Trends in Canadian shorebirds

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Canadian Biodiversity: Ecosystem Status and Trends 2010
Technical Thematic Report No. 13
Published by the Canadian Councils of Resource Ministers

[1] All authors are with Environment Canada

Library and Archives Canada Cataloguing in Publication

Trends in Canadian shorebirds.

Issued also in French under title:
Tendances relatives aux oiseaux de rivage canadiens.
Electronic monograph in PDF format.
ISBN 978-1-100-20626-4
Cat. no.: En14-43/13-2012E-PDF

This report should be cited as:
Gratto-Trevor, C., Morrison, R.I.G., Collins, B., Rausch, J., Drever, M. and Johnston, V. 2011. Trends in Canadian shorebirds. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 13. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 32 p. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-1

PREFACE

The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[1] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[2] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[3] was a first report under this framework. It assesses progress towards the framework's goal of "Healthy and Diverse Ecosystems" and the two desired conservation outcomes: i) productive, resilient, diverse ecosystems with the capacity to recover and adapt; and ii) damaged ecosystems restored.

The 22 recurring key findings that are presented in *Canadian Biodiversity: Ecosystem Status and Trends 2010* emerged from synthesis and analysis of technical reports prepared as part of this project. Over 500 experts participated in the writing and review of these foundation documents. This report, *Trends in Canadian shorebirds*, is one of several reports prepared on the status and trends of national cross-cutting themes. It has been prepared and reviewed by experts in the field of study and reflects the views of its authors.

Acknowledgements

We thank the coordinators and hundreds of skilled volunteers in Canada who have participated in the Breeding Bird Survey and migration monitoring programs such as the Atlantic Canada Shorebird Survey, Quebec checklist program, Ontario Shorebird Survey, and the Arctic Program for Regional and International Shorebird Monitoring. Information on trends of migrating shorebirds in British Columbia were based on surveys organized by R. Butler and M. Lemon. We would also like to thank Dr. E. Krebs, Science and Technology Branch, Environment Canada, for her comments on the manuscript.

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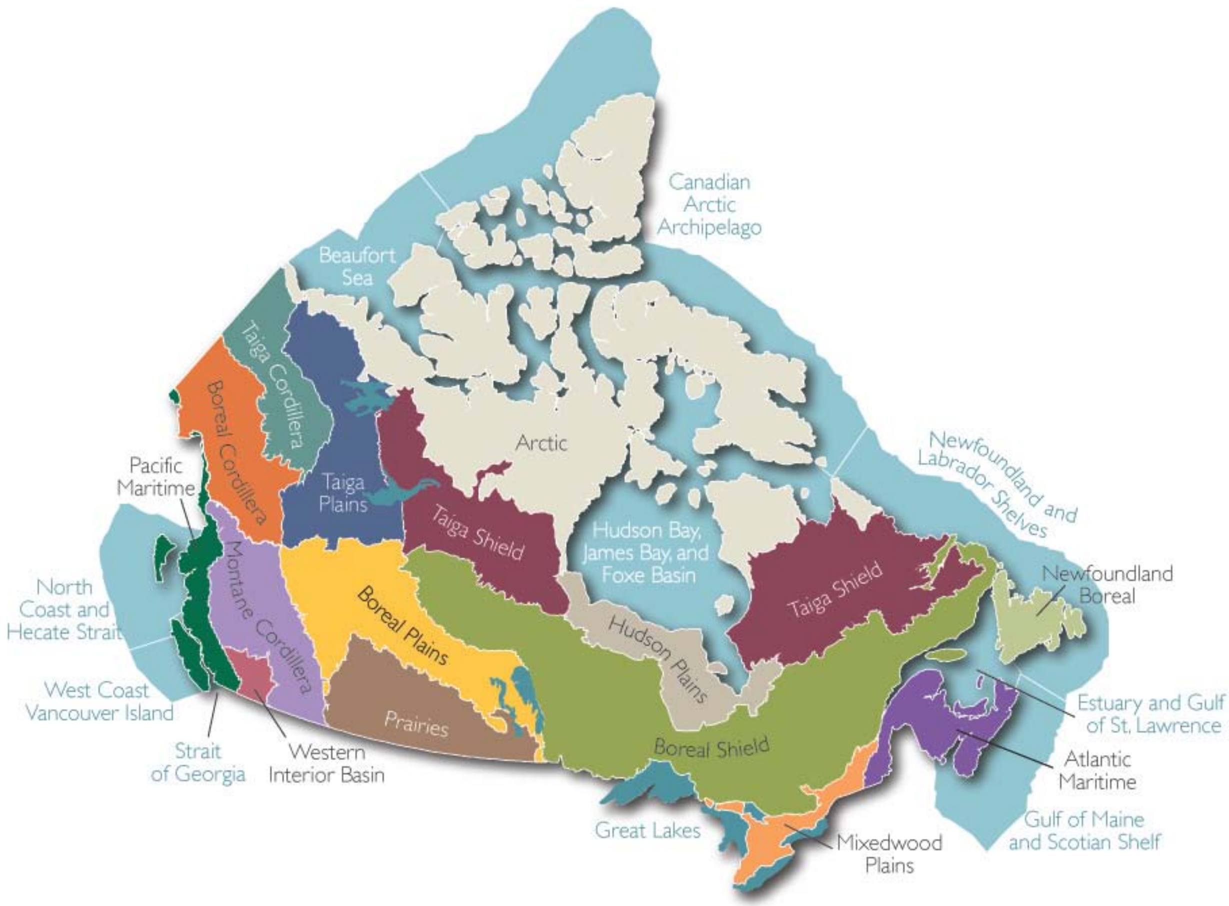
[1] Environment Canada. 2006. Biodiversity outcomes framework for Canada. Canadian Councils of Resource Ministers. Ottawa, ON. 8 p. http://www.biodivcanada.ca/default.asp?lang=En&n=F14D37B9-1

[2] Federal-Provincial-Territorial Biodiversity Working Group. 1995. Canadian biodiversity strategy: Canada's response to the Convention on Biological Diversity. Environment Canada, Biodiversity Convention Office. Ottawa, ON. 86 p. http://www.biodivcanada.ca/default.asp?lang=En&n=560ED58E-1

[3] Federal, Provincial and Territorial Governments of Canada. 2010. Canadian biodiversity: ecosystem status and trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 p. http://www.biodivcanada.ca/default.asp?lang=En&n=83A35E06-1

Ecological Classification System – Ecozones+

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,[4] provided the ecosystem-based units for all reports related to this project. Modifications from the original framework include: adjustments to terrestrial boundaries to reflect improvements from ground-truthing exercises; the combination of three Arctic ecozones into one; the use of two ecoprovinces – Western Interior Basin and Newfoundland Boreal; the addition of nine marine ecosystem-based units; and, the addition of the Great Lakes as a unit. This modified classification system is referred to as "ecozones+" throughout these reports to avoid confusion with the more familiar "ecozones" of the original framework.[5]



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[4] Ecological Stratification Working Group. 1995. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch. Ottawa/Hull, ON. 125 p. Report and national map at 1:7 500 000 scale.

[5] Rankin, R., Austin, M. and Rice, J. 2011. Ecological classification system for the ecosystem status and trends report. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 1. Canadian Councils of Resource Ministers. Ottawa, ON. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-1

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INTRODUCTION

Canada has a significant responsibility with respect to shorebirds because it contains a considerable proportion of North American breeding habitat (especially in the Arctic) and very important staging sites on the coasts and in the interior of the country. A total of 47 species breed or occur regularly in Canada, and approximately a third of those have more than half of their global breeding range in Canada (Donaldson et al., 2000). Trend data exist from several monitoring schemes. Migration surveys such as the Atlantic Canada Shorebird Survey (ACSS) (Morrison et al., 1994), Ontario Shorebird Survey (OSS) (Ross et al., 2001), and Quebec checklist (Aubry and Cotter, 2007) have provided information on trends in shorebird numbers, particularly for Arctic breeders migrating through the east. The Breeding Bird Survey (BBS) (Sauer et al., 2008) provides trend information for some southern or boreal breeding species, although this roadside singing bird survey is not optimally designed for most shorebirds, particularly those associated with wetlands. It works best for shorebirds such as Killdeer (*Charadrius vociferus*) and Upland Sandpipers (*Bartramia longicauda*). Species such as the Piping Plover (*Charadrius melodus*) have dedicated surveys on the breeding grounds in Canada. Studies in specific arctic areas have shown trends at some sites (for example Rasmussen Basin), and winter surveys in South America have been used to show trends in species such as Red Knot (*Calidris canutus*). The PRISM (Program for Regional and International Shorebird Monitoring) Arctic Surveys Program (Bart et al., 2005) will eventually provide trend information across the Canadian Arctic. Currently, survey coverage for this group of birds is rather patchy.

This report describes our knowledge of shorebird[6] trends in Canadian regions with significant shorebird use. Trends of most Canadian shorebirds appear to be negative. Potential causes of declines include: loss and degradation of coastal, wetland, and grassland habitat (during breeding, migration stop-overs, and wintering); climate (such as cooling eastern Arctic, El Nino, and droughts); changes in predator regimes (for example increased predation pressure due to a decrease in trapping of foxes or decline in DDT resulting in an increase in raptors); human disturbance; contaminants; and disease (Donaldson et al., 2000). Declining trends in shorebird numbers are of particular concern because shorebird populations are often slow to recover owing to their relatively low reproductive rate (small clutch size of four eggs, little renesting (especially in the Arctic), and usually delayed age of first breeding), longevity, and often low global population numbers. In addition, shorebirds are thought to be highly vulnerable to climate change because most are dependent on shallow water habitats for foraging during breeding, migratory staging, and wintering, and many breed in the Arctic where climate change is expected to be most extreme. Many species undergo long migrations between Arctic breeding and South American wintering sites and must time migrations to coincide with peak invertebrate productivity and/or availability at staging sites in order to acquire enough

[6] A list of common and latin names for shorebirds discussed in this report is provided in Appendix 1.

resources for their long over-water nonstop flights. The habit of many species to flock in large numbers at specific staging and wintering sites can make a large percentage of the population vulnerable to catastrophic events such as oil spills or storms, and their intertidal foraging habitat is vulnerable to rising sea levels and development.

ECOZONE+ TRENDS

Atlantic Maritime Ecozone+

The Atlantic Maritime Ecozone+ forms part of the Atlantic Northern Forest Bird Conservation Region (BCR 14 in Canada). Although this ecozone+ supports a number of breeding shorebird species, it is most important for migrant shorebirds, with coastal habitats – especially those around the Upper Bay of Fundy – of pivotal importance as key stop-over and refueling areas for various species, particularly the smaller sandpipers (Morrison, 1977; Morrison and Harrington, 1979; Hicklin, 1987). Trend estimates for migrant shorebirds are derived from the Atlantic Canada Shorebird Survey (ACSS) (previously Maritimes Shorebird Surveys (MSS)), while breeding shorebird trends can be estimated from BBS data from Canadian sites in the Atlantic Northern Forest BCR (Sauer et al., 2008).

Migrating birds

Numbers of shorebirds passing through the Canadian Atlantic provinces have declined greatly since surveys were started in 1974 (Morrison et al., 1994; Morrison et al., 2001; Morrison and Hicklin, 2001; Bart et al., 2007). Updated analyses of ACSS data confirm this (Table 1). Between 1974 and 2006, for 15 species of shorebirds for which sufficient data were available, five species showed statistically significant negative trends, including Red Knot, Least Sandpiper (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), Black-bellied Plover (*Pluvialis squatarola*), and Ruddy Turnstone (*Arenaria interpres)*. No other trends were statistically significant, but only two species (Semipalmated Plover (*Charadrius semipalmatus*) and Whimbrel (*Numenius phaeopus*)) showed positive trends, whereas 13 showed negative trends. These results show a significant tendency towards declines ($\chi 2 = 8.07$, df1, $P<0.005$) (Morrison and Collins, unpublished data).

Table 1. Trends in abundance of shorebirds migrating through coastal areas of the Atlantic Maritime Ecozone⁺, 1974-2006.

Species	Trend (% per year)	P	Abundance Index				Change (%)
			1970s	1980s	1990s	2000s	
Red Knot	-10.9	*	39.5	11.2	9.1	3.3	-97.5
Least Sandpiper	-6.6	*	80.7	22.2	9.8	11.6	-88.8
Lesser Yellowlegs	-5.0	*	29.2	52.2	16.4	9.8	-80.6
Semipalmated Sandpiper	-4.9		5170.9	4892	2623.7	3074.5	-80.0
Black-bellied Plover	-3.0	*	51.0	43.1	23.0	26.7	-62.3
Dunlin	-2.8		26.3	28.6	11.4	15.5	-59.7
Ruddy Turnstone	-2.8	**	13.2	10.9	11.4	4.2	-59.7
Short-billed Dowitcher	-2.7		292.8	281.7	39.6	141.0	-58.4
Sanderling	-2.3		42.9	34.7	19.8	24.0	-52.5
Greater Yellowlegs	-0.9		13.0	12.8	9.8	10.8	-25.1
Hudsonian Godwit	-0.9		5.5	4.1	3.5	2.9	-25.1
Willet	-0.8		16.6	15.9	11.1	14.1	-22.6
White-rumped Sandpiper	-0.2		16.1	15.3	12.6	16.4	-6.2
Semipalmated Plover	1.9		103.8	123.0	153.1	159.3	82.6
Whimbrel	2.5		1.9	1.5	3.1	4.3	120.4

Change is the percentage change over the entire period calculated from the overall trend (% per year).
Significance (P): * P<0.05, ** P<0.01
Source: Morrison and Collins, unpublished data

Negative trends generally predominated during the 32 year period of the surveys: they outnumbered positive trends in the 1970s, 1990s, and 2000s, and were especially pronounced in the 1990s. The 1980s was the only decade in which positive trends outnumbered negative ones (Morrison and Collins, unpublished data).

Red Knots are considered a flagship species in shorebird conservation because of their long migrations between breeding and wintering areas and their tendency to concentrate in large numbers in a few favoured locations. Numbers in the Atlantic Provinces reached a peak in the late 1970s and early 1980s, but by the mid-1990s had fallen to very low levels (Figure 1). These declines reflect the declines that have occurred in Western Hemisphere populations of knots (Morrison et al., 2004). The populations wintering in Tierra del Fuego and Florida were assessed Endangered and Threatened, respectively, in 2007 (COSEWIC, 2007).

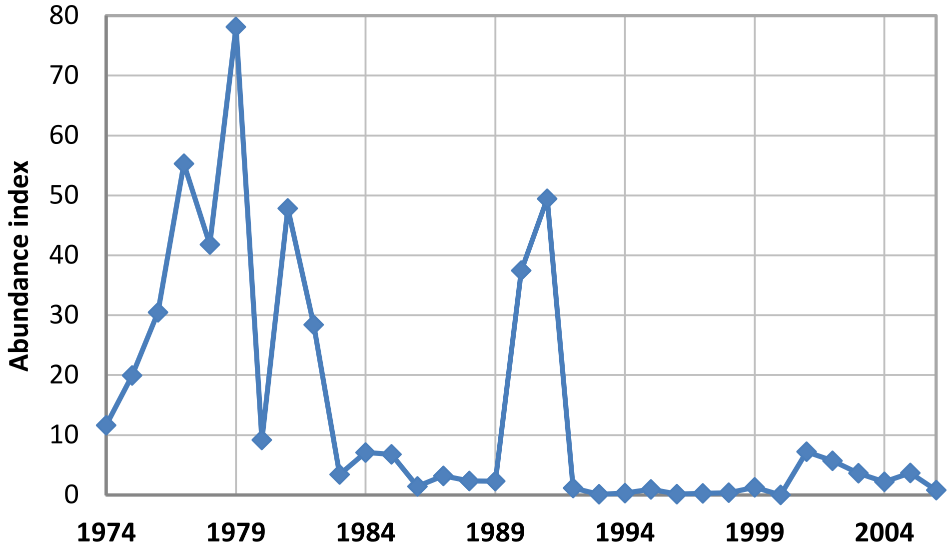

Figure 1. Trends in numbers of Red Knots migrating through the Atlantic Maritime Ecozone[+]*, 1974-2006. Source: Morrison and Collins, unpublished data*

The reasons for the observed shorebird declines in Atlantic Canada are not completely understood. Changes, such as increases in raptors, have occurred in coastal habitats used by shorebirds that could affect use of historic shorebird staging sites, or how long the birds remain in those areas (length-of-stay), and might result in decreased counts of shorebirds at some migration areas (Hicklin, 2001), without a decrease in total population numbers. However, it is likely that the negative trends for at least some species reflect real population declines caused by factors in other parts of the migration ranges of the birds. Declines in Red Knots, for instance, are thought to be caused mainly by the birds being unable to gain sufficient weight during spring migration through Delaware Bay owing to overharvesting of horseshoe crabs (*Limulus polyphemus*), leading to a decline in crab eggs, the main food source of the knots (COSEWIC, 2007). The result was a steep decline in the survival of the knots (Baker et al., 2004).

Other potential causes of declines include: loss and degradation of coastal, wetland, and grassland habitat during wintering, climate (such as cooling eastern Arctic), changes in predator regimes (for example increased predation pressure due to a decrease in trapping of foxes or decline in DDT resulting in an increase in raptors), human disturbance, contaminants, and disease (Donaldson et al., 2000). Migrant shorebirds that are declining in eastern Canada include a diverse array of species of different sizes and ecology – such as plovers, sandpipers, yellowlegs, and turnstones – suggesting a variety of problems with wetland habitats used by the birds.

Breeding birds

Relatively few species of shorebirds breed in the Atlantic Maritime Ecozone+. Nevertheless, trends can be calculated for the six species of shorebirds occurring on BBS routes (Figure 2). All six showed declines. Two species showed significant declines: Killdeer (-2.5% per year, P<0.001), a short distance migrant that is also declining significantly across its Canadian range (-3.2% per year, P<0.001), and Wilson's Snipe (*Gallinago delicata*) (-2.6% per year, P<0.01), which breeds in wetlands, but which shows a positive trend across Canada (0.5% per year, not significant) owing to population increases in the western part of its range. The decline of the other four species was not significant.

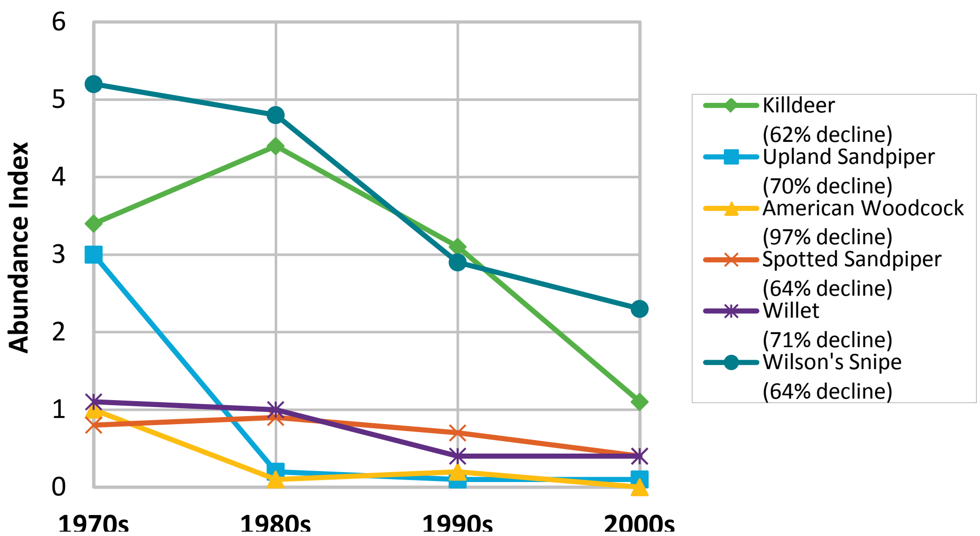

Figure 2. Trends in abundance of shorebirds breeding in the Atlantic Maritime Ecozone+.
Change indicates the percentage change over the period of the surveys (1968-2006) calculated from the trend. Killdeer and Wilson's snipe declines are significant (-2.5% per year, P<0.001 and -2.6% per year, P<0.01 respectively)
Killdeer is a short distance migrant; Upland Sandpiper is a grassland bird, American Woodcock (Scolopax minor) is a successional/shrub bird; others are wetland birds
Source: Breeding Bird Survey (Sauer et al., 2008)

Mixedwood Plains Ecozone+

The Mixedwood Plains Ecozone+ is equivalent to the Lower Great Lakes/St. Lawrence Plain BCR (BCR 13), extending through southern Ontario north of the Great Lakes and into Quebec along the shores of the St. Lawrence River. Migrant shorebirds make use of lake and river shoreline habitats and associated wetlands, as well as sewage lagoons. Some information is available on trends from the OSS. Five species breed regularly in a variety of habitats and are covered by the BBS.

Migrating birds

The only information currently available for migrant shorebirds in this ecozone+ is from the OSS for 1976 to 1997 (Ross et al., 2001). A summary of the results from these data is shown in Table 2. Shorebirds migrating through the ecozone+ form three broad groups: 1) species that breed in the Arctic and stop at the small-scale, relatively dispersed stop-over sites in southern Ontario en route to the east coast of North America; 2) species that breed to the north throughout the boreal forest; and 3) species with a widespread breeding distribution throughout Ontario, which include individuals from both local populations and those breeding farther north.

Table 2. Trends of shorebirds counted at sites in southern Ontario by the Ontario Shorebird Survey, 1976-1997.

Species	n sites	Trend (% per year)	P	Guild
Black-bellied Plover	11	4.33		Arctic
Dunlin	10	1.42		Arctic
Least Sandpiper	19	-4.19		Arctic
Pectoral Sandpiper	17	-8.34		Arctic
Sanderling	10	-1.25		Arctic
Semipalmated Plover	16	-1.97		Arctic
Semipalmated Sandpiper	18	-4.97	*	Arctic
Solitary Sandpiper	11	-1.61		Boreal
Short-billed Dowitcher	10	-6.35		Boreal
Lesser Yellowlegs	22	-7.13		Boreal
Greater Yellowlegs	16	-7.65		Boreal
Spotted Sandpiper	19	-2.25		Widespread
Wilson's Snipe	10	-15.26	*	Widespread
Killdeer	23	-2.23		Widespread
n negative trends		12		
n positive trends		2		
chi-square, df		7.14,1		
P		**		

Significance (P): * = 0.5<P<0.1, ** = <0.05

Source: adapted from Ross et al. (2001)

Declines were widespread, occurring in all groups. Negative trends (14) significantly outnumbered positive trends (2); negative trend values tended to be high, but were not significant owing to high inter-year variation in counts and small sample sizes. Only the Semipalmated Sandpiper showed a significant negative trend, a phenomenon occurring in many other regions.

Breeding birds

Five species of shorebirds, occupying a variety of habitats, were detected on BBS routes (Figure 3). With the exception of Wilson's Snipe, where no trend was detected, trends were negative, with Killdeer and Spotted Sandpipers (*Actitis macularius*) showing significant declines. Both species also showed significant negative Canada-wide trends (-3.2%per year, P<0.001; -2.0% per year, P = 0.005, respectively), as well as negative trends at migration areas (see Table 2).

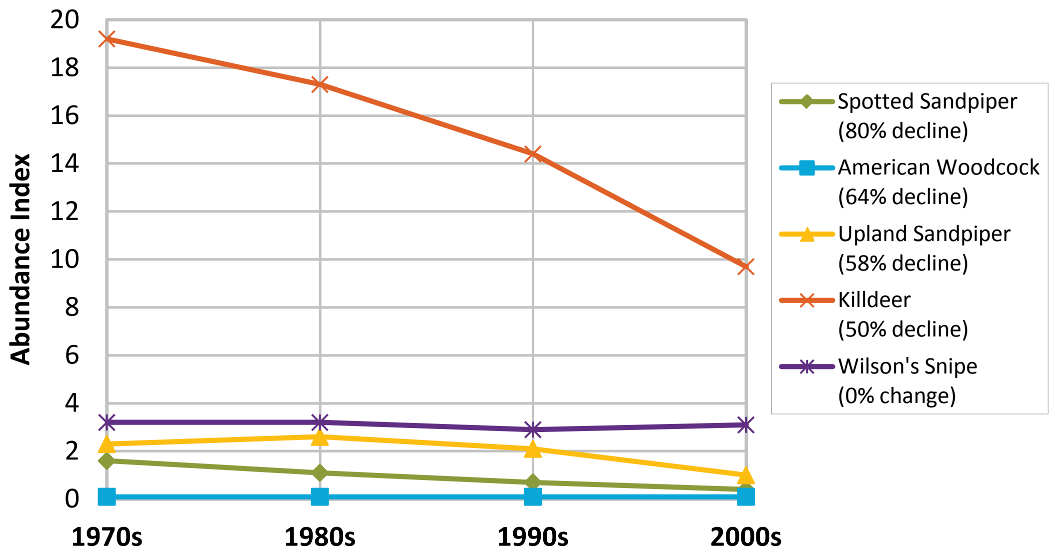

Figure 3. Trends in abundance of shorebirds breeding in the Mixedwood Plains, 1968-2006. Percentages in brackets represent the change in abundance index between the 1970s and 2000-2006. Guilds: short distance migrant (Killdeer); wetland (Spotted Sandpiper and Wilson's Snipe);grassland (Upland Sandpiper), successional/shrub (American Woodcock).
Killdeer decline (-1.8% per year) is significant at P<0.001; Spotted Sandpiper decline (-4.0% per year) is significant at P<0.01; Upland Sandpiper decline (-2.2% per year), American Woodcock (-2.6% per year) and Wilson's Snipe (0% change) are not significant.
Source: adapted from the Breeding Bird Survey (Sauer et al., 2008)

Prairies Ecozone+

The Prairies Ecozone+ provides important habitat for both breeding and migrant shorebirds including eight species whose breeding range in Canada is primarily or entirely in the Prairies (American Avocet (*Recurvirostra americana*), Marbled Godwit (*Limosa fedoa*), Piping Plover, Wilson's Phalarope (*Phalaropus tricolor*), Black-necked Stilt (*Himantopus mexicanus*), Willet (*Tringa semipalmata*), Long-billed Curlew (*Numenius americanus*), and Upland Sandpiper). In addition, the only reported (but rare) breeding occurrences of Mountain Plover (*Charadrius montanus*) and Snowy Plover (*Charadrius alexandrinus*) in Canada have been in this area. Thirty-one species of shorebirds regularly migrate through the Prairies, which provide important staging sites during both spring and fall. For migrants, from a national perspective, the Prairies are most important in the spring. Species such as Sanderling (*Calidris alba*), Red-necked Phalarope (*Phalaropus lobatus*) and White-rumped Sandpiper (*Calidris fuscicollis*) stage there in large numbers. In the fall, this region is important to Baird's Sandpiper (*Calidris bairdii*), Pectoral Sandpiper (*Calidris melanotos*), Buff-breasted Sandpiper (*Tryngites subruficollis)*, and Hudsonian Godwit (*Limosa haemastica)*, and in both spring and fall to Stilt Sandpiper (*Calidris himantopus*), Lesser Yellowlegs, and Semipalmated Sandpiper (Gratto-Trevor et al., 2001). Populations of shorebird species usually number in the tens to hundreds of thousands, with a few in the low millions, compared to much higher numbers for many landbird and waterfowl species (Morrison et al., 2006). Shorebird species are also characterized by low annual reproduction (four eggs and often little renesting) and high adult survival, so any declining trend is of concern when it reflects declines in productivity or survival, and not changes in movement patterns.

Migrating birds

The Prairies Ecozone+ is very important to shorebird migrants, many of which nest in the Arctic or boreal (Skagen et al., 1999). Based on abundance, this ecozone+ is most important during migration for the following species: Sanderling (spring), Red-necked Phalarope (spring), White-rumped Sandpiper (spring), Stilt Sandpiper (spring and fall), Baird's Sandpiper (fall), Pectoral Sandpiper (fall), Buff-breasted Sandpiper (fall), Hudsonian Godwit (fall), Lesser Yellowlegs (spring and fall), and Semipalmated Sandpiper (*Calidris pusilla*: spring and fall) (Alexander and Gratto-Trevor, 1997; Gratto-Trevor et al., 2001).

Wetland conditions in the Prairies are prone to large inter- and intra-year variations in water levels. Since shorebirds forage in shallow wetlands, which are most affected by these changes, there is considerable variation in shorebird use of specific wetlands between seasons and years, as some become dry and others are too flooded (for example, Figure 4).

Figure 4. East side of Big Quill Lake Saskatchewan: beaches are >1 km wide in dry years (left), while virtually no shoreline habitat remained in the wet year of 2007 (right).
Photos © C. L. Gratto-Trevor

In some years some species (such as White-rumped Sandpiper) stage in prairie Canada in spring in very large numbers when conditions in the mid-western states are too dry. In other years, most White-rumped Sandpipers over-fly prairie Canada if conditions in the United States are favourable (Harrington et al., 1991). Therefore, although we have information from certain wetlands and years on numbers of specific shorebird species, we have no way of measuring population trends in prairie shorebird migrants at this time, and no surveys initiated to measure such trends in the future. Some trend information may be obtained from surveys elsewhere (such as in the Arctic) for particular species, but it is difficult to know whether they are examining the same populations that move through prairie Canada. A further complication is that one does not necessarily have birds from the same breeding area migrating through prairie Canada in the spring versus the fall. For example, spring Semipalmated Sandpipers originate from the central Canadian as well as western Arctic, while fall migrants are entirely of western Arctic origin, and the central Arctic birds move south through the Atlantic coast (Gratto-Trevor and Dickson, 1994).

However, declines in shorebirds elsewhere in Canada and the United States suggest a potential problem (Donaldson et al., 2000; Brown et al., 2001), and future climate change is likely to decrease numbers of shallow prairie wetlands.

Breeding birds

While most North American shorebirds breed in the Arctic, the next highest number breed in interior grasslands and the breeding distribution of several species in Canada is restricted entirely to the Prairies. Of the seven priority prairie breeders noted in the *Prairie Canada Shorebird Conservation Plan* -- Piping Plover, Long-billed Curlew, Marbled Godwit, Willet (western subspecies), American Avocet, Wilson's Phalarope, and Upland Sandpiper (Gratto-Trevor et al., 2001) – all but Piping Plover are covered to some extent by the BBS. That survey was not designed for non-singing, often wetland associated species however, so trend information from the BBS is more appropriate for some shorebird species than others. For the seven species listed above, trends for Upland Sandpipers are probably most accurate, and Long-billed Curlews (low numbers), American Avocet, and Wilson's Phalarope (wetland species) least useful. Primarily this means that trends are unlikely to be statistically significant. Nevertheless, since no other consistent surveys for these species exist, BBS results for all (except Piping Plover) are shown in Figure 5.

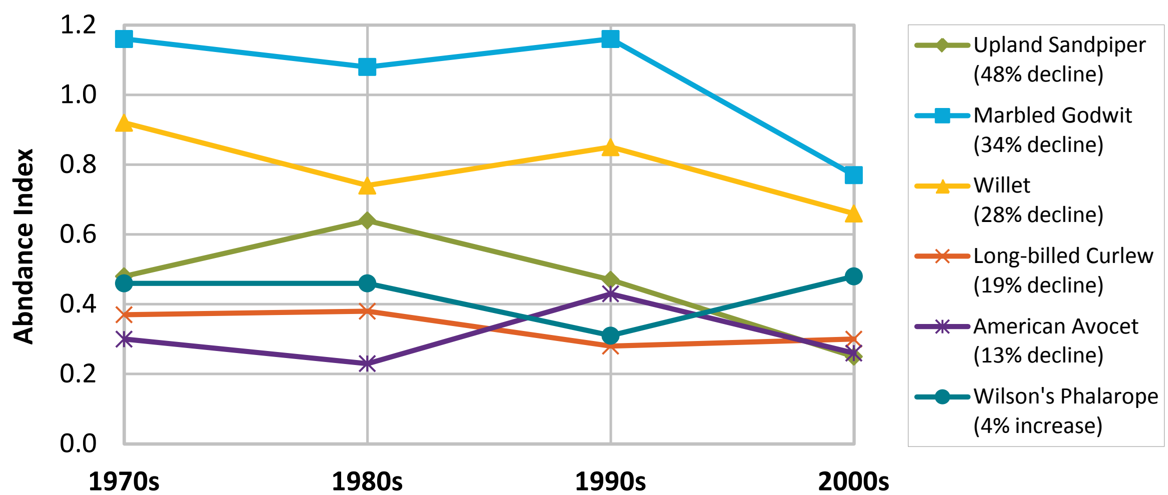

Figure 5. Trends in abundance of priority Prairies Ecozone+ shorebird breeders, 1970s-2000s.
Percentages indicate change from the 1970s to 2000s.
Marbled Godwit is the only significant decline (-1.1% per year)
Source: Breeding Bird Survey (Sauer et al., 2008)

The only statistically significant decline is in Marbled Godwit, which is important as approximately 60% of the world population breeds in prairie Canada (Gratto-Trevor, 2000). All of the other upland breeding species (Upland Sandpiper, Willet, and Long-billed Curlew) show a decrease in the BBS Abundance Index between the 1970s and 2000s, although overall trends are not significant. This decline is thought to be related to continued loss of ephemeral wetland habitat, which is likely to be exacerbated by future climate change.

Trends in Piping Plovers (assessed as Endangered in Canada by COSEWIC), are determined by a census carried out every five years throughout the breeding range of the species (United States and Canada), starting in 1991 (Figure 6). The prairie Canada population was at a low in the 2001 census, but had increased again in 2006 to the 1996 level. The increase between 2001 and 2006 appears to be due to improvements in habitat conditions (fewer droughts, floods, and hail at hatch, plus management efforts in protecting nests with exclosures in some areas). Since 2006, conditions in Saskatchewan (where the majority of the prairie Canada population breeds) have been poor, and productivity low. One important breeding area, Big Quill Lake, has been flooded (a fifty year high) since 2007, and another, Lake Diefenbaker (a reservoir), flooded four years in a row (2005 through 2008) from run-off and rains in Alberta. A drought resulted in many Missouri Coteau wetlands (southern Saskatchewan) being dry in 2008. Shorebirds are often affected by flood and drought cycles in the west, as the wetlands they use for foraging and chick rearing are usually very shallow.

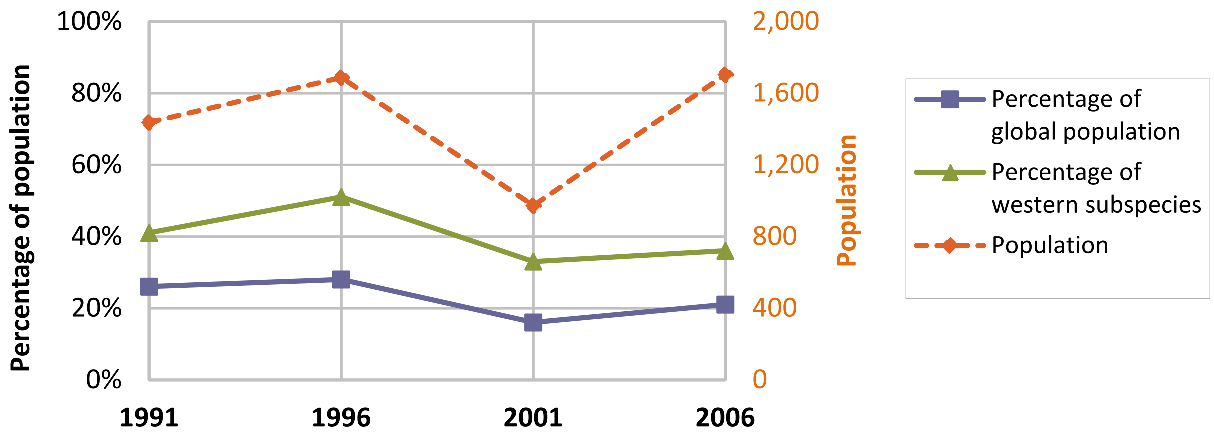

Figure 6. Trends in numbers of Piping Plovers in prairie Canada, 1991-2006.
Ten year change is 1% increase in total number.
Secondary y-axis is population and is represented on brown dotted line
Sources: adapted from the following sources for specified years: 1991 (Haig and Plissner, 1993), 1996 (Plissner and Haig, 2000), 2001 (Ferland and Haig, 2002), and 2006 (Elliott-Smith et al., 2009)

Pacific Maritime Ecozone+

A comprehensive shorebird monitoring plan for the Pacific Maritime is still in development, although existing information suggests that species that breed within British Columbia are steady or declining, and that most wintering and migrating species show stable population trends (see below). However, the uncertainties and the limited scope of these surveys suggest that results should be interpreted with caution, and continued attention should be paid to shorebird species within this ecozone+.

Population trend estimates for 1999 to 2009 are available for some species in British Columbia. These trend estimates are derived from data from the BBS, the BC Coastal Waterbird Survey, spring migration monitoring in the Fraser River Delta, and fall migration monitoring in the Strait of Georgia. These data sources cover different areas and suites of species, but represent the best available data on trends in shorebird abundance in British Columbia during the breeding, wintering, and migration seasons. Although both the BBS and migration monitoring can provide trend information prior to 1999, the BC Coastal Waterbird Survey only provides information for 1999 to 2009, and we therefore restricted trend analyses to this time period to allow comparisons. No migration monitoring occurred in 1998, so data for migration monitoring were extended to 1997.

Migrating birds

Migration monitoring in British Columbia has focused on counts during the spring at Brunswick Point on Roberts Bank in the Fraser River Delta and on fall counts of mudflats on Sidney Island in the Strait of Georgia. Numbers of Western Sandpipers counted on Brunswick Point vary widely from year to year, and have a non-significant trend (Table 1, Figure 7). Dunlin at Brunswick Point increased in abundance between 1997 and 2009. Fall migration counts of Western Sandpipers and Least Sandpipers did not show a significant trend between 1997 and 2009. While these results should be treated with caution because the areas surveyed only cover a small proportion of all sites used during migration, the results suggest no large population declines during this time period.

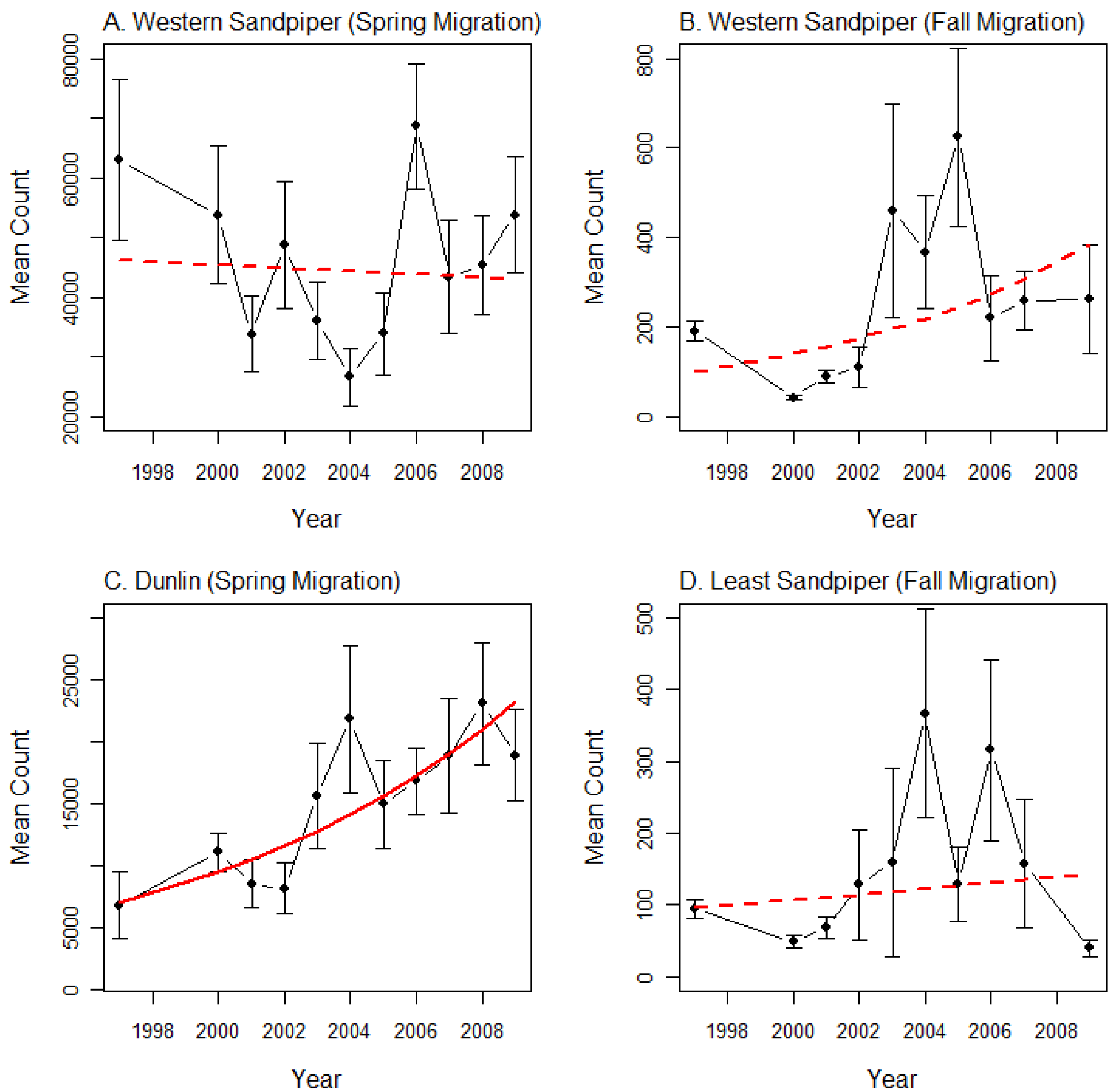

Figure 7. Shorebird migration monitoring in British Columbia, 1997-2009.
Spring migration monitoring is conducted at Brunswick Point on the Fraser River Delta near Vancouver.
Fall migration monitoring is conducted at Sidney Island in the Strait of Georgia.
Vertical lines indicate ± 1 Standard Error on the mean count, solid red lines indicate significant trends (P<0.05), and dashed lines indicate non-significant trends.
Source: Lemon and Drever, unpublished data

Breeding birds

The BBS is considered an adequate survey for a few shorebird species that can breed in accessible areas in proximity to road networks. The BBS provides reports for Bird Conservation Regions as well as for all of British Columbia, but these were similar to the provincial trends (Environment Canada, 2010), and so only provincial trends are reported here. For the time period 1999-2009, the BBS provides trends for four species in BC (Table 3), two of which show no trend (Greater Yellowlegs and Spotted Sandpiper). Two common species (Wilson's Snipe and Killdeer) show significant declines. Wilson's Snipe has wide population fluctuations, and temporal trends for this species vary widely throughout the country. In contrast, Killdeer have shown a steady decline that mirrors the range-wide decline of this species throughout Canada.

Table 3. Temporal trends in population counts for selected shorebird species in British Columbia during breeding, wintering, and migration periods, 1997- 2009.

Breeding **(Breeding Bird Survey, 1999–2009)**	**Trend**	**P**	**N (routes)**
Killdeer	-9.4	<0.05	77
Greater Yellowlegs	3.6	>0.10	24
Spotted Sandpiper	0.7	>0.10	85
Wilson's Snipe	-3.9	<0.05	80
Wintering **(BC Coastal Waterbird Survey, 1999 -2009)**			
Black Oystercatcher	2.30	0.31	
Killdeer	-7.31	0.00	
Black-bellied Plover	-6.19	0.22	
Greater Yellowlegs	-4.42	0.20	
Black Turnstone	7.21	0.08	
Surfbird	-12.41	0.19	
Dunlin	-3.41	0.57	
Sanderling	-12.14	0.06	
Spring Migration **(Fraser River Delta, 1997 - 2009)**			
Dunlin	0.09	0.0002	
Western Sandpiper	0.01	0.7	
Fall Migration **(Georgia Strait, 1997-2009)**			
Western Sandpiper	0.11	0.15	
Least Sandpiper	0.03	0.65	

Source: Environment Canada (2010); Crewe et al. (2010); Lemon and Drever, unpublished data

Wintering birds

The BC Coastal Waterbird Survey monitors waterbird species during the winter months (September to April) throughout large sections of British Columbia's coastlines, and provides trend information for eight species (Crewe et al. 2010, Table 3). Of the eight species, six have no significant trend. Killdeer have a significantly negative trend, and Black Turnstone showed a positive trend. Despite the lack of significant trends, we note that trends for five of the six species had negative point estimates, which may reflect an underlying fragility in their population status. British Columbia has high jurisdictional responsibility for several of the rock intertidal species (Black Turnstone, Surfbird, and Black Oystercatcher) that have large proportions of their wintering range in the province, and therefore monitoring efforts for these species should be given high priority.

Boreal and Taiga Ecozones+

Information on boreal-breeding shorebirds is limited because their breeding habitat is remote, difficult and expensive to access, and techniques designed for more open ecozones+ such as the Prairies or the Arctic, cannot be easily adapted to the densely-treed ecozones+ (Sinclair et al., 2004). An additional complication to assessing trends in boreal and taiga shorebirds is that they do not concentrate along migration routes, at stop-over sites, or on the wintering grounds. This makes them difficult to census and monitor throughout their annual cycle.

Species selected for reporting in this section are those outlined by Sinclair et al. (2004) as priority species for these ecozones+ (Table 4). The population estimates that are available for boreal and taiga shorebirds are reported with low or poor confidence for all species (Brown et al., 2001) making determination of trends difficult. The trend information provided by the BBS data reports low reliability for all shorebirds in the taiga and boreal Bird Conservation Regions (BCRs) -- BCR4 (Boreal and Taiga Cordillera ecozones+), BCR6 (Boreal and Taiga Plains ecozones+), BCR7 (Taiga Shield and Hudson Plains ecozones+), and BCR8 (Boreal Shield Ecozone+). From the BBS data as summarized by BCR from 1966 to 2007, only Lesser Yellowlegs shows a significant trend (decline; -8.7% change per year, $P<0.01$) (Sauer et al., 2008). Trend information for boreal shorebirds in Quebec (Aubry and Cotter, 2007) shows most species are increasing or have stable populations. Only Wilson's Snipe was found to have a significantly declining trend (

Table 5). However, when compared with qualitative trend information for boreal species across Canada, most species are believed to be declining (Table 4) (Brown et al., 2001; Morrison, 2001). An assessment of various migration surveys separated into two major regions (North Atlantic BCR and Midwest BCR) found declining population trends for Solitary Sandpiper (*Tringa solitaria*) (-6.3% per year) in the North Atlantic Region (Table 6) (Bart et al., 2007).

Table 4. Population trend assessments for shorebirds breeding in the boreal and taiga regions.

Species	Ecozones[+] for which this is a Priority Species[1]						U.S. Shorebird Conservation Plan	Canadian Wildlife Service Shorebird Committee	Trend Summary[2]
	Plains		Shield		Cordillera				
	B	T	B	T	B	T			
Greater Yellowlegs	x	x	x	x			Not enough information	Mixed trends	↔
Lesser Yellowlegs	x	x		x	x	x	Significant decline	Significant decline	↓↓
Solitary Sandpiper	x	x	x		x	x	Mixed trends	Decline	↓?
Short-billed Dowitcher	x	x	x	x			Significant decline	Significant decline	↓↓
Wilson's Snipe	x	x	x	x	x	x	Significant decline	Significant decline	↓↓

[1] Taken from Sinclair et al. (2004).
[2] ↓↓ significant declining population trend; ↓ probable or declining population trend, not statistically significant; ↔ not enough information to conclusively determine population trend (mixed trends); ↓? or ↓↓? conflicting information
B = boreal; T = taiga

Source: adapted from (Brown et al., 2001; Morrison, 2001). Trend data are based on many localized data sets across the North America spanning 1970s-2000s as well as expert opinions

Table 5. Trends of boreal shorebirds occurring in Quebec.

Species	Quebec[1]						Canada
	Spring Migration			Autumn Migration			
	r	P	Trend	r	P	Trend	Trend
Greater Yellowlegs	0.305	0.157	Stable	0.017	0.938	Stable	Stable
Lesser Yellowlegs	0.443	0.034	Increasing**	-0.091	0.679	Stable	Declining^
Solitary Sandpiper	0.344	0.108	Stable	-0.177	0.419	Stable	Declining
Wilson's Snipe	-0.365	0.087	Declining*	-0.602	0.002	Declining**	Declining^

[1] ** strong (significant) trend $P<0.05$; * weak trend $0.10>P\geq0.05$
"Declining^" denotes predominantly negative trends with significant declines in at least one region of Canada; "Declining" denotes predominately negative trends; "Stable" denotes both positive and negative trends have been calculated.

Source: Quebec data from Aubry and Cotter, (2007); Canada data from Donaldson et al. (Donaldson et al., 2000)

Table 6. Estimated population trends for shorebirds expressed as the annual rates of change.

Species	**Estimated Trend**	
	North Atlantic	**Midwest**
Greater Yellowlegs	0.992	1.011
Lesser Yellowlegs	0.964	0.992
Solitary Sandpiper	0.937**	0.972
Short-billed Dowitcher	1.018	1.110
Wilson's Snipe	0.966	1.038

A value less than 1 denotes a population decline where each 0.01 is 1% decrease per year (for example 0.98 mean a decline of 2% per year.
** P-value<0.01; * P-value 0.01 to 0.049
Source: data from Bart et al. (2007)

Intensive shorebird studies have been carried out in the Taiga Shield Ecozone+ near Yellowknife and Dettah, NWT (Johnston, 2000; Johnston et al., 2008a) and in the Taiga Plains Ecozone+ near Ft. Simpson and Wrigley, NWT (Johnston et al., 2008b) to determine if shorebirds in the boreal and taiga ecozones+ can be surveyed from a helicopter. Use of aerial surveys was recommended by the Boreal PRISM Committee as a potential tool for monitoring boreal and taiga shorebirds (Sinclair et al., 2004). Unfortunately, boreal and taiga shorebirds rarely flush and if they do, flush approximately ten seconds after the helicopter has passed so they are not properly recorded by the aerial surveyors, resulting in very low or incalculable detection ratios (estimated number of bird x seen from the air divided by the actual number of bird x on the ground). Thus, aerial surveys are an unsuitable method of obtaining absolute population estimates (Elliott and Johnston, 2009).

Large-scale, intensive, and costly ground studies will be required to get reliable population and trend estimates for boreal and taiga breeding shorebirds. However, since much is still unknown about the breeding ecology of these species, further research is required before an effective monitoring program can be designed (Howe et al., 2000; Bart et al., 2005). Suggestions by Sinclair et al. (2004) for potential research and monitoring which are in progress, include the use of combinations of existing protocols such as the North American BBS, off-road point counts with modified but complementary data to the BBS, ground-based breeding season surveys, and further examination of stop-over site data to assess its usefulness for boreal and taiga shorebird monitoring and trend assessment.

Hudson Plains Ecozone+

The vast Hudson Bay Lowlands, lying behind the coastlines of James Bay and Hudson Bay, supports a number of breeding species of shorebirds. Very little information is available on population trends. Shorebirds have been studied extensively at Churchill, Manitoba, and nearly all studies have reported widespread declines in shorebirds and other birds (Jehl and Lin, 2001; Jehl, 2004). Declines were particularly notable in the Semipalmated Sandpiper, which used to be the most abundant breeding shorebird in the Churchill region up to the 1940s, but which by 2004 could no longer be found breeding in the area (Allen, 1945; Gratto-Trevor, 1994; Jehl, 2007). A similar situation was reported at Cape Henrietta Maria at the north end of James Bay, where the species was abundant in the 1970s but had become scarce by 2004/2005 (G. Peck and M. Peck in Peck and James, 1983; Cadman et al., 1987; Jehl, 2007). These results appear to be consistent with the declines reported for Semipalmated Sandpipers on migration in many other regions (for example Morrison et al., 1994; Morrison et al., 2001; Bart et al., 2007; and other work summarized by Jehl, 2007). Somewhat anomalous results were reported by Sammler *et al.* (2008) at a study area 60 km east of Churchill, where results of line transect surveys indicated an increase in Semipalmated Sandpipers between 1984 and 1999, though many other larger ground-nesting species declined. While the precise reasons for the decline in Semipalmated Sandpipers remain unclear, it did not appear to be linked to the extensive damage to coastal habitats caused by increasing populations of Lesser Snow Geese (Jehl, 2007; Sammler et al., 2008), and is more likely to be related to conditions outside the breeding grounds (Jehl, 2007).

The coastlines of Hudson Bay and James Bay are extremely important as migration corridors for many shorebirds breeding in the central Canadian Arctic en route to and from their nesting grounds (Morrison and Harrington, 1979). Many Hudsonian Godwits are thought to fly directly from the James Bay area to stop-over areas in South America (Morrison, 1984), and James Bay is also a key area for the Endangered Red Knot (COSEWIC, 2007). No trend information is available for shorebird migrants passing through the area.

Arctic Ecozone⁺

The Arctic Ecozone⁺ is of great importance globally for shorebird production. Sixty percent of North American shorebirds breed in the Arctic. The Canadian Arctic alone provides 75% of the North American breeding range for 15 of the 49 species of shorebirds that are common to North America (Donaldson et al., 2000).

Globally, 44% of estimated population trends for Arctic-breeding shorebirds are declining (Figure 8) making the problem more widespread than was originally thought (Morrison et al., 2001). Overall, the Arctic breeders as a group are declining 1.9% per year (Bart et al., 2007).

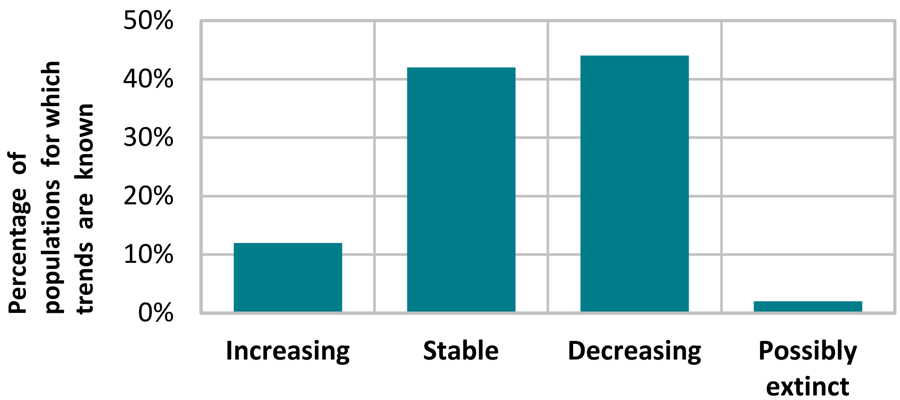

Figure 8. Summary of population trends for Arctic-breeding shorebirds, 2003.
Globally, population trends have been estimated for 52% of Arctic-breeding shorebirds (100 biogeographical populations of 37 species). Of these, 12% are increasing, 42% are stable, 44% are decreasing and 2% are possibly extinct.
Source: Delany and Scott (2006)

An analysis of fall migration count data was undertaken to determine if the declining numbers of birds recorded on migration counts could be explained by changes in migration routes or timing or by changes in detection rates (Bart et al., 2007). The authors concluded that migration counts most likely reflected a true reduction in population size. They found no evidence of major shifts in the number of birds migrating along specific routes and no major changes in variables related to detection. Annual rates of change were calculated over the period 1974 to 1998 in this study – results are shown in Figure 9 for Arctic-breeding shorebirds with sufficient survey counts in fall migration surveys conducted in the Canadian-United States North Atlantic or United States Midwest regions.

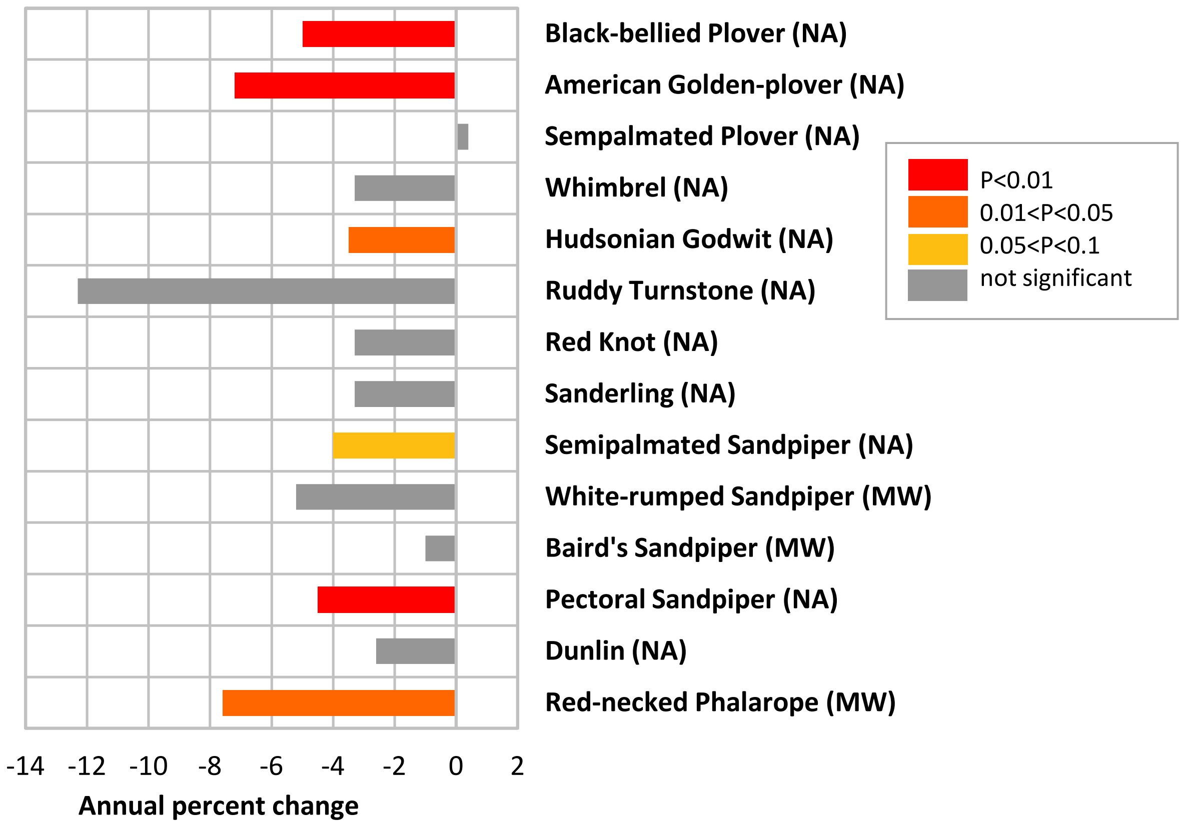

Figure 9. Estimated trends in Arctic-breeding shorebird fall migration counts, 1974-1998.
NA = North Atlantic migration survey; MW = Midwestern migration survey.
Source: data from Bart et al. (2007)

Two major shorebird trend reviews by the U.S. Shorebird Conservation Plan Committee (in 2001 and 2004) and Canadian Wildlife Service Shorebird Committee (in 2001) assessed 18 species of Arctic-breeding shorebirds with very similar results (Table 7). Eight species were listed in both assessments as having significant population declines (Brown et al., 2001; Morrison et al., 2001; U.S. Shorebird Conservation Plan, 2004).

Table 7. Population trend assessments for Arctic-breeding shorebirds.

Species	Trend summary[1]	U.S. Shorebird Conservation Plan	Canadian Wildlife Service Shorebird Committee
Black-bellied Plover	↓↓	Significant decline	Significant decline
American Golden-Plover	↓↓	Significant decline	Significant decline
Semipalmated Plover	↓?	Not enough information	Significant decline
Eskimo Curlew	↓↓	Significant decline	Likely extinct
Whimbrel	↓?	Significant decline	Mixed trends
Hudsonian Godwit	↓	Not enough information	Decline
Ruddy Turnstone	↓↓	Decline	Significant decline
Red Knot	↓↓	Significant decline	Significant decline
Sanderling	↓↓	Significant decline	Significant decline
Semipalmated Sandpiper	↓↓	Significant decline	Significant decline
White-rumped Sandpiper	↔	Not enough information	Mixed trends
Baird's Sandpiper	↓?	Not enough information	Decline
Pectoral Sandpiper	↔	Not enough information	Mixed trend
Purple Sandpiper	↓?	Stable	Significant decline
Dunlin	↓↓	Significant decline	Significant decline
Buff-breasted Sandpiper	↓	Decline	Decline
Red-necked Phalarope	↓↓	Decline	Significant decline
Red Phalarope	↓↓	Significant decline	Significant decline

[1] ↓↓ significant declining population trend; ↓ probable or declining population trend, not statistically significant; ↔ not enough information to conclusively determine population trend (mixed trends); ↓? conflicting information
Trend data are based on many local data sets across the North America spanning 1970s-2000s, as well as on expert opinion.

Source: extracted from the U.S. Shorebird Conservation Plan (2004); Brown et al. (2001); and Morrison et al. (2001)

What is of most concern is that over the past 30 years many species trends have changed from slightly declining to significantly declining, indicating that the decline is persistent and ongoing (Morrison et al., 2001; Delany and Scott, 2006). The declines are observed in species with a range of migration, habitat, and breeding strategies and needs. Preliminary investigations by Thomas et al. (2006a) and Bart et al. (2007) found no common factors among declining species.

In the *U.S. Shorebird Conservation Plan* (Brown et al., 2001), population trend information was combined with five other variables (relative abundance, threats during breeding season, threats during non-breeding season, breeding distribution, and non-breeding distribution) to create a conservation prioritization scheme. The scheme, adopted in the *Canadian Shorebird Conservation Plan* (Donaldson et al., 2000), is useful because species with stable or slightly downward-trending populations with threats on their wintering grounds and very specific breeding ground habitat requirements may be more at risk than species with significant population declines. The highest priority species were those designated ‘highly imperiled’. Using this prioritization scheme, the only Arctic species listed in 2001 as ‘highly imperiled’ (Eskimo Curlew) is believed to be extinct (Environment Canada, 2007).

In 2004, species were re-evaluated (U.S. Shorebird Conservation Plan, 2004) and the status of several species was upgraded (Table 8).

Table 8. Conservation status of tundra-nesting shorebirds as classified in the U.S. Shorebird Conservation Plan.

Highly imperiled (first priority)	Species of high concern (second priority)
Eskimo Curlew (believed to be extinct) *Buff-breasted Sandpiper (globally) *Red Knot (Canadian Arctic-Atlantic Coast population)	American Golden-Plover (globally) Whimbrel (North American populations) Hudsonian Godwit (globally) Ruddy Turnstone (North American populations) Red Knot (populations other than the Canadian Arctic-Atlantic Coast population) Sanderling (North American populations) *Dunlin (Alaska-East Asian and Alaska-Pacific Coast populations)

Upgraded species are denoted with an asterisk (*).
Source: U.S. Shorebird Conservation Plan (2004)

Local studies have recorded population declines over a range of periods. Analysis of the Atlantic coastal migration stop-overs from 1972 to 1983 (Howe et al., 1989) found significant declines for Black-bellied Plover (decreasing by 5.4% per year), Whimbrel (-8.3% per year) and Sanderling (-13.7% per year). Breeding populations of Red Phalarope (*Phalaropus fulicarius*), Black-bellied Plover, and American Golden-Plover decreased significantly, by 76, 87, and 79% respectively, in the Rasmussen Lowlands (Central Arctic) over a 20-year period (Gratto-Trevor et al., 1998). Given the long time interval between studies, natural fluctuation as a result of a series of poor breeding seasons rather than a persistent and continuous population decline could explain the differences between the two study periods, but it may represent a true decline in these species (Gratto-Trevor et al., 1998).

A study in the Foxe Basin (Prince Charles and Air Force Islands) found significant population declines for White-rumped Sandpiper (-61%) and Red Phalarope (-43%) over an eight-year time span (1989-1997) (Johnston and Pepper, 2009). For Red Phalarope the decline was even more pronounced at East Bay, Southampton Island, where there was a 93% decline over six years (1999-2005) (Pirie et al., 2012). All shorebird species (n = 5) at East Bay declined by more than 90% over the same interval. In 2007, there was a small rebound to about 33% of the original 1999 values. This coincided with a high lemming (and therefore low predation) year (Pirie et al., 2012).

Near Churchill Manitoba, a comparison of six qualitative bird abundance studies between 1930 and the 1990s found that Semipalmated Sandpiper, Stilt Sandpiper and Red-necked Phalarope experienced a 'great decrease', and Dunlin (*Calidris alpina*) a 'decrease' (Jehl and Lin, 2001). Huge declines were also noted at La Perouse Bay, Manitoba (40 km east of Churchill), for Semipalmated Sandpiper and Red-necked Phalarope (Gratto-Trevor, 1994).

One of the current major limitations to determining population trends for Arctic-breeding shorebird species is the lack of two reliable population estimates. In many cases intensive surveys of shorebirds on the Arctic breeding grounds have led to increases to the world population estimate for a given species (Johnston et al., 2000; Latour et al., 2005; Johnston and Pepper, 2009). This does not reflect an increase in world population size but instead is an indication that initial population estimates were probably low (Brouwer et al., 2003; Morrison et al., 2006). The large-scale PRISM, which has an Arctic component, is partway through a multi-year survey program that will produce continental population estimates for 19 species of shorebirds that breed in the North American Arctic. Once the first pass of surveys is complete, a second set is planned to assess species-specific as well as North American Arctic-wide population trends (Skagen et al., 2003; Bart and Earnst, 2004; Bart et al., 2005; Bart and Johnston (eds), 2012).

Proposed causes of shorebird population declines include: loss of migration stop-over sites, loss of wintering habitat, and life history characteristics (that is, migratory behaviour, life history, biogeography) which may predispose shorebirds to population decline. Future population decline is expected to be accelerated by habitat changes on the Arctic breeding grounds.

Since many shorebirds are long-distance migrants that tend to gather in very large numbers at relatively few sites, loss of one or two major stop-over sites could have a huge effect on shorebird populations. Declining food availability at existing stop-over sites can also have a large impact on populations because birds may not be able take in enough fuel to move to the next stop-over site, or may not be able to acquire the body stores essential for survival and successful reproduction (Senner and Howe, 1984; Donaldson et al., 2000; Morrison et al., 2001; Baker et al., 2004; Morrison et al., 2004; Morrison et al., 2007). Analysis of population trends of North American shorebirds found species that followed continental migration routes (as opposed to coastal or oceanic migration routes) were at higher risk of population decline because of ecosystem loss and alteration (Thomas et al., 2006a; Bart et al., 2007). Continental migrants use small, ephemeral ponds and wetlands that are scattered over a large area. These ponds and wetlands are difficult to delineate for conservation initiatives making it harder to preserve them as compared to larger stop-over sites (Thomas et al., 2006a). Little is known about Arctic stop-over sites because of their remoteness. Observations along a 200 km stretch of coast line in the Kivalliq Region (northwestern Hudson Bay) during the 2008 spring migration found hundreds of High Arctic nesting migrants feeding on insects in the wrack lines on their journey north to the breeding grounds (Johnston and Rausch, unpublished data). The importance of sites such as these to migration and subsequent breeding success is not known.

Loss or degradation of habitat on the non-breeding grounds from human activities such as oil pollution (Harrington and Morrison, 1980), mechanical dredging or fishing (Piersma et al., 2001), conversion of native grasslands and wetlands to agriculture (Isacch and Martinez, 2003; Shepherd et al., 2003) and tourism and development on marine beaches (Blanco et al., 2006) may be a cause of population decline (Thomas et al., 2006a). Complicating our assessment of the importance of wintering habitat is that little is known about food resources on the wintering grounds (Morrison et al., 2004). Threats on the wintering grounds, however, have been found to have a weak influence on the likelihood of a species being in population decline (Thomas et al., 2006a).

The intrinsic biology of shorebird species may make them more susceptible to population decline. Migratory behaviour (such as distance and routes) is suspected to be the most influential intrinsic factor, with more continental migrants in population decline than coastal or oceanic migrants (Thomas et al., 2006a). Phylogenic characteristics such as body and clutch size, lifespan, and relatedness were found to be unimportant to population decline, but limited clutch sizes means that recovery following a decline is likely to be slow (Myers et al., 1987). Sexual selection may have an influence on declining populations since most socially polygamous species have declining populations while socially monogamous species have stable or increasing population trends – but the data are not conclusive. There are no clear intrinsic factors held in common by shorebird species with declining population trends and extrinsic factors are more likely to be the primary cause of decline (Thomas et al., 2006a; Thomas et al., 2006b; Bart et al., 2007).

Habitat changes in the Arctic caused by climate change are expected to have an exacerbating effect on the declining population trends of Arctic-breeding shorebirds (Bart et al., 2007). Arctic-breeding shorebirds are adapted to the annually variable weather conditions of the Arctic during the breeding season. However, their conservative life-history strategy (low reproduction and long lifespan) makes it difficult for them to adapt to accelerated climate change. This puts Arctic-breeding shorebirds more at risk of population decline than other groups (Donaldson et al., 2000; Meltofte et al., 2007). Effects of accelerated climate change on breeding habitat include: drying of tundra ponds (Walsh et al., 2005; Smol and Douglas, 2007), shrub encroachment (Callaghan et al., 2005), and asynchrony of insect-chick hatch (Tulp and Schekkerman, 2006).

The synchrony of shorebird chick hatch with the peak of insect emergence is not as critical as hatch occurring when there is sufficient food supply. The availability of the food supply is strongly influenced by weather and a sufficient supply is only available for 40% of the insect season (Tulp and Schekkerman, 2008). The peak date of insect emergence fell between 8 July and 23 July for 75% of the 33-year study period. These earliest and latest peak emergence dates were recorded in consecutive years, showing that the date of peak emergence is not advancing linearly with time. Overall, however, the date of peak insect emergence as well as the range of dates with sufficient food available for the normal growth of chicks is getting earlier in the season (Tulp and Schekkerman, 2008). Since Arctic shorebirds time nest initiation to occur as soon as the snow melts, the advancement in the timing of insect emergence is not critical for the survival of chicks hatched from the earliest nests. It could, however, be a serious problem for chicks from late nests, or from re-nests (clutches laid late to replace an earlier nest that was unsuccessful) because they will hatch too late in the season to obtain sufficient food resources (Meltofte et al., 2007). Further analysis is needed to determine if snow melt is advancing at the same rate as the timing of insect emergence, which would permit birds to nest earlier. It is not known whether shorebirds will be able to adjust their migration strategies to arrive on the breeding grounds sooner in response to an earlier snow-free season. Species which make the final jump to the breeding ground from latitudes closer to the Arctic may be more successful than species that use internal length-of-day cues to initiate migration from very distant wintering grounds (Tulp and Schekkerman, 2008).

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Appendix 1. Common and scientific names for shorebirds

Common Name	**Scientific Name**
Black-bellied Plover	*Pluvialis squatarola*
American Golden-Plover	*Pluvialis dominica*
Snowy Plover	*Charadrius alexandrinus*
Common Ringed Plover	*Charadrius hiaticula*
Semipalmated Plover	*Charadrius semipalmatus*
Piping Plover	*Charadrius melodus*
Killdeer	*Charadrius vociferus*
Mountain Plover	*Charadrius montanus*
American Oystercatcher	*Haematopus palliatus*
Black Oystercatcher	*Haematopus bachmani*
Black-necked Stilt	*Himantopus mexicanus*
American Avocet	*Recurvirostra americana*
Spotted Sandpiper	*Actitis macularius*
Solitary Sandpiper	*Tringa solitaria*
Greater Yellowlegs	*Tringa melanoleuca*
Willet	*Tringa semipalmata*
Lesser Yellowlegs	*Tringa flavipes*
Upland Sandpiper	*Bartramia longicauda*
Whimbrel	*Numenius phaeopus*
Long-billed Curlew	*Numenius americanus*
Hudsonian Godwit	*Limosa haemastica*
Marbled Godwit	*Limosa fedoa*
Ruddy Turnstone	*Arenaria interpres*
Black Turnstone	*Arenaria melanocephala*
Surfbird	*Aphriza virgata*
Red Knot	*Calidris canutus*
Sanderling	*Calidris alba*
Semipalmated Sandpiper	*Calidris pusilla*
Western Sandpiper	*Calidris mauri*
Least Sandpiper	*Calidris minutilla*
White-rumped Sandpiper	*Calidris fuscicollis*
Baird's Sandpiper	*Calidris bairdii*
Pectoral Sandpiper	*Calidris melanotos*
Purple Sandpiper	*Calidris maritima*
Rock Sandpiper	*Calidris ptilocnemis*
Dunlin	*Calidris alpina*

Stilt Sandpiper	*Calidris himantopus*
Buff-breasted Sandpiper	*Tryngites subruficollis*
Short-billed Dowitcher	*Limnodromus griseus*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Wilson's Snipe	*Gallinago delicata*
American Woodcock	*Scolopax minor*
Wilson's Phalarope	*Phalaropus tricolor*
Red-necked Phalarope	*Phalaropus lobatus*
Red Phalarope	*Phalaropus fulicarius*