribution (Barter and Cao 2007) (Figure 12). Dunlin are particularly prevalent in Jiangsu, Zhejiang, and Fujian Provinces, and through the wetlands of the middle reaches of the Yangtze River. Although the Yellow River floodplain has not been surveyed, this region is unlikely to have many Dunlin due to lack of suitable habitat and colder winters. In contrast, Guangdong Province is likely to have large numbers (Barter and Cao 2007).

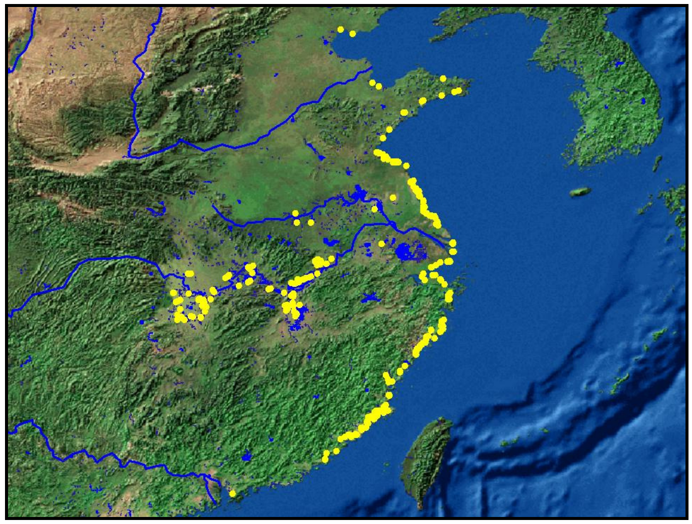

Figure 12. Sites at which nonbreeding Dunlin (including *C. a. arcticola, sakhalina, kistchinski,* and *actites* subspecies) have been recorded during surveys conducted between 2003 and 2007 in the People's Republic of China (from Barter and Cao 2007).

When individual site count data are combined to estimate the total number of Dunlin for larger wetland areas, a few sites appear to be more important (Figure 13). The largest regional concentrations occurred in northern and central Jiangsu, central Fujian, and at a number of wetlands in the Yangtze floodplain. In addition, over 20,000 Dunlin were reported along the south and west coasts of Republic of Korea (Moores 1999, 2006).

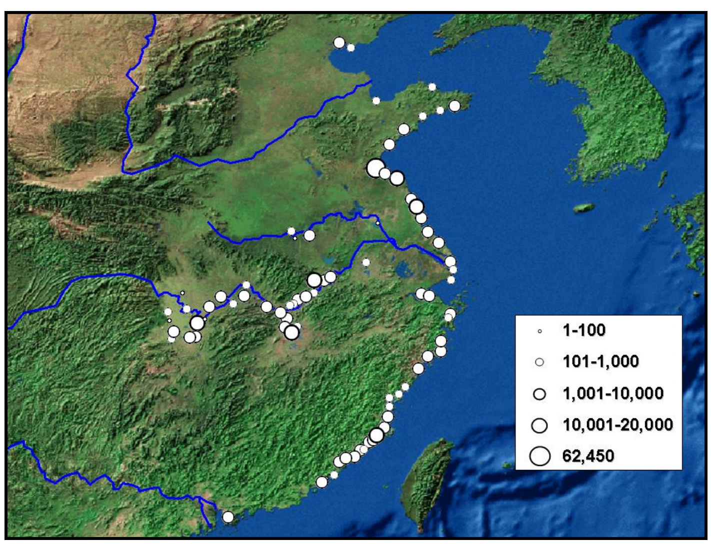

Figure 13. Abundance estimates at sites where nonbreeding Dunlin (including *C. a. arcticola, sakhalina, kistchinski,* and *actites* subspecies) were recorded during surveys conducted between 2003 and 2007 in the People's Republic of China (from Barter and Cao 2007).

Table 2. List of important sites (or complexes of sites) used by ***Calidris alpina arcticola*** during the Southward Migration (SM), Nonbreeding (NB), and Northward Migration (NM). Site designation criteria: IBA = Important Bird Area; EA-ASNW = East Asian-Australasian Shorebird Network Site, NNA = National Nature Reserve; RAMSAR = Ramsar site; WHSRN = Western Hemisphere Shorebird Reserve Network. Only sites with >7,000 birds included.

Site	Province– State	Country	SM	NB	NM	Site Designation	Source
Colville River Delta	Alaska	U.S.	21,733				Andres 1989, 1994
Pogik Bay	Alaska	U.S.	15,488				A. Taylor, unpubl. data
Ikpikpik Delta/Smith Bay	Alaska	U.S.	29,920				A. Taylor, unpubl. data
E. Dease Inlet and C. Simpson	Alaska	U.S.	13,270				A. Taylor, unpubl. data
W. Kasegaluk Lagoon			40,762				A. Taylor, unpubl. data
Noatak River Delta[1]	Alaska	U.S.	>30,000				Connors and Risebrough 1978
Cape Espenberg[1]	Alaska	U.S.	9,707				Schamel *et al*. 1979
Shishmaref Inlet[1]	Alaska	U.S.	>75,000				Connors and Connors 1985.
Yukon River Delta[1]	Alaska	U.S.	>200,000			WHSRN	Jones and Kirchoff 1977, 1978
Central Yukon-Kuskokwim Delta[1]	Alaska	U.S.	264,229			WHSRN	Gill and Handel 1990
Kamchatka[2]		Russia			32,330		Gerasimov and Huettmann 2006
Moroshechnaya Estuary[3]	Kamchatka	Russia	9,161		18,500		Schuckard *et al*. 2006
Yancheng National Nature Reserve[4]	Jiangsu	People's Republic of China	18,559		57,867	RAMSAR, NNR	Wang 1997, Barter 2002
Dong Sha[4]	Jiangsu	People's Republic of China	13,081				Wang and Barter 1998
Yalu Jiang National Nature Reserve[4]	Liaoning	People's Republic of China			43,875	EA-ASNW, NNR	Riegen *et al*. 2006, Barter *et al*. 2000a, Barter 2002
Shuangtaizihekou	Liaoning	People's			16,411	EA-ASNW, NNR	Barter *et al*. 2000b, Barter

National Nature Reserve[4]		Republic of China					2002
Huang He National Nature Reserve[4]	Shandong	People's Republic of China			24,106	NNR	Zhu *et al*. 2000, Barter 2002
Mangyeung Gang Hagu[4]	Chollabuk	Republic of Korea	22,000		47,650		Yi and Kim, unpubl. data
Tongjin Gang Hagu[4]	Chollabuk	Republic of Korea	22,004		38,850	EA-ASNW	Yi and Kim, unpubl. data
Saemangeum Estuary[4]		Republic of Korea	41,300		62,508		Moores 2006
Geum Estuary[4]		Republic of Korea			21,829		Moores 2006
Namyang Man[4]	Kyonggi	Republic of Korea			15,200		Yi and Kim, unpubl. data
Ganghwa Do[4]	Kyonggi	Republic of Korea			17,000		Yi and Kim, unpubl. data
Asa Man[4]	Chunchongman	Republic of Korea			14,000		Yi and Kim, unpubl. data
Yeong Jong Do[4]	Inchon	Republic of Korea	12,110		13,208		Yi and Kim, unpubl. data
Fujimae Higata[4]	Honshu	Japan	1,148	1,085	2,669		Shorebird Census of Japan, WWF Japan, unpubl.
Daijugarami[4]	Kyushu	Japan	4,700	3,360	5,400		Shorebird Census of Japan
Shira-kawa Kakou[4]	Kyushu	Japan	4,489	4,157	1,420		Shorebird Census of Japan
Yatsu Higata[4]	Honshu	Japan	741	310	1,788		Shorebird Census of Japan
Sanbanze[4]	Honshu	Japan	2,100	1,600	2,038		Shorebird Census of Japan

[1] These sites contain an undetermined number of *C. a. arcticola* and *C. a. pacifica* during southward migration.
[2] Total estimated use: 250,000 (northbound). The abundance of *C. a. arcticola* in the region has not been determined.
[3] Total estimated use: 150,000 (northbound); 350,000 (southbound). The abundance of *C. a. arcticola* at the site has not been determined.
[4] Totals for the site include individuals of up to four subspecies of *C. alpina*. The abundance of *C. a. arcticola* at the site has not been determined.

C. a. pacifica

Forty-two sites were identified as supporting at least 5,000 Dunlin and appear to support a large proportion of the *C. a. pacifica* population (Table 3). Based on high counts, some of the most important sites [per state] included: the Copper River Delta, Yukon-Kuskokwim Delta, Nelson Lagoon-Mud Bay, Yakutat Foreland, Egegik Bay, and Cook Inlet (Alaska, USA); Grays Harbor, Puget Sound, and Willapa Bay (Washington, USA); Columbia River Estuary and Willamette Bay (Oregon, USA); San Francisco Bay, the Central Valley, the Sacramento Valley, and Humboldt Bay (California, USA). Other important sites include Mud Bay and the Fraser River Delta (British Columbia, Canada), and Laguna Ojo de Liebre–Guerro Negro (Baja California Sur, Mexico).

Numerous sites in Alaska support two Dunlin subspecies, making it difficult to understand the value of any particular site to a given subspecies during migration (Table 3 and Figure 11). Only twelve sites (29%) were used by Dunlin in more than one season. The annual cycle activities and inter-seasonal differences in migration strategies of *C. a. pacific* are clearly reflected in their geographic and seasonal patterns of site use.

During the southward migration, 21 sites (50%) met our threshold of at least 5,000 Dunlin (Table 3). Birds stage at several key estuaries in western and southwest Alaska prior to a trans-Pacific flight to the nonbreeding grounds that bypasses the Copper River Delta and other more northern estuaries along the Pacific Coast. The sites supporting the greatest numbers of southward Dunlin included the Central Yukon-Kuskokwim Delta and Yukon River Delta, Nelson Lagoon-Mud Bay, and Egegik Bay (all in Alaska). Other important sites [per state] include Willapa Bay, Grays Harbor, and associated beaches in Washington, and the Central Valley in California.

Twenty-two sites (52%) were identified as meeting the threshold during the nonbreeding season (Table 3), when Dunlin rely on several, key coastal and inland sites. The most important sites are the Central Valley and San Francisco Bay in California, and Grays Harbor in Washington. Other important sites [per state] include: the Fraser River Estuary and Mud Bay in British Columbia; Puget Sound and Willapa Bay in Washington; Willamette Valley, Columbia River Estuary, and Coos Bay in Oregon; and the Sacramento Valley in California. Only one site in Mexico was identified as supporting substantial numbers of Dunlin during the nonbreeding season: Laguna Ojo de Liebre–Guerrero Negro.

During the northward migration, 17 sites (40%) were identified as supporting at least 5,000 Dunlin (Table 3). Northward migration is largely coastal; different cohorts of birds use a few to several estuaries as they move north, with migration culminating for most with a stopover at Alaska's Copper River Delta. Other important sites [per state] include: Yakutat Foreland and Cook Inlet in Alaska; Grays Harbor, Puget Sound, and Willapa Bay in Washington; the Columbia River Estuary in Oregon; San Francisco Bay, the Central Valley, and Humboldt Bay in California; the Lahontan Valley in Nevada; and Laguna Ojo de Liebre–Guerrero Negro in Baja California, Mexico.

Table 3. List of important sites (or complexes of sites) used by ***Calidris alpina pacifica*** during the Southward Migration (SM), Nonbreeding (NB), and Northward Migration (NM). Site designation criteria: BIRE = Biosphere Reserve; IBA = Important Bird Area; NP = National Park, NWR = National Wildlife Refuge; PA = Protected Area; RAMSAR = Ramsar site; SWA = State Wildlife Area; WHSRN = Western Hemisphere Shorebird Reserve Network, WMA = Wildlife Management Area. Counts represent high counts unless otherwise indicated. Only sites with >5,000 birds included.

Site	Province– State	Country	SM	NB	NM	Site Designation	Source
Noatak River Delta[1]	Alaska	U.S.	>30,000				Connors and Risebrough 1978
Cape Espenberg[1]	Alaska	U.S.	9,707				Schamel *et al*. 1979
Shishmaref Inlet[1]	Alaska	U.S.	>75,000				Connors and Connors 1985
Yukon River Delta[1]	Alaska	U.S.	>200,000			WHSRN	Jones and Kirchoff 1977, 1978
Central Yukon-Kuskokwim Delta[1]	Alaska	U.S.	264,229			WHSRN	Gill and Handel 1990
Kuskokwim River Delta[1]	Alaska	U.S.	99,315			NWR	R. Gill *et al*., unpubl. data
Nushagak Bay	Alaska	U.S.	21,872			WHSRN	R. Gill *et al*., unpubl. data
Kvichak Bay	Alaska	U.S.	41,187			WHSRN	R. Gill *et al*., unpubl. data
Egegik Bay	Alaska	U.S.	106,800			SWA	R. Gill *et al*., unpubl. data
Ugashik Bay	Alaska	U.S.	55,000			SWA	R. Gill *et al*., unpubl. data
Cinder-Hook Lagoon	Alaska	U.S.	69,900			SWA	R. Gill *et al*., unpubl. data
Port Heiden	Alaska	U.S.	93,400		47,000	SWA	R. Gill *et al*., unpubl. data
Seal Islands	Alaska	U.S.	25,165			SWA	R. Gill *et al*., unpubl. data
Nelson Lagoon-Mud Bay	Alaska	U.S.	184,000			SWA (in part)	Gill and Jorgenson 1979, Gill *et al*. 1981
Izembek-Moffet Lagoon	Alaska	U.S.	28,000			NWR, RAMSAR	Tibbitts *et al*. 1996
Cook Inlet (Tuxedni Bay)	Alaska	U.S.			8,860	NP (in part)	Bennett 1996, R. Gill *et al*., unpubl. data
Cook Inlet (Redoubt Bay)	Alaska	U.S.			83,000 Note: value = mid of 2-r census	SWA	Gill and Tibbitts 1999

Kachemak Bay	Alaska	U.S.			5,100	WHSRN, SWA	West 1994
Copper River Delta	Alaska	U.S.			493,994[2]	WHSRN	Bishop *et al*. 2000
Yakutat Foreland	Alaska	U.S.			137,000		Andres and Browne 1998
Fraser River Delta	British Columbia	Canada		40,000		WHSRN, IBA	Shepherd 2001b
Mud Bay	British Columbia	Canada		60,000			Paulson 1993
Grays Harbor	Washington	U.S.	10,000[3]	100,000	95,400	WHSRN, IBA, NWR (part)	Brennan *et al*. 1985, Paulson 1993, Buchanan 2005, PRBO, unpubl. data
Willapa Bay	Washington	U.S.	37,750	69,850	41,640	IBA, NWR (part)	Buchanan and Evenson 1997, PRBO, unpubl. data
Puget Sound[4]	Washington	U.S.	-[5]	78,792	67,770	SWA, PA, NWR, IBA (part)	Evenson and Buchanan 1997, PRBO, unpubl. data
Grayland Beach	Washington	U.S.	10,194	10,540	-[6]		Buchanan 1992, J. Buchanan, unpubl. data
North Beach (Longbeach Peninsula)	Washington	U.S.	76,486	33,424	-[6]	NWR, IBA (part)	Buchanan 1992, J. Buchanan, unpubl. data
Ocean Shores Beach	Washington	U.S.	22,000	10,515	-[6]		Paulson 1993, Buchanan 1992, J. Buchanan, unpubl. data
Columbia River Estuary	Oregon	U.S.		20,483	88,513	NWR (part)	Contreras 1995, Warnock 2003, PRBO, unpubl. data
Coos Bay	Oregon	U.S.		11,000			Paulson 1993
Tillamook Bay	Oregon	U.S.		7,600			Paulson 1993
Willamette Valley	Oregon	U.S.		>30,000			Sanzenbacher and Haig 2002
Humboldt Bay	California	U.S.		35,694[7]	50,891	WHSRN, IBA	Colwell 1994
Bodega Harbor	California.	U.S.		7,046[7]			PRBO, unpubl. data
Tomales Bay	California	U.S.		10,815[7]			PRBO, unpubl. data
Point Reyes Esteros	California	U.S.		8,399[7]			PRBO, unpubl. data
Bolinas Lagoon	California	U.S.		5,052[7]			PRBO, unpubl. data
San Francisco Bay	California	U.S.		124,624[7]	139,713	WHSRN, IBA	PRBO, unpubl. data, Stenzel and Page 1988
Elkhorn Slough	California	U.S.		6,146[7]		WHSRN, IBA	PRBO, unpubl. data

Central Valley	California	U.S.	58,231[7]	134,942	72,786		Shuford *et al*. 1998
Sacramento Valley[8]	California	U.S.		78,215		WHSRN	PRBO, unpubl. data
South Grasslands[8]	California	U.S.			16,422	WHSRN	PRBO, unpubl. data
North Grasslands[8]	California	U.S.			9,766	WHSRN	PRBO, unpubl. data
Lahontan Valley	Nevada	U.S.			11,136	WHSRN, IBA, WMA	Chisholm and Neel 2002, PRBO, unpubl. data
Laguna Ojo de Liebre–Guerrero Negro	Baja California	Mexico		34,304	13,000	WHSRN, RAMSAR, IBA, BIRE	Page *et al*. 1997, Danemann *et al*. 2002

[1] These sites contain an undetermined number of *C. a. arcticola* and *C. a. pacifica* during southward migration.
[2] Mean of four counts from 1992–1995.
[3] Count from only one part of the estuary (Brennan *et al*. 1985).
[4] The following individual sites in the Greater Puget Sound area have supported ≥5500 Dunlin in one or more season: Bellingham Bay, Drayton Harbor, Lummi Bay, Padilla Bay, Port Susan Bay, Samish Bay, Skagit Bay, and Totten Inlet (Buchanan 1988, Evenson and Buchanan 1997, Buchanan 2005).
[5] Systematic autumn count data are lacking, but estimates of 10,000 – 50,000 birds are reported in most years at individual sites in the Greater Puget Sound region (J. Buchanan, unpublished data).
[6] Systematic northbound count data are lacking, but it is almost certain that totals in this season are comparable to nonbreeding totals at this site.
[7] November count, some birds likely migrants.
[8] Area included in Central Valley totals.

C. a. hudsonia

Thirty-five sites were identified as supporting at least 2,000 Dunlin (Table 4). Based on high counts, the binational Laguna Madre (USA-Mexico), Minnewaukan Flats–Devil's Lake (North Dakota, USA), Ottawa National Wildlife Refuge (Ohio, USA), Edwin B. Forsythe National Wildlife Refuge (New Jersey, USA), Shiawassee National Wildlife Refuge (Michigan, USA), and Chincoteague National Wildlife Refuge (Virginia, USA) appear to be critical sites for *C. a. hudsonia*.

Eleven U.S. sites (32%) met the threshold during the southward migration. The sites supporting the greatest numbers of Dunlin included the Edwin B. Forsythe National Wildlife Refuge (New Jersey), Chincoteague National Wildlife Refuge (Virginia), and Duxbury Beach (Massachusetts) (Table 4).

Only three sites (9%) were identified during the nonbreeding season as meeting the threshold requirement, with the most important site being the Laguna Madre (Texas, USA; Tamaulipas, Mexico). The other two are Shoalwater Bay and Colorado River Delta (Texas) (Table 4). However, various wetlands in Mexico and the southern United States support substantial numbers of Dunlin during the nonbreeding season, but comprehensive count data are lacking (or have not been published) for these regions. The database we developed to evaluate Christmas Bird Count results included many U.S. locations between New England and coastal Texas with observer coverage between 1979–80 and 2006–07. Although we were unable to associate Dunlin totals with specific sites within the count circles, we noted 33 Christmas Bird Count locations with at least one count of at least 2,000 Dunlin. Three Christmas Bird Count locations had counts exceeding 10,000 (13,604 at Bombay Hook, Delaware; 34,400 at Cape May, New Jersey; and 11,165 at Chincoteague, Virginia). Seven additional locations had counts exceeding 5,000 Dunlin (Cedar Keys, Coot Bay, and Tampa, Florida; Sabine, Louisiana; Cape Cod, Massachusetts; Hilton Head, South Carolina; and Freeport, Texas).

Twenty-one U.S. sites (62%) were identified as supporting at least 2,000 Dunlin during the northward migration (Table 4). The most important sites included the Minnewaukan Flats–Devil's Lake (North Dakota); Ottawa National Wildlife Refuge (Ohio); Shiawassee National Wildlife Refuge (Michigan); Bombay Hook National Wildlife Refuge (Delaware); and Grand Terre, Jefferson Parish (Louisiana).

Table 4. List of important sites (or complexes of sites) used by ***Calidris alpina hudsonia*** during the Southward Migration (SM), Nonbreeding (NB), and Northward Migration (NM). Site designation criteria: BIRE = Biosphere Reserve; IBA = Important Bird Area; NWR = National Wildlife Refuge; RAMSAR = Ramsar site; SGA = State Game Area; WHSRN = Western Hemisphere Shorebird Reserve Network. Only sites with >2,000 birds included.

Site	Province–State	Country	SM	NB	NM	Site Designation	Source
Minnewaukan Flats–Devil's Lake	North Dakota	U.S.			25,000		Skagen *et al*. 1999
Shiawassee National Wildlife Refuge	Michigan	U.S.			9,000	NWR	ISS, unpubl. data
Pointe Mouillee State Game Area	Michigan	U.S.			5,500	SGA	ISS, unpubl. data
Ottawa National Wildlife Refuge	Ohio	U.S.			13,242	NWR	ISS, unpubl. data
Duxbury Beach	Massachusetts	U.S.	8,500				ISS, unpubl. data
Parker River National Wildlife Refuge	Massachusetts	U.S.	6,768			NWR	ISS, unpubl. data
South Beach Island, Chatham	Massachusetts	U.S.	4,500				ISS, unpubl. data
Monomoy National Wildlife Refuge	Massachusetts	U.S.	4,000			WHSRN, NWR	ISS, unpubl. data
Jamaica Bay National Wildlife Refuge	New York	U.S.	6,330			NWR	ISS, unpubl. data
Delaware Bay (Thompson's Beach)	New Jersey	U.S.	6,000			WHSRN	ISS, unpubl. data
Edwin B. Forsythe National Wildlife Refuge	New Jersey	U.S.	12,000			NWR	ISS, unpubl. data
Bombay Hook National Wildlife Refuge	Delaware	U.S.			8,000	NWR	ISS, unpubl. data
Underwoods Corner	Delaware	U.S.			5,500		ISS, unpubl. data
Ted Harvey, Logan LN, South	Delaware	U.S.			5,500		ISS, unpubl. data
Little Creek	Delaware	U.S.			5,000		ISS, unpubl. data
Chincoteague National Wildlife Refuge	Virginia	U.S.	8,840				ISS, unpubl. data

Clam Shoal	North Carolina	U.S.			5,500		ISS, unpubl. data
Huntington Beach State Park	South Carolina	U.S.			4,700	SP	ISS, unpubl. data
Yawkey Wildlife Center	South Carolina	U.S.			2,369		ISS, unpubl. data
Cape Romano	Florida	U.S.			4,610		ISS, unpubl. data
Honeymoon Island	Florida	U.S.			3,000		ISS, unpubl. data
Merritt Island National Wildlife Refuge	Florida	U.S.		1,385			Sprandel *et al*. 1997
Grand Terre, Jefferson Parish	Louisiana	U.S.			8,000		ISS, unpubl. data
Between Duson and Crowley	Louisiana	U.S.	2,385		3,710		Skagen *et al*. 1999
Brazoria National Wildlife Refuge	Texas	U.S.			5,242	NWR	Skagen *et al*. 1999
Bolivar Flats	Texas	U.S.			4,040	WHSRN	ISS, unpubl. data
San Bernard National Wildlife Refuge	Texas	U.S.			3,495	NWR	Skagen *et al*. 1999
Airport, Port Aransas	Texas	U.S.			2,768		ISS, unpubl. data
South Padre Island	Texas	U.S.			2,547		Skagen *et al*. 1999
Matagorda National Wildlife Refuge	Texas	U.S.			2,014	NWR	Skagen *et al*. 1999
Laguna Madre	Tamaulipas–Texas	Mexico-U.S.		52,000		WHSRN, RAMSAR, NWR, IBA, PA	B. Ortego and L. Elliot, unpubl. data
Shoalwater Bay	Texas	U.S.		5,000			B. Ortego and L. Elliot, unpubl. data
Colorado River Delta	Texas	U.S.		2,700			B. Ortego and L. Elliot, unpubl. data
Mad Island Wildlife Management Area	Texas	U.S.	2,743			WMA	Skagen *et al*. 1999
Trinity Bay	Texas	U.S.	2,500				Skagen *et al*. 1999

CONSERVATION THREATS

Dunlin conservation is an issue of concern because, like other shorebird species, aspects of its ecology make it vulnerable to degradation or loss of the resources required to breed, migrate, and survive the nonbreeding period (Myers *et al*. 1987). These features include: 1) a tendency to aggregate in a limited number of locations during migration and on the nonbreeding grounds, which means deleterious change(s) can affect a large proportion of the population at once (Page *et al*. 1997, Page *et al*. 1999, Bishop *et al*. 2000); 2) a limited reproductive output, subject to vagaries of weather and predator cycles in the Arctic, which, in conjunction with long lifespan, suggests slow recovery from population declines (Holmes 1966, Warnock and Gill 1996); 3) a migration schedule closely timed to seasonally abundant food resources and tidal regimes, suggesting that there may be limited flexibility in migration routes or schedules (Bishop *et al*. 2000, Warnock *et al*. 2004); and 4) occupation and use of wetland habitats that are affected by a wide variety of human activities and developments, especially water diversion (Bildstein *et al*. 1991, Page and Gill 1994) and reclamation for other purposes (Wetlands International – Oceania 2004).

This section of the plan reviews the factors that represent potential threats to Dunlin. We classified conservation threats as: habitat loss and degradation, environmental contamination, human disturbance, climate change, and disease outbreaks. For convenience, we discuss each of the threats present in the sensitive periods (e.g., breeding, migration, and nonbreeding) of the annual cycle of the Dunlin. Although we have little information on the effects of the various factors on Dunlin populations, it seems likely that they are in some cases additive, both within and among seasons.

HABITAT LOSS AND DEGRADATION

Reclamation of Intertidal Areas for Economic Activities

Vast amounts of intertidal flats critically important to shorebirds and other migratory waterbirds are still being reclaimed by humans. Of the three subspecies, *C. a. arcticola* appears to face the greatest threat from habitat loss due to reclamation of intertidal areas on its nonbreeding grounds. For example, in the Republic of Korea, 1% of intertidal flats are reclaimed annually for human development (Korean Wetlands Alliance 2006). The largest such project, the Saemangeum reclamation project, involved draining 30,000 hectares of tidal flats and 10,000 hectares of estuarine shallows. Saemangeum represents what is arguably the most important shorebird site (including for *C. a. arcticola*) in not only the Republic of Korea but in all the Yellow Sea, and affects shorebirds from around the Pacific Basin (Barter 2002, Woodley 2006). Likewise due to reclamation, there has been a 62% loss of habitat in the Lower Chang Jiang Basin in the People's Republic of China, a 70% loss of the coastal wetlands in the Republic of China, and a 45% loss of the tidal flats in Japan (Wetlands International – Oceania 2004). Additionally, the diversion of fresh water from shorebird habitat for urban expansion threatens Dunlin populations at many interior western sites, such as at the Salton Sea (Shuford *et al*. 2004). Furthermore, the reduction in water and sediment flows can seriously affect the sediment input rate to coastal areas. This often results in erosion of estuaries and intertidal areas, and a decreased ability to supply intertidal flats with fresh silt and nutrients, potentially causing detrimental changes in the benthic fauna community (Barter 2002). The rate at which new intertidal areas are created in the future is likely to decline, as a consequence of the reduced river flows to the Yellow Sea (Barter 2002).

In all seasons, shorebirds roost during much of the period when they are not foraging or actively traveling. These resting periods allow them to conserve stored lipids that enhance nonbreeding survival and fuel migration flights. Although some roost sites can be very dispersed within a wetland or agricultural area (Conklin and Colwell 2007), others are small or localized (J. B. Buchanan, unpubl. data). The loss of or human disturbance to roost sites has been identified as an issue of management concern in various regions (Drut and Buchanan 2000, Wetlands International – Oceania 2004, Moores 2006).

Habitat degradation can occur when large dams are built on major river systems. These dams trap sediments and this results in loss of sediment accretion in river deltas and changes in seasonal flows of water in nearby rivers. The recently completed Three Gorges Dam in the People's Republic of China has already begun to affect the Chang Jiang River and wetlands downstream (Wetlands International – Oceania 2004).

Mariculture (Shrimp farms)

Along the coast of Sinaloa, Mexico, over 21,000 hectares of intertidal and mangrove swamps important to shorebirds, including *C. a. pacifica*, have been converted to shrimp farms since the 1990s (Ducks Unlimited 2006). Most of the shrimp farms were built on brackish flats and emergent brackish marshes, and have affected the hydrodynamics and connectivity of coastal wetlands (Hernández-Cornejo and Ruiz-Luna 2000). These converted areas no longer provide suitable habitat for Dunlin.

Changes in Agricultural Practices

C. a. pacifica and *C. a. hudsonia* make significant use of agricultural habitats such as rice fields and flooded agricultural fields (Shuford *et al*. 1998, Elphick and Oring 2003, Evans Ogden *et al*. 2005). Therefore, the increasing conversion of North America's agricultural lands to housing and other urban uses threatens these subspecies throughout North America. In contrast, fish farms located just inside seawalls in the Republic of China and the People's Republic of China provide essential habitat when exceptionally high tides flood all intertidal areas on the outer coast (R. Lanctot, pers. obs.).

Restoration of Salt Marshes (Salt ponds)

Along the Pacific coast of North America, salt pond habitat supports large numbers of *C. a. pacifica*, most notably at Laguna Ojo de Liebre–Guerrero Negro, Baja California Sur, Mexico (Page *et al*. 1997); San Diego Bay, California (Terp 1998); and San Francisco Bay, California (Page *et al*. 1999). In recent years, salt pond habitat at San Francisco Bay and San Diego Bay is being converted back to a mixture of tidal marsh habitat (Warnock 2005, see also Paracuellos *et al*. 2002). Modeling of the effects of converting open salt pond habitat to vegetated tidal marsh generally predicts significant declines of small shorebirds using that habitat in areas of restoration (Stralberg *et al*. 2003). Specific effects on Dunlin populations are unknown but will need to be tracked.

Exotic Species (Spartina spp.)

Invasive species potentially threaten shorebird species worldwide (Warnock *et al*. 2001). Exotic *Spartina* poses a serious threat to *C. a. pacifica*. For example, at Willapa Bay, Washington, nonbreeding and spring shorebird use declined over 60% in recent years as *Spartina* meadows replaced tidal mudflats (Jacques 2002). Several areas in Willapa Bay that supported substantial numbers of migrant and nonbreeding *C. a. pacifica* in the early 1990s were completely or largely covered by *Spartina* by the late 1990s (Buchanan 2003). There is an urgent need to take appropriate conservation measures to restore affected tidal flats and to prevent invasion of *Spartina* to other important sites (Buchanan 2003). Stralberg at al. (2004) modeled the spread of *Spartina alterniflora* in San Francisco Bay, California, and the predicted loss of habitat value for shorebirds ranged from 9% to 80%. They identified the upper mudflats (due to their greater exposure time) and the east and south shore mudflats (areas used by high numbers of birds) as the areas of greatest potential for *Spartina* invasion. Other sites vulnerable to *Spartina* invasion range from San Francisco Bay, to Puget Sound in Washington, and possibly the Fraser River estuary in British Columbia, Canada (Daehler and Strong 1996, Buchanan 2003, Stralberg *et al*. 2004). In 2000, the California State Coastal Conservancy established the Invasive *Spartina* Project (ISP) in San Francisco Estuary. The ISP is comprised of a number of components including outreach, research, permitting, mapping, monitoring, and the allocation of funds for efforts to eliminate populations of nonindigenous *Spartina*. In Britain, the spread of *Spartina anglica* resulted in the national decline of Dunlin (Goss-Custard and Moser 1988); clearing the plant increased shorebird use locally (Evans 1986). Efforts to eradicate *Spartina* at Willapa Bay, Washington, have been effective (but costly), and Dunlin and other shorebirds have begun using restored areas (Patten and O'Casey 2007).

ENVIRONMENTAL CONTAMINATION

The main pollutants of concern to Dunlin subspecies are oil and agricultural and industrial chemicals. Oil spills pose local threats to Dunlin, where major stopover and staging sites are in close proximity to shipping channels and refineries. For *C. a. arcticola*, several sites important during migration and the nonbreeding season have oil fields, such as the Colville River Delta in Alaska and the Yellow Sea in the People's Republic of China. A major oil spill at such sites during seasons of peak use could have catastrophic consequences to the Dunlin populations (Andres 1989, Barter 2002). For *C. a. pacifica*, major spills are a threat along the Alaska, Washington, Oregon, and California coasts and in major inland waters, as a significant amount of marine vessel traffic passes through these waters annually (Alaska Shorebird Working Group 2000, Drut and Buchanan 2000). An oil spill at San Francisco Bay, California, in November 2007 oiled many species of shorebirds, including Dunlin (N. Warnock, unpubl. data). For *C. a. hudsonia*, navigation channels in the coast of Texas are heavily used by the petroleum industry (B. Ortego, pers. comm.).

In northwestern Mexico and in the People's Republic of China's Yellow Sea, tons of industrial effluent and domestic sewage are discharged annually. Thus *C. a. arcticola* and *C. a. pacifica* may be exposed to potentially harmful chemicals (Barter 2002, Soto-Jimenez *et al*. 2003). Enrichment with excessive levels of naturally occurring materials (including nutrients) may change the vegetative community of coastal wetlands. For example, the extensive growth of cattail marshes in coastal wetlands of the Mexican State of Sinaloa as a consequence of agricultural runoff enriched with organic matter may decrease the quality of these wetlands to *C. a. pacifica* (Carrera and Fuente de León 2003). In San Francisco Bay, the reduced water circulation and discharge from industrial sources are responsible for the highest levels of some trace elements in the area that may affect *C. a. pacifica* (Hui *et al*. 2001).

Chemicals used for agriculture or other purposes, either individually or in combination, have the potential to harm shorebirds on-site or elsewhere as runoff (Buchanan 2000). Pesticide levels in coastal wetlands and tidal flats along the Pacific Coast are unknown. Although the use of DDT has been banned throughout much of the Western Hemisphere, Dunlin are still being exposed in the East Asian-Australasian Flyway. Even replacement chemicals currently used, such as such as organophosphates and carbamates, can result in high mortality and impaired behavior and physiology (Strum 2008). Many other potentially toxic pesticides and chemicals continue to be used as well (e.g., Warnock and Schwarzbach 1995). Although the implications to *C. a. arcticola* are poorly understood, monitoring on the coast of the People's Republic of China showed that shellfish had unacceptably high levels of pollutants, such as oil chromium, arsenic, and DDT (see Barter 2002). There has been little monitoring of contaminants in Dunlin, and much of this work was conducted 20 years ago (e.g., Schick *et al*. 1987, Custer and Myers 1990). Pesticides and other environmental contaminants have the potential to impact shorebirds locally, and the mortality or reproductive failure associated with bioaccumulation needs further study.

HUMAN DISTURBANCE

As a result of increasing populations, mobility, and leisure time, the presence of humans in many areas important for shorebirds is likewise increasing. Given the restricted nature of the remaining areas of suitable habitat, and increasing concerns about shorebird conservation, the issue of whether human presence has adverse effects on shorebird populations has become ever more important in recent years (Gill and Sutherland 2000). A major concern for conservationists is that, in response to human presence, animals may avoid or under-use areas; thus, human presence may be equivalent to habitat loss or degradation. Disturbance by humans could therefore be just as damaging as actual habitat loss or degradation, but since the habitat is unchanged, the effects are potentially reversible (Gill and Sutherland 2000).

Some shorebirds apparently perceive humans as predators (Frid and Dill 2002). Therefore, when humans are present, they will seek to reduce perceived risks by changing their feeding behavior (Fitzpatrick and Bouchez 1998, Thomas *et al*. 2003). The extent of this behavioral change can vary from subtle declines in swallow rates (Goss-Custard and Verboven 1993) to more drastic changes such as a permanent avoidance of an entire estuary (Mitchell *et al*. 1989). It is well established that human disturbance can have an adverse effect on shorebird fitness. First, it compels them to pay the high energetic cost of flying; second, it may reduce the amount of time that the birds are able to feed; and third, it can deprive them from feeding in the most profitable sites. Any overall reduction in energy intake as a result of these responses is the net impact of disturbance on energy budgets and, hence, survival (Gill and Sutherland 2000, Baker *et al*. 2004). Despite these concerns, the effects of human activities on migrating or nonbreeding Dunlin (i.e., *C. a. arcticola, pacifica,* and *hudsonia*) are unknown.

A source of conflict that has generated much debate is the interaction between migratory shorebirds and shellfish and other invertebrate harvesters working by hand at low tide (Shepherd and Boates 1999, Goss-Custard *et al*. 2000). The increasing human disturbance associated with harvesting by hand could pose a threat to the migratory process, especially during adverse weather events. Shellfishing and digging by hand may reduce, directly or indirectly, the benthic prey stocks or disturb the shorebirds, forcing them to feed in areas of less quality (Shepherd and Boates 1999, Goss-Custard *et al*. 2000, Barter 2002). Human disturbance not only occurs on the feeding areas but also in the saltpans and shrimp and fish ponds, which are often the only available roosting areas for shorebirds at high tides (Barter 2002). Disturbance from oil exploration, drilling, and extraction activities can be serious in the People's Republic of China's Huang He and Shuangtaizihekou National Nature Reserves (Barter 2002).

Hunting is another factor that could threaten populations of *C. a. arcticola* during migration or nonbreeding in Asia and Russia. In many of the countries in these regions, shorebirds are trapped, netted, snared, or shot for food or sale. This has, in general, greatly decreased over the past decade (see Barter 2002). Subsistence hunting of this subspecies and *C.*

a. pacifica also occurs in Alaska, although the number of birds harvested is likely to be low (Wetlands International – Oceania 2004).

CLIMATE CHANGE

Weather is of major importance for the population dynamics of birds, but the implications of climate change have only recently begun to be addressed. Potential effects of climate change pose serious concerns in many areas and in all seasons. Of concern in the Dunlin's sub-arctic and arctic breeding grounds is the unknown effect of climate change on breeding success. It is well documented that major breeding areas like the Yukon-Kuskokwim Delta in Alaska are being affected through fewer days with snow cover and warmer days on average (Niehaus and Ydenberg 2006). The Yukon-Kuskokwim Delta in Alaska has experienced a significant warming trend between 1977 and 2003, but no temporal trends in first arrival dates were found in 17 shorebird species. A similar pattern was found on the other side of the Bering Strait (Meltofte, *et al.* 2007). It is not well understood, however, how this climate change would affect the reproduction and survival of *C. a. pacifica*.

Climate change is expected to result in the acceleration of current rates of sea-level rise, inundating many low-lying coastal and intertidal areas. This could have important implications for organisms that depend on these sites, including shorebirds that rely on them for feeding habitat during their migrations and in the nonbreeding season (Bildstein *et al.* 1991, Page *et al.* 1999, Lindström and Agrell 1999, Piersma and Lindström 2004). Galbraith *et al.* (2002) modeled the potential changes in the extent of intertidal foraging habitat for shorebirds. Even under a scientifically conservative climate change scenario, they projected major intertidal habitat loss at Willapa Bay, Humboldt Bay, San Francisco Bay, and Delaware Bay; these losses might jeopardize the ability of these sites to continue to support their current shorebird numbers. The most severe losses are likely to occur at sites where the coastline is unable to move inland because of steep topography, seawalls, or other human developments, and where the effects of sea-level rise may be exacerbated by additional anthropogenic factors (Galbraith *et al.* 2002). Similar losses are predicted along the coastal regions of the People's Republic of China (Hulme *et al.* 1992).

In addition to sea level rise, climate change will continue to affect broad-scale climatology that will in turn likely affect Dunlin during all phases of their annual cycle. Most notably is the projected change in the position, frequency, and seasonality of storm tracks, especially in the Northern Hemisphere. Along the east coasts of Asia (*C. a. arcticola*) and North America (*C. a. hudsonia*) some climate change models predict summer cyclones will increase in both frequency (number of cyclones per area per season) and intensity (Geng and Sugi 2003). Other models indicate no increase in intensity but regional reductions in the number of weaker cyclones and a poleward shift of the storm track in the Atlantic and North Pacific (Graham and Diaz 2001, Brayshaw 2005, Bengtsson *et al*. 2006, Yin 2006). Yet others (McCabe *et al*. 2001) indicate a likely increase in frequency and intensity of high-latitude cyclones, particularly in the North Pacific, potentially affecting both *C. a. arcticola* and *C. a. pacifica*.

The consequences to Dunlin populations of such change are many. An increase in severe (hurricane-force) storms over the western Atlantic in late summer would likely affect *C. a. hudsonia* directly through increased mortality and indirectly through dramatically altered coastal habitats (Michener *et al*. 1997). At least one (*C. a. pacifica*) of the three North American populations of Dunlin is a wind-selected migrant (Warnock and Gill 1996, R. Gill, unpubl. data), using storms of particular strength and track to assist southward migration from Alaska to the west coast of temperate North America. What affect the projected change in frequency, intensity, and track of storms in the North Pacific will have on the migration strategy of Dunlin (likely also *C. a. arcticola*) is unknown, but potentially significant.

Besides affecting migratory behavior, changing storm regimes will also affect habitats upon which Dunlin depend during other phases of their annual cycle. For example, dramatically accelerated coastal erosion of Dunlin nesting habitat in northern Alaska has been linked to climate change, not only to warming of permafrost but also to shrinking pack ice that has increased wave fetch and contributed to more intense storms (Mars and Houseknecht 2007). A similar process is occurring on the Yukon-Kuskokwim Delta where both nesting habitats and littoral habitat used during post-breeding are being substantially altered by increased frequency and intensity of storms, including more frequent coastal flooding (U.S. Geological Survey, unpubl. data).

Away from the breeding grounds we can expect changing storm regimes also to affect littoral and coastal wetland habitats upon which Dunlin rely during winter and northward migration. Since the Dunlin is essentially a coastal species throughout its annual cycle, the actions of increased storm activity coupled with rising sea level do not bode well for the stability of Dunlin populations.

Disease Outbreaks

A number of diseases are known to have had negative impacts on bird populations (at least at local levels), or have the potential to do so. Avian botulism is a paralytic disease caused by ingestion of a toxin produced by the bacterium *Clostridium botulinum* (USGS National Wildlife Health Center 2007). West Nile virus has spread rapidly across North America in the last several years, affecting many species of birds since its discovery in the Western Hemisphere in 1999 (Kilpatrick *et al*. 2007). The virus has killed species in most Orders of North American birds and is particularly deadly to corvids (Center for Disease Control 2007). Avian flu is caused by influenza A viruses that occur naturally among birds. There are different subtypes of these viruses that also can be found in birds. The avian flu currently of concern is the H5N1 subtype (USGS National Wildlife Health Center 2007). The *C. a. arcticola* subspecies may have the highest likelihood of acquiring H5N1 since it spends the nonbreeding season in the People's Republic of China, where outbreaks have occurred in recent years. To date, only a small number (5/1413) of samples collected from *C. a. arcticola* and *C. a. pacifica* in Alaska has tested positive for avian influenza (but not the highly pathogenic H5N1) using a matrix-RT-PCR test (H. Ip, pers. comm.). The extent to which diseases such as avian botulism, West Nile virus, and avian flu affect Dunlin is unknown. Dunlin have not been killed by avian botulism, nor has West Nile virus or the H5N1 subtype been reported in them (Center for Disease Control 2007, USGS National Wildlife Health Center 2007).

CONSERVATION STRATEGIES AND ACTIONS

Current or Potential Collaborators

This conservation plan serves to synthesize what we know about Dunlin ecology, the location of important sites, and identification of threats. The next step will be to conduct projects that are broad-scale, international, and collaborative to fill gaps in our knowledge about Dunlin and about the threats to their future. Agencies and organizations that have been involved in Dunlin research, bird surveys, and/or monitoring, and which may represent potential collaborators on combined efforts now or in the future, are listed below. More details regarding specific individuals and their contact information are included in Appendix 2.

Asia/Russia

Birds Korea
Fudan University (Shanghai)
Massey University (New Zealand)
Pacific Institute of Geography, Russian Academy of Science
Russian Working Group on Waders
Taiwan Wader Study Group
University of Science and Technology of China
Wetlands International – Asia Pacific

Canada

Canadian National Shorebird Working Group
Canadian Wildlife Service
Centre for Wildlife Ecology, Simon Fraser University
Ducks Unlimited Canada
North American Bird Conservation Initiative – Canada

United States

Alaska Shorebird Group
Cascadia Research Collective
Ducks Unlimited, Inc.
Gulf Coast Joint Venture
Humboldt State University
Institute for Arctic Biology
Lower Columbia River Estuary Partnership
Manomet Center for Conservation Sciences
North American Bird Conservation Initiative – U.S.
National Audubon Society
Pacific Coast Joint Venture
PRBO Conservation Science
Prince William Sound Science Center
San Francisco Bay Joint Venture
Shorebird Sister School Program
The Nature Conservancy
U.S. Fish and Wildlife Service, Migratory Bird Management
U.S. Geological Survey, Alaska Science Center
U.S. Geological Survey, San Francisco Bay Field Station
U.S. Shorebird Plan Council
Washington Department of Fish and Wildlife
Western Hemisphere Shorebird Reserve Network
Yukon Delta National Wildlife Refuge

Mexico

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

Colegio de la Frontera Sur
Comisión Nacional para el Conocimiento y uso de la Biodiversidad (CONABIO)
Dirección General de Vida Silvestre, SEMARNAT
Ducks Unlimited de México, A.C. (DUMAC)
North American Bird Conservation Initiative - Mexico
Pronatura Noroeste, A.C.
Pronatura Veracruz
Universidad Autónoma de Baja California Sur (UABCS)
Universidad Nacional Autónoma de México (UNAM)

CONSERVATION ACTIONS

Analyses of the situation for the three subspecies that occur in North America (*C. a. arcticola, C. a. pacifica*, and *C. a. hudsonia*) show that the conservation threats, and the proposed solutions, are very similar among the three subspecies.

Habitat Protection

Overall, the highest-priority conservation action identified within each subspecies's range is habitat protection, particularly during the nonbreeding and migration seasons. We acknowledge that conserving and protecting habitat in North America is different than in Asia, as are the challenges faced. While this section is more oriented towards North America, efforts need to be carried out on both continents to fully benefit Dunlin.

To safeguard Dunlin populations, we have to protect the interconnected chains of wetlands they depend upon from further deterioration and disappearance. Because adult survival is a critical variable in determining population size of [long-lived] migratory shorebirds, it is very important to maintain and secure high-quality habitats. The habitat goal is to protect, restore, and enhance the conditions necessary to achieve each subspecies' population goals. Achieving this habitat goal will likely provide important habitats for other shorebird species as well.

Although methods of habitat protection will undoubtedly vary by political climates, opportunities, and programs available at various jurisdictional levels, the primary limiting factor for habitat protection is the lack of funding. Thus, a crucial first step is to develop fundraising strategies that earmark funds specifically for habitat protection. This will require understanding what motivates the landowners and other major stakeholders, seeking at least their passive—if not active—support, and garnering the support of others, such as local organizations, businesses, and individuals interested in shorebird conservation. It also requires strengthening or developing relationships with existing or potential partners whose own interests also could be advanced through Dunlin conservation efforts.

Important sites should be protected through various means, including acquisition, conservation easement, and voluntary conservation plans. The main purpose of an easement program should be the conservation and sustainable management – in perpetuity – of privately owned or communal lands important to Dunlin and other migratory shorebirds. Furthermore, these legally binding agreements should respect traditional users' ownership or other rights, and include as an incentive access to federal or other funds that would be available to promote restoration or more sustainable use of the site's natural resources.

Although the fate of migratory shorebirds is very closely linked to the availability of extensive and healthy wetlands, it is unrealistic to expect that these areas will be protected solely for the sake of shorebirds. However, some of these sites supply very important economic and social benefits for local residents; thus, shorebird conservation is best achieved by the implementation of plans that maintain these benefits by protecting the region's biodiversity and encouraging sustainable use of wetland resources. For this reason, the protection of shorebird habitat should be placed in the context of maintaining healthy and functioning ecosystems for other human values, such that benefits of a protection strategy have more broad appeal and support among local and regional stakeholders.

For *C. a. pacifica*, large-scale habitat restoration projects in San Francisco Bay and San Diego Bay, in which salt ponds are converted to vegetated tidal marshes, have the potential to negatively impact shorebird populations. Maintaining ponds of varying salinities and depths should be a management priority, as well as annual monitoring to assess changes in Dunlin response to local conditions (Warnock *et al*. 2002, Warnock 2005). Also, the presence, spread, and control of non-native *Spartina* (especially *S. alterniflora* and hybrids) may present a different challenge in each estuary of the northern Pacific coast of North America. Without systematic survey data, it is impossible to assess the potential influence of the current spread of *Spartina* on shorebirds. It is important to promote local partnerships to address concerns about *Spartina* management (Buchanan 2003).

Recognition of Important Sites

Opportunities for effective habitat conservation for migratory shorebirds are enhanced when important sites are properly recognized at local, regional, and international scales that favor conservation actions on a flyways basis. For this reason, there is great value in formally establishing or identifying new protected areas and sites that meet WHSRN, East Asian-Australasian Shorebird Site Network, Ramsar Convention, or Important Bird Areas (IBA) criteria. To qualify for inclusion in WHSRN for example, a site must be of demonstrated importance for shorebirds at regional (at least 20,000 birds annually or 1% of the biogeographic population for a species), international (at least 100,000 birds annually or 10% of the biogeographic population for a species), or hemispheric (at least 500,000 birds annually or 30% of the biogeographic population for a species) scales. According to the Ramsar Convention, a wetland should be considered internationally important if it regularly supports 20,000 or more shorebirds or 1% of the individuals in a population of one species. The criteria used by the IBA program are internationally agreed upon, standardized, quantitative, and scientifically defensible. Ideally, each IBA should be large enough to support self-sustaining populations of as many key bird species as possible for which it was identified or, in the case of migrants, to fulfill their requirements for the duration of their presence. Examples of such candidate sites for Dunlin (relative to documented use by the species) are in Tables 2–4.

Public Awareness and Education Programs

Because human activities frequently harm critical wetland sites used by Dunlin, an education and outreach program would be valuable to increase public awareness about migratory shorebird ecology in general, conservation issues, and the importance of protecting coastal wetlands. Ideally, the programs could promote such awareness through strategic activities and educational products, based on existing migratory shorebird and wetland communication networks. Where possible, these networks could help to promote the conservation of Dunlin. Also, it would be helpful to implement a communication strategy to promote the exchange of information on shorebird conservation and habitat management, particularly as it pertains to Dunlin, between all levels of government, nongovernmental organizations, regional natural-resource management bodies, industry, and communities. Community awareness-raising workshops are also needed—not only to promote the benefits of conserving wetlands, but also to inform landowners about incentive programs for which they may be eligible. Programs could be developed to inspire landowners and other stakeholders to work with their political representatives towards policies and legislation that would further promote and fund wetland conservation, benefiting Dunlin and other migratory shorebird species.

RESEARCH AND MONITORING NEEDS

Although the Dunlin, especially *C. a. pacifica*, is one of the best-studied shorebird species in North America, there are still major gaps in knowledge about factors that limit Dunlin populations and have the greatest influence on their fitness and survival. This section of the plan gives an overview of the research and monitoring needs relevant for effective conservation of Dunlin populations. In many ways, research and monitoring needs are closely related and will require cooperation and coordination among agencies, organizations, and individuals at local, regional, national, and international levels.

RESEARCH NEEDS

Migratory Connectivity

Populations may be influenced by events acting within or interactively among the breeding or nonbreeding grounds or during migration (e.g., Sillett *et al*. 2000). To pinpoint causes of population change, we must understand the functional links between sites and know how sites work relative to the ecosystems that migrants depend upon. Such knowledge of migratory connectivity is not only critical for identifying the factors that limit populations, but also for developing models that successfully predict declines in the future and for making recommendations for management actions to prevent them (Dolman and Sutherland 1995). The migration route used by some subspecies is not well known. Resighting of marked birds, stable isotopes (e.g., Evans Ogden *et al*. 2005), genetic information (e.g., Haig *et al*. 1997), and radio telemetry (e.g., Warnock *et al*. 2004) can help determine migratory strategies of each subspecies. Initial analysis of Dunlin from around the world show minor population structuring based on maternally inherited MtDNA (Wenink *et al.* 1996, Wennerberg 2001), although preliminary analysis with bi-parentally inherited microsatellites indicate no difference in genetic profiles between *C. a. arcticola* and *C. a. sakhalina* (S. Haig and M. Johnson, unpubl. data). Further study into the five designated Beringia subspecies is underway (R. Lanctot, pers. comm.).

Density-dependent Effects of Habitat Loss

Understanding density dependence as a limiting factor is key to understanding the relationships between habitat availability and population dynamics and thereby predicting the effect of habitat loss on shorebirds. Any habitat change or loss which disproportionately affects a particular age or sex group is likely to have a greater impact on population size than would be predicted if all animals were affected equally. In *C. a. pacifica*, there are age-related differences in habitat distribution on a local scale (Warnock 1994, Shepherd and Lank 2004), and susceptibility to raptor predation (Page and Whitacre 1975, Kus *et al*. 1984). It has been shown that predation by raptors can cause density-dependent mortality of nonbreeding Dunlin (Whitfield 2003). The interplay between social and foraging behavior in nonbreeding Dunlin deserves further study, as it could reveal why some individuals may be predisposed to greater mortality risk. We also need to gain a better understanding of the consequences of habitat loss on Dunlin. Behavior-based models have been developed in an attempt to predict how bird populations will be affected by environmental change, such as habitat loss, disturbance, and climate change (West and Caldow 2006). Although these individuals-based models are often complex and take a long time to develop, such models have already proved useful in a range of issues and locations in Europe (Durell *et al*. 2005, West and Caldow 2006). Alternatively, habitat-based models can be used to predict how habitat change, through processes like loss, restoration, and climate change, will affect the distribution and abundance of birds like the Dunlin, as has been done at San Francisco Bay (Stralberg *et al*. 2005).

Factors Affecting Survival and Population Dynamics

Populations of migratory shorebirds can be influenced by events that occur during breeding, migration, and nonbreeding periods; population regulation can occur by a combination of mechanisms operating in one or more of these seasons (Piersma and Baker 2000). To enhance conservation efforts for Dunlin, we need to understand the relative effects on population dynamics of those impacts that are manifested during breeding, nonbreeding, and migratory periods. The use of demographic modeling to elucidate the processes that substantially influence population dynamics within different broad regions of nonbreeding occurrence should be a priority. Adult survival has the greatest potential to influence rates of population change in shorebirds and other long-lived vertebrates (Hitchcock and Gratto-Trevor 1997, Sandercock 2003). Thus, one of the main goals of research should be to identify stressors, throughout the annual cycle, that influence demographic parameters such as adult survival (Warnock *et al*. 1997). Ideally, it will be important to identify where Dunlin experience these stressors, and seek to determine whether they are associated with measures of population performance. Seasonal estimates of survival for breeding, migration, and nonbreeding periods (by subtracting from annual estimates) would be valuable information, as this might help focus the significance of specific stressors. Also, data on juvenile dispersal and juvenile survival, especially during the southward migration, are highly relevant to migratory connectivity.

MONITORING NEEDS

Population Status

One of the most basic yet critical information gaps regarding the Dunlin is population trends, especially west of the Rocky Mountains and on the breeding grounds for each subspecies. At present, we lack the ability to decide whether observed population declines in several estuarine systems are real or a result of other factors (e.g., changes in turnover rate, redistribution among sites, etc.). Establishing adequate population monitoring to determine the current population status of Dunlin should be a high-priority goal. Without this information, conservation and management of Dunlin populations will likely be difficult and lack direction. The overall goal will be to maintain current population levels of each subspecies. Population targets have been developed in the U.S. Shorebird Conservation Plan (Brown *et al*. 2001); however, these targets are preliminary and will likely be refined using more comprehensive information. Future refinement will be particularly important to improve Dunlin conservation and management efforts. Additionally, population targets for subspecies having experienced declines should reflect recovery or enhancement to a former level of abundance.

Perhaps the greatest uncertainty involving these three subspecies is the nonbreeding distribution and status of *C. a. arcticola*. Its occurrence intermixed with other Dunlin subspecies along the East Asian-Australasian Flyway makes it difficult to understand important aspects of its status. It will be a high priority to work within the nonbreeding and migration range to identify the key areas used by this subspecies during those periods, and to develop the ability to assess or monitor trends in abundance (or aspects of demography) in these locations.

There should be two general approaches to population monitoring: (i) the population level, and (ii) site-specific and regional assessments. The latter will be used to evaluate Dunlin responses to habitat changes and to further refine our understanding of the location of important sites in specific regions during the nonbreeding season. If possible, there should be a link between Dunlin-specific population monitoring and more widespread, shorebird survey efforts, such as the International Shorebird Survey (ISS) and the Program for Regional and International Shorebird Monitoring (PRISM), to integrate and strengthen existing shorebird survey efforts. The closer coordination and expanded survey effort at important stopover sites will provide a strong, statistically valid framework for detecting trends in Dunlin populations, and will assist local managers in meeting their shorebird conservation goals.

Habitat Use

The loss of habitat important to shorebirds has been particularly dramatic in the last 100 years (Bildstein *et al*. 1991, Page and Gill 1994). Although some of the most important sites are protected to some extent from direct industrial and urban development, many other sites are unprotected lands or on lands not specifically managed to address shorebird habitat needs. Thus, the goal will be to monitor the condition, distribution, availability, use, and productivity (i.e., the functional value) of habitat. Although many important sites for Dunlin have been identified and are presented in this report, research is needed to understand the value of smaller sites and particularly the importance of alternative habitats such as agricultural fields and salt ponds (Shepherd *et al*. 2003). It will be necessary to develop specific habitat-use and distribution information for Dunlin at each site. If possible, there should be a link between the population monitoring efforts and site/habitat assessment.

Environmental Contaminants

Determining the effects of contaminants on the health of Dunlin is an important research and monitoring need. The goal will be to evaluate impacts of contaminants (e.g., lead, agricultural chemicals, industrial chemicals, and oil on Dunlin during migration and nonbreeding). This can be accomplished in a number of ways, including: a) assessing impacts of contaminant events (e.g. oil or chemical spills); b) assessing risk of contaminant events; c) developing risk-reduction strategies; and d) monitoring potential exposure to a broad spectrum of environmental pollutants through comprehensive sampling and toxicology programs.

CONSERVATION ACTION TIMELINE

RANGE-WIDE

High Priority (to be initiated or completed within the next 2–5 years)

❖ **Create a GoogleEarth placemark file** of important breeding, migration, and nonbreeding sites for *C. a. articola, pacifica,* and *hudsonia*, indicating any sites that are known to be of higher priority/importance. WHSRN Executive Office and plan authors proactively **distribute this map** to conservation partners.

❖ Researchers establish a **periodic remote-sensing scheme** at important sites for *C. a. arcticola* that will quantify changes over time in the amount of available habitat, especially within the East Asian-Australasian Flyway.

❖ Researchers evaluate existing survey data or establish new **monitoring programs or research studies** to determine:

- distribution and accurate estimates of population size and trend throughout the ranges for *C. a. arcticola*, *pacifica*, and *hudsonia*;
- potential limiting factors on population growth through the measurement of demographic parameters, such as adult survival and productivity, at key locations; and
- the potential to geographically differentiate populations of *C. a. arcticola*, *pacifica*, and *hudsonia* (and other adjacent subspecies) through the use of genetics, stable isotopes, mark-band resightings, vocalizations, or other techniques.

❖ Researchers further develop models to evaluate **potential effects of climate change** on Dunlin's habitat use, migration behavior and timing, and demographic vital rates. This work can be done in conjunction with similar modeling for other shorebird species as appropriate.

❖ Partners establish new, or strengthen existing, mechanisms of **cooperation and communication** between shorebird conservationists/researchers in the Western Hemisphere and the East Asian-Australasian Flyway, as well as among all relevant governments, private groups, and communities throughout the Dunlin's range.

❖ Partners **enroll** 75% of the total sites in Tables 2–4 of the plan that qualify as new **Sites of International or Hemispheric Importance** per WHSRN and/or East Asian-Australasian Shorebird Site Network criteria.

❖ Partners implement the **WHSRN Site Assessment Tool** at 50% of the important Dunlin sites in the Hemisphere. Compare and collectively analyze the rankings for each site's condition, threat levels, and trends for an overall status of important Dunlin sites range-wide.

Medium Priority *(to be initiated or completed within the next 5–10 years)*

❖ Researchers establish a **periodic remote-sensing scheme** at important sites for *C. a. pacifica* and *C. a. hudsonia* that will quantify changes over time in the amount of available breeding, migration, and nonbreeding habitat.

❖ Researchers investigate the effects of various and potentially significant forms of **human disturbance** at key sites (e.g., habitat alteration and development, agricultural runoff, and hunting) on Dunlin behavior, physiology, or demography.

❖ Researchers determine the prevalence of **avian influenza and other diseases** in Dunlin, and their potential impact(s) on the population.

❖ Researchers quantify **hunting** of *C. a. arcticola* by humans in southern People's Republic of China and in Alaska, and determine its effect(s) on the subspecies' population.

❖ Authors of this plan **update Cornell's "Birds of North America" account** for Dunlin.

MIGRATION AND/OR NONBREEDING

High Priority *(to be initiated or completed within the next 2–5 years)*

❖ Using the most appropriate research and monitoring methods available, researchers identify *C. a. arcticola's* nonbreeding **sites as well as routes** to and from its breeding and nonbreeding grounds.

❖ Managers of tidal marsh restoration projects in California (San Francisco Bay and San Diego Bay) agree to retain enough **salt pond areas** sufficient for supporting high counts of migrating and nonbreeding *C. a. pacifica*.

❖ Appropriate partners address **habitat restoration** at Willapa Bay, Washington, to benefit migrating and nonbreeding *C. a. pacifica* by:

- restoring tidal mudflats affected by *Spartina* to pre-invasion quality; and
- developing and implementing a strategy to prevent or control recurring invasions.

❖ Appropriate partners develop and implement a strategy for preventing or treating ***Spartina* invasions** at vulnerable sites such as San Francisco Bay (California), Puget Sound (Washington), and Fraser River Estuary (British Columbia, Canada), important to migrating and nonbreeding *C. a. pacifica.*

❖ Researchers determine the potential effects of the following threats on *C. a. arcticola* at major stopover areas in the East Asian-Australasian flyway:

- loss of intertidal areas due to human reclamation and reduced accretion of soil resulting from declining river flows;

- ○ high levels of pollution leading to reduced benthic productivity and, thus, declining food supplies for shorebirds; and
- ○ unsustainable harvest of benthic fauna by humans.

❖ Researchers quantify **use and abundance** at nonbreeding sites for *C. a. arcticola*.

❖ Using Tables 2–4 in the plan as a guide, partners provide Dunlin-specific information to existing **environmental education programs** in communities located in/around areas important to migrating and nonbreeding Dunlin.

❖ Partners develop **outreach programs for stakeholders** that will improve their understanding of how the maintenance or enhancement of ecosystem functions benefits Dunlin, other wildlife, and natural resources of direct value to communities.

❖ At interior areas dominated by agriculture, partners work with land managers to develop **wetland-management practices supportive of Dunlin**, such as ensuring availability of high-quality water in wetlands and protecting wetland habitats from fragmentation or urban encroachment.

Medium Priority *(to be initiated or completed within the next 5–10 years)*

❖ Researchers determine the level, type, and effect of **Dunlin's exposure to contaminants** at important migration and nonbreeding sites, as a potential limiting factor to adult survival.

❖ Researchers quantify **use and abundance** at nonbreeding sites for *C. a. pacifica and C. a. hudsonia*.

❖ Using all methods available, researchers document **movements between major stopover and staging sites** during northward and southward migration of *C. a. articola, pacifica,* and *hudsonia*.

❖ Through all methods available, researchers assess **movements during the November-March nonbreeding period** for *C. a. articola* and *hudsonia*.

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APPENDIX 1

EXPLANATION OF PROCEDURES USED TO ANALYZE CHRISTMAS BIRD COUNT (CBC) DATA

Data used for the analysis of trends in the nonbreeding abundance of Dunlin for this conservation plan were obtained from www.audubon.org/bird/cbc/, accessed in Spring 2007. Sites were required to meet two criteria to be included in the analysis: 1) the site was active between CBC 80 (Winter 1979–80) and CBC 106 (Winter 2005–06), and 2) Dunlin were regularly present in the count circle. This resulted in 43 Christmas Bird Count sites within Washington, Oregon, and California (involving *C. a. pacifica*), and 66 sites along the east coast of North America, from Massachusetts to Texas (involving *C. a. hudsonia*).

In some years, counts were not conducted in some Christmas Bird Count locations. In these cases, the values from counts that occurred 2 years prior to and after the missing count were summed, and the average of this value was used to represent the missing value. For *C. a. pacifica,* there were 1,161 potential CBC counts in the 27-year period between CBC 80 and CBC 106 in Washington, Oregon, and California, of which 37 (3.2%) were missing. There were 1,782 potential CBC counts within the range of *C. a. hudsonia* during the analysis period, of which 42 (2.4%) were missing.

We used raw data for the analyses because it is our belief that sites supporting Dunlin and other shorebird species were well covered in Christmas Bird Counts; use of index values based on observer effort were therefore unwarranted. Count data were summed for each year for all sites in each analysis block (Washington, Oregon, California, mid- and north-Atlantic states, southeast Atlantic states, and Texas).

APPENDIX 2

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