Program for Regional and International Shorebird Monitoring (PRISM)

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Jonathan Bart, Brad Andres, Stephen Brown, Garry Donaldson, Brian Harrington, Heather Johnson, Vicky Johnston, Stephanie Jones, R. I. G. Morrison, Michel Sallaberry, Susan K. Skagen, and Nils Warnock

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Abstract

This report describes the "Program for Regional and International Shorebird Monitoring" (PRISM). PRISM is being implemented by a Canada-U.S. Shorebird Monitoring and Assessment Committee formed in 2001 by the Canadian Shorebird Working Group and the U.S. Shorebird Council. PRISM is based on the shorebird conservation plans recently completed in Canada and the U.S. and provides a single blueprint for implementing both of these plans. The goals PRISM are to (1) estimate the size of breeding populations of 74 shorebird taxa in North America; (2) describe shorebirds' distribution, abundance, and habitat relationships; (3) monitor trends in shorebird population size; (4) monitor shorebird numbers at stopover locations, and; (5) assist local managers in meeting their shorebird conservation goals. It has three main components: arctic and boreal breeding surveys, temperate breeding surveys, temperate non-breeding surveys, and neotropical surveys. Progress on, and action items for, each major component are described. We believe that the most important major tasks for immediate action are formulating a plan to carry out the northern surveys, evaluating aerial photographic surveys for migration and winter counts, and carrying out several regional analyses to design the program of migration counts. The Summary and Recommendations section contains a brief justification for these conclusions along with a list of the other actions needed to implement PRISM.

Introduction

This document describes the Program for Regional and International Shorebird Monitoring (PRISM). PRISM is a single blueprint for monitoring shorebirds in Canada and the United States and is based on the Canadian and U.S. shorebird conservation plans (Brown 2001, Donaldson 2001). The goals of PRISM are to:

1. Estimate the size of breeding populations of shorebirds in North America.

2. Describe shorebirds' distribution, abundance, and habitat relationships.

3. Monitor trends in shorebird population size.

4. Monitor shorebird numbers at stopover locations.

5. Assist local managers in meeting their shorebird conservation goals.

Most of this report is focused on the goal of estimating trend in population size because we believe that is technically the most difficult goal. Bart and Francis (2001) have proposed goals and standards for comprehensive avian monitoring programs. Their general goal, building on earlier work by Butcher et al. (1993), is 80% power to detect a 50% decline occurring during 20 years, using a two-tailed test with the significance level set at 0.15 and acknowledging effects of potential bias. They analyze existing and feasible levels of accuracy for shorebirds and show that relatively few species meet the proposed standard at present but that if the Canadian and U.S. bird conservation initiatives are implemented, the standard will probably be met for most shorebird species breeding regularly in North America. We adopt their proposed standard for this draft of the PRISM description, while acknowledging that their proposal will need review and perhaps revision by the ornithological community.

A four-part approach for estimating trends in population size has been developed:

1. Arctic and boreal breeding surveys.

2. Temperate breeding surveys.

3. Temperate non-breeding surveys.

4. Neotropical surveys.

The rationale underlying this scenario is that trends in population size can best be studied during the breeding season, on the breeding grounds. At this time, populations are stable rather than mobile, surveys are relatively straightforward because the birds are dispersed, and extrapolation from sampled plots to the entire population can be made using standard methods from classical sampling theory. This approach works well in temperate

latitudes. In northern areas, where gaining access is difficult and costly, we propose an initial survey on the breeding grounds, to obtain estimates of population size, and then opportunistic data collection from these areas and a comprehensive program of surveys in staging, migration, and wintering areas at lower latitudes, where access is reasonably easy, to provide indications of population declines. When such warning signs appear, or at intervals of 10-20 years, the breeding ground surveys can be repeated to get updated population sizes and thus estimates of change in population size. This approach avoids the high cost of annual surveys in remote northern areas but also avoids complete reliance on trend estimates from migration when several sources of bias are possible.

The U.S. Plan suggested that selected subspecies and distinct populations, in addition to all species that breed regularly in the U.S. and Canada, should be included in the monitoring and assessment program. The rationale for this suggestion was that many subspecies, and a few populations, have such different breeding and/or non-breeding ranges that separate management efforts would be needed if they declined. For example, the three subspecies of dunlins in North America winter in different parts of the world, and evidence exists that one (C*alidris alpina arcticola*) of them may be declining whereas this is not true for the other two. Computing a single species-wide trend for dunlins does not provide managers the information they need. Furthermore, it is relatively straightforward to calculate separate trends for the three subspecies since they spend both the breeding and non-breeding periods in almost completely non-overlapping areas. The same rationale holds for a few distinct populations. For example, small populations of marbled godwits breed near James Bay and in western Alaska. They are separated from the main population by hundreds of kilometers, and certainly each warrant population-specific conservation actions by managers. It thus seems appropriate to identify them as separate taxa in monitoring and assessment program.

The U.S. shorebird plan identified 72 species, subspecies, or distinct populations that warrant separate monitoring and assessment efforts. With slight modifications following review by Canadian shorebird specialists, this list now covers 74 taxa including 49 species (Table 1; Appendix One).

Table 1. Focal taxa that warrant long-term population monitoring and proposed approaches yet to be evaluated. Existing surveys are identified by acronym[1] and targeted protocols (in Appendix 3 of Brown et al. 2001) for one or a few species are identified by protocol number. Existing surveys in parentheses require improvement and re-evaluation for adequate monitoring of species; protocol numbers in parentheses indicate surveys for which the species or subspecies is secondary.

Species (common name)	Species or subspecies[2] (scientific name)	Conservation Category (USSCP)[3]	Breeding Surveys in Temperate Regions[1]	Breeding Surveys in Arctic and Boreal Regions[1]	Migration and Staging Surveys[1]	Winter Surveys[1]
Black-bellied plover	*Pluvialis squatarola squatarola*	4		ABBS	(P16)	
	P. s. cynosurae	3		ABBS	MS (P19)	
American golden-plover	*Pluvialis dominica*	4		ABBS (P13)	MS	
Pacific golden-plover	*Pluvialis fulva*	4		ABBS (P13)	(P16)	P3
Snowy plover	*Charadrius alexandrinus nivosus* (Pacific coast)	5	P1			(P22)
	C. a. nivosus (interior and Atlantic)	4	P1 (IPPC)			(IPPC)
	C. a. tenuirostris	5	P1 (IPPC)			(IPPC)
Wilson's plover	*Charadrius wilsonia*	4	P4 (IPPC)			(IPPC)
Semipalmated plover	*Charadrius semipalmatus*	2			MS	
Piping plover	*Charadrius melodus melodus*	5	IPPC (P10)			IPPC
	C. m. circumcinctus Great Lakes	5	IPPC			IPPC
	C. m. circumcinctus Great Plains	5	IPPC			IPPC
Killdeer	*Charadrius vociferus*	3	BBS		MS	
Mountain plover	*Charadrius montanus*	5	P5			X[4]
American oystercatcher	*Haematopus palliatus palliatus*	4	(P10)		MS	P6
	H. p. frazari	4			MS	
Black oystercatcher	*Haematopus bachmani*	4	P7			P7 BCCWS

Table 1. Continued.

Species (common name)	Species (scientific name)	Conservation Category (USSCP)[1]	Breeding Surveys in Temperate Regions[1]	Breeding Surveys in Arctic and Boreal Regions[1]	Migration and Staging Surveys[1]	Winter Surveys[2]
Black-necked stilt	*Himantopus mexicanus mexicanus*	3	P8		MS (P9)	
	H. m. knudseni	4	P8			
American avocet	*Recurvirostra americana*	3	(BBS) P8		MS P9 (P25)	
Greater yellowlegs	*Tringa melanoleuca*	3		ABBS	MS	
Lesser yellowlegs	*Tringa flavipes*	3		ABBS	MS	
Solitary sandpiper	*Tringa solitaria solitara*	2		ABBS	MS	
	T. s. cinnamomea	3		ABBS	MS	
Willet	*Catoptrophorus semipalmatus semipalmatus*	3	BBS P10		MS (P19)	
	C. s. inornatus	3	BBS		MS	P11
Wandering tattler	*Heteroscelus incanus*				P12	
Spotted sandpiper	*Actitis macularia*	2	(BBS)	ABBS	MS	
Upland sandpiper	*Bartramia longicauda*	4	BBS	ABBS	MS	
Bristle-thighed curlew	*Numenius tahitiensis*	4		ABBS P13		
Whimbrel	*Numenius phaeopus hudsonicus*	5		ABBS	MS P14 (P19)	
	N. p. rufiventris	3		ABBS (P13)	MS	
Long-billed curlew	*Numenius americanus americanus*	5	(BBS) P15			(P11)
	N. a. parvus	5	(BBS) P15			
Hudsonian godwit	*Limosa haemastica (*Alaska*)*	4		ABBS	MS	P17
	*Limosa haemastica (*Canada*)*	4		ABBS	MS	P17
Bar-tailed godwit	*Limosa limosa baueri*	4		ABBS (P13)	P16	
Marbled godwit	*Limosa fedoa fedoa* (Great Plains)	4	(BBS)		(P9)	P11 (P6)
	L. f. fedoa (Hudson Bay)	4		ABBS	MS	
	L. f. beringiae	4		ABBS	MS (P16)	P11

Table 1. Continued.

Species (common name)	Species (scientific name)	Conservation Category (USSCP)[1]	Breeding Surveys in Temperate Regions[1]	Breeding Surveys in Arctic and Boreal Regions[1]	Migration and Staging Surveys[1]	Winter Surveys[2]
Ruddy turnstone	*Arenaria interpres interpres* (Alaska)	3		ABBS		
	A. i. interpres (high arctic Canada)	3		ABBS		
	A. i. morinella (low arctic Canada)	4		ABBS	MS P19	
Black turnstone	*Arenaria melanocephala*	4		P18	MS (P12,20)	BCCWS
Surfbird	*Aphriza virgata*	4			MS P20 (P12)	BCCWS
Red knot	*Calidris canutus rufa*	4		ABBS	MS P19	(P6,17)
	C. c. islandica	3		ABBS		
	C. c. roselarri	3			MS	
Rock sandpiper	*Calidris ptilocnemis tschuktschorum*	4			MS P21 (P16)	BCCWS
	C. p. ptilocnemis	4		ABBS P21		P21
	C. p. cousei	4		ABBS P21		
Sanderling	*Calidris alba*	4		ABBS	MS P19	P22
Semipalmated sandpiper	*Calidris pusilla*	3		ABBS (P18)	MS (P19)	
Western sandpiper	*Calidris mauri*	4		ABBS	MS P23	
Least sandpiper	*Calidris minutilla*	3		ABBS	MS	(P11)
White-rumped sandpiper	*Calidris fuscicollis*	2		ABBS	MS	(P17)
Baird's sandpiper	*Calidris bairdii*	2		ABBS	MS	
Pectoral sandpiper	*Calidris melanotos*	2		ABBS	MS	
Purple sandpiper	*Calidris maritima maritima*	4		ABBS		(CBC)
	C. m. belcheri	4		ABBS	MS	CBC
Dunlin	*Calidris alpina pacifica*	4		ABBS (P18)	MS (P16,P23)	P11 BCCWS
	C. a. arcticola	5		ABBS		
	C. a. hudsonia	3		ABBS	MS	CBC (P6)

Table 1. Continued.

Species (common name)	Species (scientific name)	Conservation Category (USSCP)[1]	Breeding Surveys in Temperate Regions[1]	Breeding Surveys in Arctic and Boreal Regions[1]	Migration and Staging Surveys[1]	Winter Surveys[2]
Stilt sandpiper	*Calidris himantopus*	3		ABBS	MS	
Buff-breasted sandpiper.	*Tryngites subruficollis*	4		ABBS	MS	
Short-billed dowitcher	*Limnodromus griseus griseus*	4		ABBS	MS	(P6)
	L. g. hendersoni	4		ABBS	MS	
	L. g. caurinus	3		ABBS	MS (P23)	(P11)
Long-billed dowitcher	*Limnodromus scolopaceus*	2		ABBS	MS	(P11)
Common snipe	*Gallinago gallinago*	3	BBS	ABBS		
American woodcock	*Scolopax minor*	4	AWSGS			
Wilson's phalarope	*Phalaropus tricolor*	4	(P8)		MS P25 (P9)	
Red-necked phalarope	*Phalaropus lobatus*	3		ABBS (P18)	MS P26 (P9)	
Red phalarope	*Phalaropus fulicaria*	3		ABBS	P26	

[1] Existing surveys are listed by acronyms. BBS - Breeding Bird Survey; ABBS - Arctic and Boreal Breeding Survey; MS - a combination of migration surveys, including the International Shorebird Survey, the Maritimes Shorebird Survey, the Western Shorebird Survey, surveys by the Canadian Wildlife Survey and the British Columbia Coastal Waterbird Survey, and the South Atlantic Migratory Bird Initiative; CBC - Christmas Bird Count; IPPC - International Piping Plover Census; AWSGS - North American Woodcock Singing-ground Survey; and BCCWS - British Columbia Coastal Waterbird Survey as it pertains to winter surveys (also included in MS).

[2] See Appendix One for more information on subspecies and geographic regions.

[3] Conservation categories are as follows: 1 - species not at risk, 2 - species of low concern, 3 - species of moderate concern, 4 - species of high concern, 5 - highly imperiled.

[4] Protocol not yet in place.

Arctic and Boreal Breeding Surveys

A substantial amount of work has been carried out recently to develop breeding surveys for shorebirds in remote areas in the arctic and boreal regions. The current proposal has three components: (1) an extensive survey, to be carried out at 10-20 year intervals, using random sampling and methods that permit estimating abundance (not just an index to it) across all arctic and boreal regions of North America; (2) annual or semi-annual surveys at 10-20 non-randomly selected permanent shorebird sites using either index or density methods; and (3) collection of checklist data, using a standard protocol, at as many sites and as often as possible.

This program is based on the assumption that reliable information on breeding populations, as has been collected on waterfowl for many years, is also needed for shorebirds. Unlike waterfowl, breeding shorebirds cannot be counted by aerial surveys, and annual surveys on the ground of all or a large portion of northern North America would be prohibitively expensive. Thus, periodic surveys, to be carried out at an interval of 10-20 years, are proposed to provide reliable information on population size. This program will be augmented by surveys every 1 to 5 years at a series of sites selected non-randomly on the basis of practical issues such as high quality habitat, frequent visitation by shorebird biologists, and easy access. We expect to define a variety of protocols that would differ in methods, cost, and precision of estimates. The third component is a checklist program. A protocol is being developed that can be used any time qualified observers visit shorebird breeding areas. This component of the program will yield information from many more areas than the regular surveys. Taken together, these components will provide annual data from numerous, but non-randomly selected, sites and periodic comprehensive surveys that will provide essentially unbiased estimates of actual population size and thus of change in size since the last major survey. The program will provide information of value in many ways other than monitoring. For example, new information on distribution and local abundance will be collected as will information on how weather affects shorebird distribution and nesting activity. Providing regular reports on these topics will help ensure continued funding. The three major components of this approach are each described in more detail below.

Continental Survey

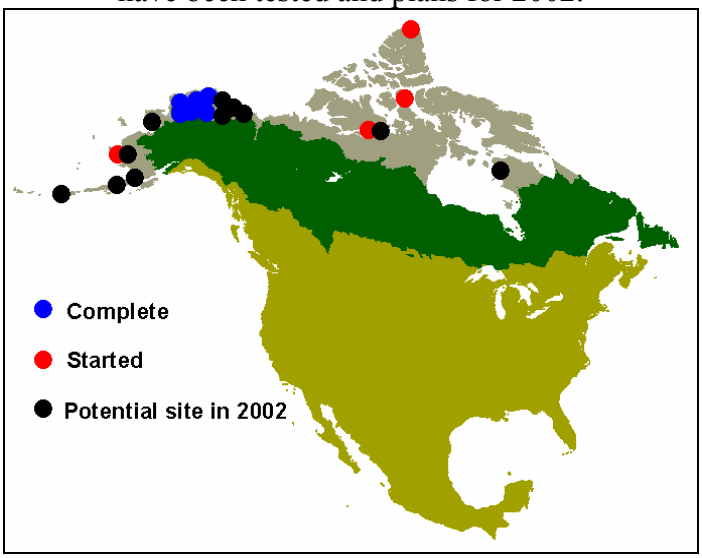
The continental surveys use a combination of GIS methods to select plots and a technique known as double sampling to collect the bird information. In much of the arctic, shorebirds are concentrated in irregularly shaped patches that cover only a small fraction of the landscape. Stratified sampling is therefore used to separate the good and less good habitat so that sampling effort can be concentrated in the higher quality areas. Patch borders are usually irregular so plot boundaries follow the natural borders. Thus, plots are of unequal size.

Double sampling, which is being used to estimate bird abundance on the sample plots, is a standard statistical method from the survey sampling literature (Cochran 1977,

Thompson 1992). When used to estimate bird density, the method involves one sample surveyed using a rapid method such as area searches, point counts, or variable circular plots counts, and a second subsample of these plots on which actual density is determined through intensive methods. The ratio of the result using the rapid method to actual density is used to adjust the results from the large sample of plots. The method yields unbiased estimates of density – and thus of trend in density – if the subsample is selected randomly and the intensive methods provide accurate counts. No assumptions are required about how the index ratio in the initial surveys varies with observer, time of day, habitat or other factors. Thus detection rates may vary, even considerably, with these factors. In addition to providing unbiased estimates of density, and thus trend in density, double sampling has several other advantages: (1) the rapid method can be changed as new methods become available, (2) domains can be compared even if detection rates differ (though separate estimates of the detection rates are then needed), (3) total population size can be estimated, and (4) valuable ancillary information (e.g., nest success) can be obtained on intensive plots with little additional effort. Double sampling has been used to survey waterfowl for many years (e.g., Eberhardt and Simmons 1987, Prenzlow and Lovvorn 1996) and has also been used occasionally in other wildlife studies (Handel and Gill 1992, Anthony et al. 1999). See Bart and Earnst (2002) for additional description of the method in bird surveys.

Results from the plot surveys are used to build regression models that predict the number of birds that would be recorded on rapid surveys covering each plot in the study area. The sum of these numbers is the estimated number that would be recorded if the entire study area were surveyed using the rapid method. This number is divided by the detection rate obtained from the intensive plots to produce an unbiased estimate of population size. For more details of the approach see "2001 Annual Report for the PRISM arctic shorebird surveys" on the PRISM web page (http://wss.wr.usgs.gov). Fig. 1 shows locations surveyed in 2001 and potential sites for 2002.

Fig. 1. Sites where the comprehensive surveys have been tested and plans for 2002.



Regular Surveys at Permanent Sites

These surveys will permit more intensive monitoring in a sample of areas that are of known importance to shorebirds. There are often sharp differences in spring weather from year to year at a given site, and surveys in consecutive years will help avoid erroneous conclusions caused by erratic weather conditions. Preference should be given to sites that are easy to access, or that host ongoing, long-term research programs and facilities, and that have high-quality shorebird habitat. Some sites should also be contained within existing protected areas (where there is reasonable certainty that sites will not be disturbed, and where wildlife-oriented habitat classifications of satellite data often exist). Possible sites for these surveys in arctic regions of Canada include Cambridge Bay, Victoria Island; East Bay Bird Sanctuary, Southampton Island; Polar Bear Pass National Wildlife Area, Bathurst Island; Truelove Lowland, Devon Island; Prince Charles Island, Foxe Basin; Coats Island; Dewey-Soper Bird Sanctuary, Baffin Island; Creswell Bay, Somerset Island; and Bathurst Inlet. In Alaska, possible sites in the arctic include the Arctic National Wildlife Refuge, Prudhoe Bay, the Colville River Delta, Barrow, Wainwright, and one or more locations in each of the six National Wildlife Refuges (Selawik, Yukon Delta, Togiak, Alaska Peninsula, Izembek, Alaska Maritimes) in western Alaska.

Potential sites in boreal regions have not yet been identified.

A Checklist Program

In 2001, the Canadian Wildlife Service started work on a network of arctic locations where the NWT/Nunavut Bird Checklist Survey will be conducted each year. Special consideration will be given to shorebirds in site selection. Checklist Survey data can be used to identify annual variation in shorebird distribution, breeding locations and breeding phenology, and over time it can provide a general indication of trends in distribution and abundance. Surveys are easy so the network of survey locations can be extended to other jurisdictions.

Boreal Regions

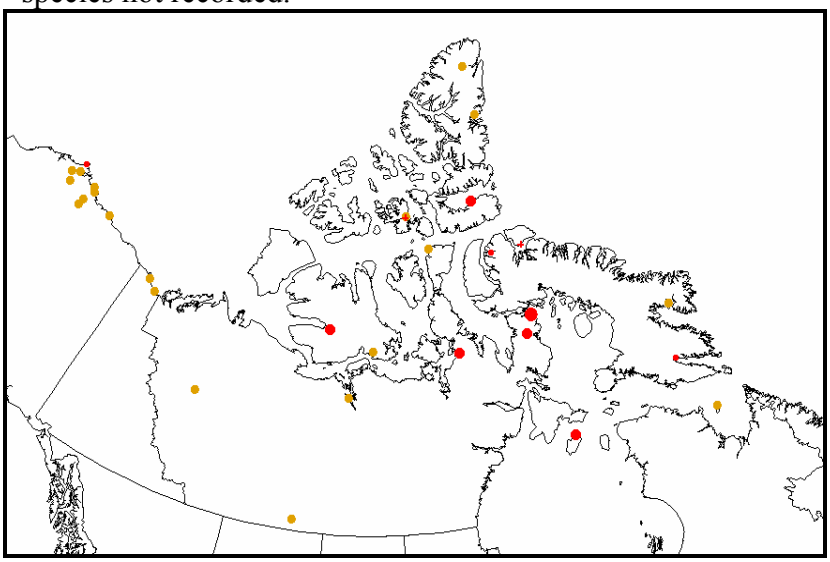
Seven shorebird species breed extensively (and in four cases largely) in boreal zones. It is not clear what method of monitoring will be most appropriate for boreal North America; different surveys may be needed for different species. In the Northwest Territories the Canadian Wildlife Service will test the use of “mini-BBS” routes (walking routes that will replace conventional driving routes in roadless portions of the Territory) to monitor population trends of boreal-nesting shorebirds such as common snipe and lesser yellowlegs. River BBS routes in Alaska have high encounter rates of boreal-breeding shorebirds. It may be possible to extend the double-sampling survey methodology south of the treeline. Aerial surveys to identify staging lakes might be coupled with breeding ground surveys to identify important areas within the boreal

region. More planning is needed before a boreal shorebird monitoring program is implemented. This effort should be coordinated with planning for boreal songbird monitoring as it is desirable to combine monitoring efforts for these two groups of birds.

Other Projects in Support of the Northern Surveys

An extensive literature review is being conducted to capture and summarize all existing information on the distribution and abundance of shorebirds nesting in boreal and arctic regions of North America. A considerable proportion of arctic shorebird data resides in unpublished government and industry reports that are not widely accessible. The literature review will make this information available for such purposes as selecting survey sites and estimating historical and recent population size. A map showing distribution and abundance for each species is being prepared from this database (Fig. 2). The database contains the following information: (1) location data (place name, geographic coordinates, habitat type); (2) species presence/absence; (3) species breeding status and general abundance; (4) species densities; and (5) literature citation.

Fig. 2. Example of the maps being prepared from the literature review of northern surveys. This map shows white-rumped sandpiper distribution. Red dots indicate locations with the species (large = abundant, medium = common, small = uncommon); yellow dots = species not recorded.



Natural history information of use to field surveyors in deciding how many individuals are nesting on plots they have surveyed is being compiled for each of the northern-nesting species. These “Survey Tips” are being prepared by species specialists following uniform guidelines prepared for this project. All accounts will be posted on a web site, and shorebird specialists will be invited to contribute their own observations to the accounts, which will be updated frequently.

An "Atlas of Beringian Shorebirds" is being created to increase access to the large amount of information collected on shorebird distribution, abundance, biology and

migration in Beringia (western Alaska, eastern Siberia and nearby areas) over the past two decades. Beringia is the most significant center of shorebird diversity within the Holarctic region. Numerous species, such as western sandpipers, Baird's sandpipers, pectoral sandpipers, and rock sandpipers, occur in both the Alaskan and Russian parts of Beringia. Several Beringian endemics have relatively small ranges in Russia (e.g., great knot) or Alaska (e.g., black turnstone) and several nesting species are rare and may require special protective measures (e.g., bristle-thighed curlew, spoonbill sandpiper). In addition, some species that nest in Northeast Asia migrate through Alaska enroute to wintering grounds in Central and South America. The Atlas and accompanying electronic database will be used to assess the status of specific shorebird populations in the region and identify future needs for management, research, and conservation.

Temperate Breeding Surveys

The breeding ranges of 17 shorebird species are mainly confined to the central, temperate region of North America, in the areas of Canada and the U.S. generally accessible by roads (Table 1). This group includes three species (spotted sandpiper, upland sandpiper, common snipe) where more than 2/3 of the breeding range also extends into northern areas considered inaccessible by road, and these species will also be monitored by the northern surveys. Priority for monitoring these 17 species mainly depends on the adequacy of their coverage under existing surveys, and their conservation needs and status. One species (piping plover) is listed as threatened under the ESA and covered by the International Piping Plover Census (Plissner and Haig 1997); another (mountain plover) is a Candidate 1 species under the ESA and will require a targeted single species survey developed by the recovery team, if it is listed. The American woodcock is presently being monitored by the North American Woodcock Singing-ground Survey (Tautin et al. 1983).

The Breeding Bird Survey (BBS) may adequately monitor four additional species. Species are considered adequately monitored by the BBS if the standard error of the estimated rangewide trend, expressed as a percent, is less than 0.9 and there is no reason to believe that bias (e.g., roadside bias) is especially large (Bart and Francis 2001). The SE criterion is met for killdeer, willet, upland sandpiper, and common snipe (Table 1), and is nearly met for spotted sandpiper (SE = 1.0) (Sauer et al. 2001, Bart and Francis 2001). An evaluation is needed to assess whether roadside or other bias is particularly large for these five species. Coverage under the BBS for these species, as well as for the American avocet and marbled godwit, could be improved by increasing in the number of routes and/or by reducing potential survey biases, and these options may be worth exploring. SEs for all other species, except the long-billed curlew, are >1.50 suggesting that even with substantial improvement, the BBS will not provide adequate coverage for them. Regardless, the ability of the BBS to monitor breeding shorebirds needs to be considered carefully for species with prioritization scores of 3 or less in the U.S. and Canadian shorebird plans.

High priority species, such as the long-billed curlew, will require specially designed monitoring programs. The U.S. and Canadian shorebird plans presently contain survey protocols for all these species on their breeding grounds, although these protocols have not been prioritized, analyzed for possible combinations, or subjected to peer review. The next step should be a formal peer review and analysis of the suggested protocols by people most familiar with or interested in the particular species. Priorities for surveys should be given to species with high conservation concerns (e.g. scores of 4 or 5) under the U.S. and Canadian shorebird plans and to combining species with similar ranges and natural histories. Of the species not adequately covered by existing surveys, three are highly imperiled (Snowy Plover, Mountain Plover, Long-billed Curlew) and six are species of high conservation concern (Wilson's Plover, American Oystercatcher, Black Oystercatcher, Marbled Godwit, Wilson's Phalarope) (Brown et al. 2001). Each

Table 1. Standard errors (SEs) for annual rates of change (expressed as a percent) for shorebird species breeding in accessible areas calculated from BBS data (Sauer et al. 2000).

Species	SE < 0.90	SE 0.91 to 1.30	SE 1.31 to 1.86	SE > 1.86
Killdeer	0.23			
Mountain plover				4.51
Black-necked stilt				2.00
American avocet			1.36	
Willet	0.80			
Spotted sandpiper		0.97		
Upland sandpiper	0.58			
Long-billed curlew		1.10		
Marbled godwit			1.38	
Common snipe	0.42			
American woodcock				2.13
Wilson's phalarope			1.57	

protocol should include a description of recommendations in the U.S. and Canadian shorebird plans, results of consultation with species specialists to consider alternative methods, and recommended approaches that warrant detailed design, peer review, and field evaluations, with eventual implementation. Species with lower conservation scores could be combined in surveys of the species of high concern.

One aspect that should be considered in the design and review of these new protocols is the use of 'direct' or 'unbiased' counts. Many specialists in avian population biology recommend that, whenever possible, new monitoring programs use methods that yield 'direct', or 'essentially unbiased' estimates of population density (e.g., counts when all birds are visible), rather than relying on indirect, or index, methods (Nichols et al. 2000, Bart and Francis 2001). The rationale for this recommendation is that too many sources of bias exist with index methods for high confidence in the trend estimates that they produce. An additional advantage is that they also yield essentially unbiased estimates of population size, and thus achieve the first PRISM goal. We believe that this recommendation should be followed whenever possible in designing new breeding surveys for accessible species of special concern, although this criterion is not met in existing surveys (e.g. BBS).

Currently, six species are adequately monitored by existing surveys (if bias is not a serious problem), and four other species might be adequately monitored by the BBS with increased effort. The remaining high priority species will require special programs. Highest priority should be given to those species considered highly imperiled or of high conservation concern (priority number 5 or 4 according to the U.S. and Canadian shorebird plans).

Temperate Nonbreeding Surveys

Surveys during the nonbreeding period will monitor use at stopover locations, elucidate habitat relationships during this period, and help local managers meet their shorebird management goals. There is some debate at present over whether nonbreeding counts can also provide useful information about population trend, some people believing this is possible for most species, others feeling the potential inaccuracies are so great that such surveys might be misleading too often to be of any value. Most people seem to be agreed that counts during the nonbreeding period in the foreseeable future will not provide sufficient reliability to be the only basis for trend estimation, and will, at a minimum, have to be supplemented by the breeding surveys discussed above. Because nonbreeding surveys will be carried out in many areas for other purposes, and because many people feel that they do have considerable potential as trend estimators, we believe that the issues should be explored in detail by identifying potential problems, designing a comprehensive survey to minimize them, and carrying out a careful assessment of reliability of the resulting program. This section discusses ways to implement this approach.

The rationale, and challenge, in using nonbreeding surveys to estimate trends in population size may be explained as follows. Suppose that each year about the same fraction of birds is in the study area during the study period, apart from random year effects, and that the survey provides a good estimate of this number. In this case, trend in the survey result will be a good estimate of trend in population size. On the other hand, suppose that the ratio of the survey result to population size gradually falls from 0.10 to 0.05 during several years. Then the survey result will suggest a 50% decline even if the population is actually stable. The key issue in designing and evaluating nonbreeding surveys is thus whether a long-term trend is likely in the ratio of the survey result to population size (the "index ratio"). Low precision of the survey result is also a possible problem, but investigation of this issue (Bart et al. 2002) shows that large enough samples can probably be obtained that sampling error will be relatively small (e.g., CVs < 0.15). The potential for bias is thus the major problem to be solved in designing the nonbreeding surveys.

We have identified three potential problems – referred to below as frame bias, selection bias, and measurement bias - that would cause a long-term trend in the index ratio, and thus cause bias in the trend estimate. The conditions under which each problem *could* arise are first identified below; then the conditions under which the problem *does* occur are identified. Frame bias is only possible if the study area does not include all the areas used by birds during the study period. Failure of the study area to include all birds does not necessarily cause bias but it does if there is a long-term trend in the proportion of the population that is in the study area during the study period. For example, if an average of 10% of the population is in the study area during the study period at the start of the monitoring program, but this fraction gradually falls to 5%, then the trend estimate will tend to suggest a 50% decline even if the population is stable.

Selection bias is only possible when some parts of the study area cannot be surveyed, usually due to access problems. The existence of non-surveyable areas does not necessarily cause bias but it does if any long-term trend exists in the proportion of birds that are in the non-surveyable areas. For example, if 50% of the birds are in non-surveyable portions of the study area initially but this fraction gradually falls to 25%, then the trend estimate will tend to suggest an increase even if the number of birds in the study area during the study period is actually stable. Selection bias could be combined with frame bias by *defining* the study area to be only the surveyable areas but we believe it is helpful to distinguish these potential problems and discuss them separately. Measurement bias is only possible when some of the birds in the surveyed areas are not recorded or more generally when the ratio of number recorded to number present does not equal 1.0. Ratios other than 1.0 do not necessarily cause bias but do if they exhibit a long-term trend. For example, if 50% of the birds are missed in the early years of the survey because they are hidden by vegetation, but this fraction falls to 25% because of changes in vegetation or survey methods, then the survey will tend to indicate an increase even if the number of birds present in the surveyed areas is stable.

Quantitative expressions for frame, selection, and measurement bias can be derived as follows (those not inclined towards mathematical presentations are urged to skip this paragraph). Assume the study area is subdivided into strata, that $\bar{y}_{jk}$ is the mean for stratum *k*, and that the survey result in year *j*, $\bar{y}_j$, is the sum of the stratum-specific results, $\bar{y}_j = \sum \bar{y}_{jk}$. Consider the following:

$$\begin{aligned}
\sum \bar{y}_{ij} &= \sum \bar{y}_{ij} \left(\frac{X_j^*}{X_j^*} \frac{\sum \bar{X}_{jk}}{\sum \bar{X}_{jk}} \frac{\sum \hat{\bar{X}}_{jk}}{\sum \hat{\bar{X}}_{jk}} \right) \\
&= X_j^* \left(\frac{\sum \bar{X}_{jk}}{X_j^*} \frac{\sum \hat{\bar{X}}_{jk}}{\sum \bar{X}_{jk}} \frac{\sum \bar{y}_{jk}}{\sum \hat{\bar{X}}_{jk}} \right) \\
&= X_j^* R_{Fj} R_{Sj} R_{Mj}
\end{aligned}$$

The first line is a tautology, the second line is a re-arrangement of the first line, and the third line simply defines new terms. Thus the expression above is true regardless of how the terms are defined. The terms can be defined, however, so that R_{Fj}, R_{Sj}, and R_{Mj} may be interpreted as sources of frame, selection, and measurement bias respectively. Let $\bar{X}_{jk}$ = the average number that would be recorded in stratum *k* with complete coverage during the study period in year *j* and let $\hat{\bar{X}}_{jk}$ = the estimate of $\bar{X}_{jk}$ from the survey. R_{Fj} is then the average proportion of the population, in year *j*, that is in the study area during the study period (the average is taken across all times in the study period within year *j*). R_{Sj} is the ratio of the estimated number that would be recorded with complete coverage (i.e., all locations being surveyed at all times) to the number that would actually be recorded with complete coverage. R_{Sj} would differ from 1.0 if some areas cannot be surveyed and estimates of the number that would be recorded there are inaccurate. R_{Mj} is the ratio of

number recorded in surveyed areas to number present there. We define the difference between number recorded and number present as measurement error. Measurement error does not necessarily cause any bias. Any long-term trend in R_{Fj}, R_{Sj}, or R_{Mj} (or more accurately a long-term trend in their product), however, does cause bias. We refer to the trends (possibly zero) in R_{Fj}, R_{Sj}, and R_{Mj} as frame, selection, and measurement bias respectively.

A detailed procedure has been developed to design the temperate, nonbreeding surveys. "Shorebird monitoring regions" were defined by intersecting a States and Provinces map with a Bird Conservation Regions map and eliminating small polygons. A separate sampling plan must be developed for each region that

(1) is based on all existing information on shorebird distribution and timing of use in the region,
(2) designates a survey period, usually 6-8 weeks in late summer and early fall, based on when shorebirds are present in the region,
(3) subdivides the region into (a) "Type 1" habitat that is regularly used by shorebirds and will be surveyed (usually by sampling) 3-6 times annually; (b) "Type 2" habitat that contains few, but some, shorebirds and will be surveyed every several years to document continued low use, and (c) "Type 3" habitat which is assumed to have virtually no shorebirds and will not be surveyed, and
(4) describes the monitoring plan including maps and detailed descriptions of areas to be surveyed along with survey protocols.

The potential for measurement error, measurement bias, and selection bias at the site, stratum, and regionwide level is also discussed, and pilot studies needed before the sampling plan can be completed are identified. The procedures for conducting these assessments, and examples of the products produced during the assessment, are available on the PRISM website, http://wss.wr.usgs.gov.

An assessment has been nearly completed for western Utah and is underway for western Oregon. Several groups around the country have volunteered to undertake assessment given guidance. There is thus a critical need for trained PRISM personnel to guide these efforts. One person has been hired to work Boise, Idaho, and the shorebird committee identified hiring a second person, to be stationed at Manomet, as one of the top priorities for 2002.

Current and Emerging Programs

Several programs exist at present to survey shorebirds during migration. The International Shorebird Survey (ISS) was started in 1974 by the Manomet Center for Conservation Sciences. Sites are visited every 10 days by volunteers during spring and fall. The ISS data files contain results from more than 35,000 surveys of approximately 1,700 sites widely distributed across the Western Hemisphere. About 1,300 surveys are added each year. ISS data helped spark the formation of the Western Hemisphere

Shorebird Reserve Network (WHSRN) and have been used to identify sites in North and South America that qualify for WHSRN site designation. ISS data have also been used to chart migration timing at key sites, and to develop a shorebird atlas. The ISS also sponsors workshops around the country that show managers how to maximize management returns by integrating the needs of wildlife species such as shorebirds and waterfowl.

The Maritimes Shorebird Survey (MSS) was started in 1974 by the Canadian Wildlife Service, and involves a network of volunteer observers who count shorebirds at a local study area once every two weeks during the spring and fall migration periods. The objective of the MSS was initially to provide information on the distribution, numbers and phenology of shorebirds passing through the Atlantic Provinces of Canada (NS, NB, PEI and NF), but the data have also proved valuable in assessing population trends. Overall nearly 400 sites have been covered at least once, with about 50 having been covered in 5 or more years. Data from the MSS and ISS have recently been combined, allowing for a more powerful analysis of trends.

The Western Shorebird Survey (WSS) was initiated in 2000 by the U.S. Fish and Wildlife Service and the U.S. Geological Survey to enhance shorebird monitoring during the non-breeding period, especially in the western United States where at present no comprehensive monitoring program exists. The program includes about 200 sites and is implementing many of the ideas described in the rest of this section.

Monitoring of shorebirds by the Canadian Wildlife Service in British Columbia has largely been in association with on-going research programs. The numbers of migrant western and least sandpipers on the south coast of British Columbia have been tallied since 1992. These censuses are made on the Fraser River delta and Sidney Island. Periodic surveys have been made of dunlin on the Fraser River delta and of black oystercatchers during seabird surveys of the coast. In addition, the volunteer-based British Columbia Coastal Waterbird Survey was initiated in 1999 by Bird Studies Canada and the Canadian Wildlife Service to assess the annual and long-term changes in population size and distribution of coastal waterbirds in British Columbia. More than 200 sites are included in the program. The program will provide data on wintering shorebird populations, such as dunlin, black oystercatchers and other rocky intertidal species.

Monitoring of shorebirds on the Canadian prairies (Alberta, Saskatchewan and Manitoba) by the Canadian Wildlife Service in partnership with the Saskatchewan Wetlands Conservation Corporation and Ducks Unlimited, has occurred over the past 15 years. This monitoring has primarily been in short term field studies directed at identifying potential WHSRN sites on specific wetlands or groups of wetlands. Planning is underway to develop a stronger monitoring effort on the prairies of important shorebird wetlands and lakes including WHSRN sites (designated and potential) by a partnership of wildlife agencies and volunteers. Currently, 25 selected wetlands have been surveyed extensively during the spring and fall migration periods each for a period of two years.

Observations are also submitted by volunteers on a few key wetlands across the prairies, but as yet, no consistent monitoring by a volunteer network is in place.

The South Atlantic Migratory Bird Initiative (SAMBI) Shorebird Survey was started in 1999. Presently 40 sites along the south Atlantic coast have committed to monitor shorebird migration. Shorebird numbers during migration (and wintering data at some sites) are collected using the ISS data format. Data are collected on or near the dates prescribed by the Southeastern Coastal Plains-Caribbean Regional Shorebird Plan, to allow for more direct intra- (and possibly inter-) regional comparison of shorebird movements. Survey numbers are entered via an internet site (http://samb.fws.gov/ref/index.html). Presently this site is only available to USFWS but will be available to all participants and the public in 2001. Survey data will be forwarded to the ISS. One of the primary objectives of this site is to allow coordinated management of impoundments for shorebird migration. Impoundment managers can view shorebird numbers at all the monitoring sites and fine tune their drawdown initiation to better coincide with shorebird migration. Beginning this spring the website will also allow USFWS managers to enter information on 1) the acres of impoundments being managed for shorebirds , 2) drawdown initiation dates and 3) the period the impoundments are available as shorebird habitat. Managers will be able to see the current "managed habitat goals" for their region, for the current migration period. (These goals for acres of impoundment habitat were developed in the Southeastern Coastal Plains-Caribbean Regional Shorebird Plan.) On the website, the acres of impoundments that other managers have planned for shorebird management will be contrasted with the goal. This will give managers a sense of how far away or close to the goal they are, influencing their water management plans for that migration period. At present, 15 National Wildlife Refuges are participating in the initial habitat management effort. The number of participants in the monitoring surveys and the habitat management surveys will increase once the website is made available to all SAMBI participants. SAMBI is a joint effort sponsored by the Atlantic Coast Joint Venture. Partners are USFWS, USFS, NPS, DU, TNC, Private Landowners and the states of Florida, Georgia, South Carolina, North Carolina and Virginia.

An effort is being made to integrate the ISS, MSS, and WSS, as well as any other programs interested in collaboration. The individual programs will continue but we hope to standardize approaches to site selection and data collection, develop a common data base, and increase efficiency by having each program take on certain responsibilities for the group.

Neotropical Surveys

There is clearly a need to evaluate the efficacy of surveys in Central and South America. Winter surveys may be especially valuable for species that primarily winter in southern South America (e.g., buff-breasted sandpiper, American golden-plover, Baird's sandpiper), for species which pose special problems during breeding and migration surveys (yellowlegs and some *Calidris* species), and for species which appear to be concentrated in certain areas in winter (black-bellied plover, ruddy turnstone, whimbrel; Morrison and Ross 1989). Aerial surveys of South America (Morrison and Ross 1989), Panama (Morrison et al. 1998), Central America (Morrison et al., in prep), and Mexico (Morrison et al., in prep.) identified major shorebird concentration areas along these coastlines. Additional information is available from some sites in the Caribbean. These sites could be included in the sampling frame for selection of monitoring sites. Specific issues of site access and survey timing would need to be developed for each survey site.

Surveys along the coasts of South America would sample several North American breeding species, such as the Hudsonian godwit; however, some shorebirds are dispersed among inland wetlands and grasslands. These areas also support austral shorebird migrants (e.g., rufous-chested dotterel), resident shorebirds (e.g., South American painted snipe), and other rare, endemic birds (e.g., ochre-breasted pipit). Approaches to estimate densities of wintering migrant shorebirds and residents could be adapted from methods developed for accessible, temperate breeding grounds. An initial step would be to identify sites in South America.

Cooperative shorebird projects are already underway in many parts of Latin America and the Caribbean (e.g., red knot project, WHSRN sites, western sandpiper project, Pan American Shorebird Project, identification of major sites in Baja, Mexico by the Point Reyes Bird Observatory). In addition, NABCI (North American Bird Conservation Initiative) emphasizes that bird conservation must be addressed internationally and linkages with other countries should be encouraged. We fully realize that monitoring is but one tool that can be used to accomplish the hemispheric conservation of shorebirds. We hope to use these projects and their underlying philosophies as a foundation to build a comprehensive monitoring strategy for shorebirds across the western hemisphere.

Many of the theoretical approaches previously outlined in this document are equally applicable to areas south of the U.S.- Mexico border. Close collaboration among colleagues in North, Central, and South America and the Caribbean is crucial to realistically assess the feasibility of implementing monitoring approaches at sites in Latin America and the Caribbean. Although numerous, effective partnerships currently exist, a wider network of shorebird enthusiasts needs to be encouraged. Conversely, knowledge of programs in other countries needs to be more widely distributed among shorebird workers in the U.S.

Among the recent recommendations of a Western Hemisphere Perspective Committee to the U.S. Shorebird Planning Council is a suggestion that shorebird monitoring protocols be "coordinated and compatible across the Western Hemisphere" and that we invite "participation of Latin Americans in development of these protocols."

Assistance to Local Managers

Providing assistance to local managers in meeting their shorebird conservation goals is one of the PRISM goals. Little work has been done on this goal to date because the monitoring program is not yet in place. A few examples, however, are beginning to emerge that illustrate ways in which the monitoring infrastructure can be of use to managers concerned about shorebirds. The South Atlantic Migratory Bird Initiative (see "Surveys During Migration and Staging in North America- Current and Emerging Programs" above) provides one excellent example. Another example is provided by The Point Reyes Bird Observatory which has hired a shorebird conservation specialist to work with local managers in implementing the Southern Pacific Regional Shorebird Conservation Plan. The Western Shorebird Survey developed an arrangement with the State of Utah to provide analytic assistance for their water bird survey in exchange for assistance in identifying shorebird survey sites and preparing survey protocols. The International Shorebird Survey has a long history of working with local managers on their conservation issues through holding workshops and providing direct technical assistance. Thus, a few cases exist in which people with monitoring and management expertise have joined forces. We hope that many more such collaborative efforts will occur during the next few years; promoting such efforts should be a major goal of the PRISM.

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Appendix: Shorebird Taxa

For further information, see Brown et al. 2001.

Species	Breeding Area	Wintering Area	Flyway(s) Used
American Oystercatcher			
Haematopus palliatus palliatus	Atlantic and Gulf coasts	Atlantic and Gulf coasts	Central, Atlantic
H. p. frazari	Formerly Channel Islands south into Baja	Formerly Channel Islands south into Baja, Mexico	Pacific
Black-bellied Plover			
Pluvialis squatarola squatarola	Alaska	Pacific coast and south	Pacific
P. s. cynosurae	N. Canada	Atlantic and Gulf coasts and south	Central, Atlantic
Snowy Plover			
Charadrius alexandrinus nivosus	Pacific coastal (Washington to Baja)	California to Baja	Pacific
C. a. nivosus	All other interior breeding birds and Atlantic coast birds	Southern USA and Mexico and Caribbean	Pacific, Central, and Atlantic?
C. a. tenuirostris	Gulf coast east of LA and Mexico	Caribbean, Cuba, Bahamas	Central, Atlantic
Piping Plover			
Charadrius melodus melodus	Atlantic coast	Atlantic and Gulf coasts, West Indies	Central?, Atlantic
C. m. circumcinctus	Great Lakes	Atlantic and Gulf coasts?	Central, Atlantic?
C. m. circumcinctus	Great Plains	Atlantic and Gulf coasts?	Central, Atlantic?

Species	Breeding Area	Wintering Area	Flyway(s) Used
Black-necked Stilt			
Himantopus mexicanus mexicanus	Continental USA	Coastal and interior sites along Pacific, Atlantic and Gulf coasts	Pacific, Central, Atlantic
H. m. knudseni	Hawaii	Hawaii	resident
Willet			
Catoptrophorus semipalmatus semipalmatus	Atlantic and Gulf coasts	Central and northern South America	Atlantic
C. s. inornatus	Northern Prairies and Great Basin	Pacific coast into Mexico, Gulf coast and perhaps Atlantic coast	Pacific, Central and Atlantic?
Solitary Sandpiper			
Tringa solitara solitara	British Columbia to e. Canada	Atlantic and Gulf coasts	Central, Atlantic
T. s. cinnamomea	Alaska to Mackenzie Delta	Mexico to South America	Pacific
Long-billed Curlew			
Numenius americanus americanus	Southern Great Plains from nw. Nevada into south central Texas	Pacific, Gulf and Atlantic coasts, Mexico	Pacific, Central, Atlantic
N. a. parvus	Northern Great Plains to Dakotas and n. Great Basin to ne. California	Pacific and w. Gulf states, Mexico	Pacific, Central
Whimbrel			
Numenius phaeopus hudsonicus	South and west coast of Hudson Bay	Atlantic and Gulf coasts?	Central, Atlantic
N. p. rufiventris	Alaska west to Melville Hills in NW Terr.	Pacific coast of USA south?	Pacific?

Species	Breeding Area	Wintering Area	Flyway(s) Used
Marbled Godwit			
Limosa fedoa fedoa	Great Plains	West coast into Mexico, Gulf coast	Pacific, Central
L. f. fedoa	Hudson Bay	se. U.S. coasts?	Atlantic?
L. f. beringiae	Alaska	Washington, Oregon and central California coasts?	Pacific
Hudsonian Godwit			
Limosa haemastica	Western and southern Alaska/ Mackenzie Delta	?	Pacific, Central
Limosa haemastica	Hudson Bay	?	Central, Atlantic
Ruddy Turnstone			
Arenaria interpres interpres	Alaska	Pacific islands and locally from California into Mexico	Pacific
A. i. interpres	High arctic Canada	Western Europe	Atlantic
A. i. morinella	Low arctic Canada	Atlantic and Gulf coasts	Central?, Atlantic
Rock Sandpiper			
Calidris ptilocnemis tschuktschorum	Mainland Alaska, St. Lawrence and Nunivak islands	SE Alaska into BC-WA	
C. p. ptilocnemis	Pribilofs, St. Matthew and Hall islands	Cook Inlet, AK	
C. p. cousei	Attu Island, Aleutians	Aleutians and Alaska Peninsula	
Purple Sandpiper			
Calidris maritima maritima	N. Canada, except east coast Hudson Bay	Europe	Atlantic
C. m. belcheri	east coast Hudson Bay	E. Canada and ne. USA	Atlantic

Species	Breeding Area	Wintering Area	Flyway(s) Used
Red Knot			
Calidris canutus rufa	Low arctic Canada	Southern South America	Atlantic
C. c. islandica	High arctic Canada	Western Europe	
C. c. roselarri	Alaska and Wrangel Island	California south to Atlantic and Gulf coasts	Pacific, Central?, Atlantic?
Dunlin			
Calidris alpina pacifica	Western Alaska	Pacific coast to Mexico	Pacific
C. a. arcticola	Northern Alaska	Asia	Pacific?
C. a. hudsonia	Central Canada	Atlantic and Gulf coasts	Central, Atlantic
Short-billed Dowitcher			
Limnodromus griseus griseus	Hudson Bay east to Ungava Bay	Central and South America	Central?, Atlantic
L. g. hendersoni	Canada, west of Hudson Bay	Atlantic and Gulf coasts, perhaps to n. South America	Central, Atlantic
L. g. caurinus	Southern Alaska	Pacific coast North America	Pacific