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Articles

Survey trends of North American shorebirds: population declines or shifting distributions?

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We analyzed data from two surveys of fall migrating shorebirds in central and eastern North America to estimate annual trends in means per survey and to determine whether trends indicate a change in population size or might have been caused by other factors. The analysis showed a broad decline in means per survey in Atlantic Canada and the northeastern United States (North Atlantic region). For example, 9 of 9 significant trends in this region were <1 ($P = 0.004$), and the mean, annual rate of change among 30 species was 0.9783, a decline of $-$2.17% per year ($P < 0.001$). Trends in the midwestern United States (Midwest region) showed no clear pattern. The mean among 29 species was 1.0090 ($P = 0.35$). Only 4 of the trends were significant. Several hypotheses were evaluated to identify causes of the declining means per survey in the North Atlantic region. The most likely hypothesis appears to be a decline in the breeding populations that supply migrants to the North Atlantic region, but a change in movements, for example passing through the region more quickly in recent years, cannot be excluded as an explanation. Further surveys of arctic breeding areas coupled with analysis of long-term survey data from western North America would be helpful in determining whether the declines found in this analysis are also occurring in other areas.

Knowledge of both the size and the trend in size of animal populations is of basic biological interest and is an important element in management and conservation. Shorebirds, as a group, are of particular conservation concern, owing to their long migrations, slow reproductive rate, and dependence on a wide variety of wetland habitats for which extensive losses have occurred (Myers et al. 1987, Bildstein et al. 1991, Brown et al. 2001, Donaldson et al. 2001). Evidence accumulated during the past 10–15 years has suggested that many shorebird populations may be declining in North America and Europe (Browne et al. 1996, Austin et al. 2000, Baker et al. 2004), and perhaps worldwide (Wetlands International 2002, Stroud 2003). Broad declines in numbers of shorebirds recorded during migration in eastern North America have also been reported (Howe et al. 1989, Morrison et al. 1994). A variety of studies has subsequently indicated that declines are ongoing and may be occurring in many parts of the range in North America, especially in Canada (see summary by Morrison et al. 2001). For instance, declines in shorebird numbers have been reported from the eastern USA and Canada (Howe et al. 1989, Clark et al. 1993, Harrington 1995, Morrison and Hicklin 2001), Ontario (Ross et al. 2001), Quebec (Aubry and Cotter 2001), temperate breeding areas in the USA and Canada (Page and Gill 1994, Dunn et al. 2000, Morrison 2001a), the Pacific coast of Canada (Butler and Lemon 2001), and from a number of Arctic and sub-Arctic breeding areas (Gould 1988, Pattie 1990, Gratto-Trevor 1994, Gratto-Trevor et al. 1998, 2001).

This paper examines whether shorebird population trend changes detected in earlier studies are still ongoing. Analyses are on combined data from the two major shorebird migration monitoring programs in North America, the Maritimes Shorebird Survey (MSS), covering sites in eastern Canada, and the International Shorebird Survey (ISS), which included coverage of sites in eastern and central USA. Our goals were to estimate trends in mean numbers of shorebirds reported in central and eastern North America and to evaluate whether trends in migration counts indicate a trend in size of the breeding population.

Methods

Surveys

Data from the Maritimes Shorebird Survey (MSS) and the International Shorebird Survey (ISS) were used in the analysis (Brown et al. 2001, Donaldson et al. 2001). Both programs were started in 1974, the MSS by the Canadian Wildlife Service, and the ISS by the Manomet Center for Conservation Sciences. The primary objective of both programs was to obtain better information on the distribution in space and time of shorebirds during the non-breeding season. Volunteers are asked to visit sites that they select every two weeks (MSS) or ten days (ISS) during fall, winter, and spring when birds are present at their site. All shorebirds detected at the time of the surveys are reported. Observers are requested to cover their site in a consistent manner with respect to area, tide, and other factors that might influence shorebird numbers at the site. The MSS sites are in the Atlantic Provinces of Canada. The ISS sites are mainly in the eastern United States, but include a number of inland sites in the central USA mainly east of the 100th meridian. Surveys in spring began only recently at many of the sites. We therefore used only the fall surveys in this analysis. The data set contained 32 782 surveys from 168 sites.

We designated the fall migration period for each species as the 20th and 80th percentiles of the cumulative distribution of the number of birds recorded at all sites during July–October. In calculating trends, we used only surveys within this period. Some sites in both programs were visited for only a few years and thus do not provide useful data for trend estimation. We used only sites visited at least three times in at least six years, during the fall migration period, during 1974–1998.

Coverage varied widely and was sparse in some areas. This led us to delineate two regions, a "North Atlantic region" and a "Midwest region", both of which were well-covered by survey sites (Fig. 1; see Appendix 1 for all common and scientific names). Separate analyses were made for the two regions. We did not compute rangewide trend estimates because we did not know the relative abundance of each species in our two regions, and this information is required to combine the region-specific trend estimates.

Number of sites evaluated

Since statistical analyses based on small samples can give unreliable results, we derived a minimum number of sites needed for analysis. The approach was based on determining how the frequency of improbable results, defined as absolute trends <0.90 or >1.10, varied with number of sites providing data. We selected these thresholds as convenient indicators that the estimates were not plausible. The analysis showed that with 7 or more sites, trends <0.90 or >1.10 were uncommon ($<25\%$ of the estimates), whereas their frequency rose rapidly below 7 sites. All analyses reported below are based on at least 7 sites. We inspected the detailed data for each species and region to identify sites with undue influence on the trends. This led us to eliminate 9 sites for single species. Including them would have made the results for the species dependent on a single site which we did not want to

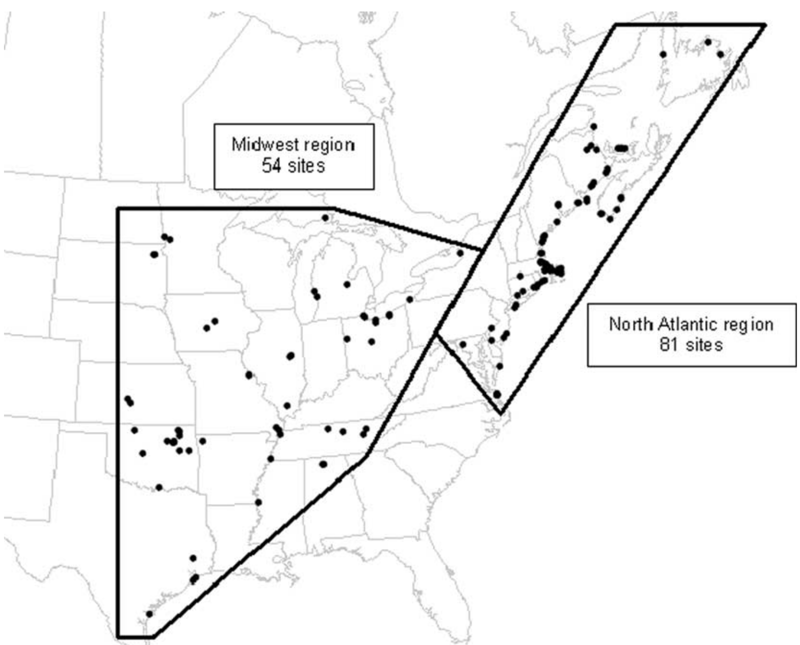

Fig. 1. Regions and sites used to estimate trends in means/survey.

occur. We also eliminated 2 sites for all species because we discovered events at the site that made us question reliability of the data. Including these sites would have made the trends more pronounced.

Trend estimation

We used the trend estimation method of Bart et al. (2003). It estimates the annual rate of change of an exponential curve fit to the expected values of the survey results for each year and was shown to be essentially unbiased in a simulation using the same data set analyzed here. In contrast, trend estimates produced by the route regression method of Link and Sauer (1994) had substantial bias (Bart et al. 2003). Sauer et al. (2004) criticized this approach, mainly on the basis that it does not automatically include observer covariates. On the surveys we studied, however, groups of observers often made the surveys and their composition changed too much to include the observer as a covariate. Other criticisms in Sauer et al. (2004) are addressed by Bart et al. (2004). Estimated trends are expressed as annual rates of change. Thus, a trend of 0.98 means a decline of 2% per year. The sites were treated as a simple random sample within each region. The reasonableness of this assumption is considered in the Discussion section.

Natural history traits

Each species was classified with regard to four natural history traits: breeding distribution (arctic, boreal, temperate), degree of concentration during the nonbreeding seasons (subjectively assigned to the following categories: concentrated, intermediate, dispersed), non-breeding distribution (north temperate, equatorial, south temperate, broadly distributed), and habitat during the non-breeding period (marine, non-marine, both).

Results

General trends

Sufficient data existed to estimate trends for 30 species in the North Atlantic region and 29 species in the Midwest region (Table 1 and 2). Most species were recorded at far more than our minimum number of sites (7) for inclusion in the analysis. For example, in the North Atlantic region, 23 species were recorded at 20 or more sites; in the Midwest region, 16 species were recorded at 20 or more sites.

Trends in the North Atlantic region tended to be <1.0 (Tables 1 and 2). The mean of the 30 estimates was 0.9783 which was significantly less than 1.0 ($P = 0.001$ using a t test). Twenty-two (73%) of the 30 estimates were <1, a result significantly different from 50% using an exact binomial test ($P = 0.016$). Nine estimates were significant at the 0.10 level, and all of them were <1 ($P = 0.004$). The mean of these 9 estimates was 0.9463 and was significantly different from 1.0 ($P < 0.001$).

Trends in the Midwest region showed no clear pattern (Tables 1 and 2). The mean of the 29 estimates was 1.009 ($P = 0.35$). Eleven of the 29 estimates were <1 ($P = 0.26$). Sample sizes (number of sites) were smaller than in the North Atlantic region, and only four estimates were significant (3 positive) at the 0.10 level. The mean of these four estimates was 1.035 and was far from significant ($P = 0.47$).

We calculated the proportion of negative trends, and the mean trend, for various sub-sets of the data defined using the natural history traits (Table 3). In the North Atlantic region, all 13 groups showed declines, and 7 were significant ($P < 0.10$). Declines occurred among all three of the breeding latitude groups, with the largest declines among temperate breeders. The proportion of trends that were negative, and the mean of the declines, was generally larger among species that were dispersed, rather than concentrated, on migration; species with broad non-breeding distributions; and species that use non-marine habitats during the non-breeding period. A multiple regression analysis failed to reveal any strong relationships between trends and natural history traits. In the Midwest region, no clear patterns were evident, and none of the mean trends was significantly different from 0.0 ($P > 0.10$).

Discussion

Population decline

We found clear evidence for a decline in the numbers of shorebirds recorded during migration in Atlantic Canada and the northeastern United States. Among 30 species, 73% declined during the study; 9 species declined significantly and none increased significantly. Sample sizes in the Midwest region were smaller, but no evidence for a broad decline was found. Only 38% of 29 trends were negative. No strong

Table 1. Trends in the number of shorebirds reported in the North Atlantic and Midwest regions (see Fig. 1).

	North Atlantic			Midwest		
	N species	P(negative)[a]	Mean[a]	N species	P(negative)	Mean
All trends	30	0.73**	0.978**	29	0.38	1.009
Significant trends	9	1.00**	0.946**	4	0.25	1.035

[a]** = $P < 0.01$.

Table 2. Estimated (E) population trends for North American shorebirds (see Appendix 1 for common and scientific names).

Species	E annual trend[a]		No. of sites		Breeding distribution[b]	Non-breeding distribution[c]	C/D[d]	Non-breeding habitat[e]
	N Atlantic	Midwest	N Atlantic	N Midwest				
BBPL	0.9492**	1.021	41	18	A	E	C	M
AGPL	0.9281**	1.1272*	25	23	A	S	D*	N
SEPL	1.0042	1.008	31	24	A	E	D*	B
PIPL	0.9602	0.952	18	11	T	N	D	M
KILL	0.9516*	1.0622~	44	28	T	N	D	N
GRYE	0.9918	1.011	46	23	B	B	D*	B
LEYE	0.9636	0.992	42	24	B	B	D*	B
SOSA	0.9372**	0.972	26	23	B	E	D	N
WILL	0.9895	1.000	23	15	T	E	D*	M
SPSA	0.9918	1.0246~	41	19	B	E	D	B
UPSA	0.9365*	1.008	11	14	T	S	D	N
WHIM	0.977	–	29	5	A	E	D*	B
HUGO	0.9646*	0.946	19	8	A	S	C	B
MAGO	0.9754	0.976	14	12	T	N	C	B
RUTU	1.0497	0.877	23	16	A	E	C	M
REKN	0.9671	1.023	30	12	A	S	C	M
SAND	0.9678	1.019	41	25	A	B	C	M
SESA	0.9598~	0.983	22	19	A	E	C	M
WESA	1.0312	0.999	8	7	A	N	C	M
LESA	0.9591	1.061	40	23	A	B	D	B
WRSA	1.0076	0.948	32	14	A	S	C	B
BASA	1.0285	0.999	25	16	A	S	D*	N
PESA	0.9545**	1.087	28	23	A	S	D	N
DUNL	0.9744	1.036	28	21	A	N	C	B
STSA	0.9354*	1.024	19	24	A	E	D*	M
SBDO	1.0175	1.110	20	25	B	E	C	B
LBDO	0.9895	1.034	15	21	A	N	C	B
COSN	0.9657	1.038	24	31	T	N	D	N
WIPH	1.0086	1.000	21	14	T	S	C	N
RNPH	1.0132	0.9244*	12	22	A	S	C	M

[a]** = P-value < 0.01; * = P-value 0.01 to 0.049, ~ = P-value 0.05 to 0.099.
[b]A = Arctic, B = Boreal, T = North temperate.
[c]Main wintering ground: N = North temperate, E = Equatorial, S = South temperate, B = Broad.
[d]Concentrated or dispersed on migration and/or winter. D* = mainly dispersed but sometimes in concentrations.
[e]Habitat during non-breeding season. M = marine; N = non-marine; B = both habitats.

trends were evident when the species were subdivided by degree of concentration, location, or habitat used during the non-breeding season although there was a suggestion that species broadly distributed were more likely to be declining.

General declines in the mean number of shorebirds per survey during migration have been reported by Howe et al. (1989) using ISS data and by Morrison et al. (1994) using MSS data. Preliminary analyses of data from Atlantic Canada indicates that declines are ongoing (Morrison and Hicklin 2001). The current study, based on the combined MSS and ISS data, updates these studies. With larger sample sizes we were able to compute region-specific estimates. The finding that trends were quite different in the North Atlantic and Midwest regions makes us reluctant to calculate rangewide trend estimates. Calculating rangewide estimates, ignoring regions, would be appropriate if sampling intensity was about the same in the two regions. We suspect, however, that a much higher fraction of all shorebird sites were surveyed in the North Atlantic region than in the Midwest region because the MSS occurs only in the North Atlantic region and the ISS was started in this region. If sampling intensity varies substantially between regions, and trends do too, then seriously biased estimates of the overall trend would result from ignoring region in the analysis. On the other hand, acknowledging regions would require an estimate of what fraction of the breeding population passes through each region, and we do not at present have that information.

Causes for the decline in numbers recorded in the North Atlantic region might be divided into three general categories: long-term change in migration, decline in detection rates, and decline in population size. Each of these potential explanations for the decline is discussed below.

The movements hypothesis

The "movements hypothesis" is that the observed change in numbers recorded was due to a long-term trend in how many birds entered the study area (e.g., due to changes in distribution or migration route as opposed to declines in the population), or how long they remained there during the

Table 3. Proportion of trend estimates that were negative, and mean trend, in relation to breeding and non-breeding distribution, degree of concentration on migration, and habitat.[a]

Species group	N sites	North Atlantic		Midwest	
		P(negative)	Mean	P(negative)	Mean
Breeding distribution					
Arctic	18[c]	0.67	0.981**	0.41	1.007
Boreal	5	0.80	0.980	0.40	1.022
Temperate	7	0.86	0.97**	0.29	1.005
Concentrated/dispersed[b]					
Concentrated	14	0.57	0.991	0.50	0.993
Intermediate	8[c]	0.75	0.977	0.29	1.02
Dispersed	8	1.00**	0.957**	0.25	1.026
Nonbreeding distribution					
North Temperate	7	0.86	0.978~	0.43	1.014
Equatorial	10[c]	0.70	0.981	0.33	1.002
South Temperate	9	0.56	0.979	0.44	1.008
Broad	4	1.00	0.971*	0.25	1.021
Nonbreeding Habitat					
Marine	10				
	0.70	0.982	0.50	0.982	
Both	12[c]	0.75	0.985*	0.36	1.013
Non-marine	8	0.75	0.964*	0.25	1.037

[a] Superscript indicates proportions significantly different from 0.5 or means significantly different from 0.0 (** = $P < 0.01$; * = $0.01 \leq P < 0.05$; ~ = $0.05 \leq P < 0.10$).
[b] During the non-breeding season; intermediate = mainly dispersed but sometimes in concentrations.
[c] One fewer site in the Midwest region (because whimbrels were recorded at only 5 sites so no estimate for them was calculated).

study period. Changes in breeding and/or wintering range are quite common in migratory birds, and many of them can be assumed to cause changes in the numbers of birds using a particular area for migration. Data on range shifts in shorebirds are scarce though a few examples have been suggested in North America (e.g., Klima and Jehl 1998). Amelioration of climate over the first half of the 20th century is thought to have led to changes in distribution and arrival dates of birds (Murphy-Klassen et al. 2005), and more recent climate change is thought to be affecting distribution and breeding performance of birds (Sorenson et al. 1998, Crick and Sparks 1999, Both and Visser 2001). Different trends in different parts of the range are not uncommon in birds generally. For example, > 10% of well-surveyed species in the Breeding Bird Survey have at least one significant negative trend, and one significant positive trend, among the six Fish and Wildlife Service regions in the coterminous United States (Bart unpubl. data). Shifts in wintering range are less well-studied but "short-stopping" in waterfowl, when habitat becomes available in areas north of their traditional wintering areas, is well known (Hestbeck et al. 1991).

The movements hypothesis would be supported by a finding that species declining in the North Atlantic region were increasing in the Midwest region (unless different subspecies, wintering in different areas, occurred in the two regions). It would be undermined by a finding that the declining species were also declining, or were stable, in the Midwest. The patterns from this study provide weak support for the movements hypothesis. Among all 20 species declining in the North Atlantic, 70% increased in the Midwest region (Table 4). The percentages were about the same for species showing significant and non-significant declines. The percentages are consistent with the movements hypothesis but are similar to the pattern for all species in the Midwest (62% of the species increasing) and thus may be due to a general pattern in the Midwest rather than to a net movement by birds from the North Atlantic region to the Midwest region. For two species, American golden plover and killdeer, which declined significantly in the North Atlantic region and increased significantly in the Midwest, the movements hypothesis is at least a possible explanation of the observed trends. However, killdeer are recorded in much higher numbers at sites in the Midwest (Table 5), so shifts of relatively small numbers of birds from the North Atlantic would be unlikely to result in significant increases, and no independent information supports such a shift.

Another form of the movements hypothesis is that the timing of migration shifted causing a decline in the number of birds in the North Atlantic region that were present during the study period. This hypothesis was evaluated by re-analyzing the data using a very wide survey interval (July 1 to December 31). This approach yielded similar results to the analysis using migration windows. In the North Atlantic region, 9 species showed significant ($P < 0.10$) declines, as in the initial analysis. In the Midwest region, 5 species showed significant declines compared to 4 in the initial analysis. Thus, the hypothesis that the timing of migration changed, causing the decline in the North Atlantic region, was not supported by the data.

A change in the mean number of surveys per year, in one region but not the other, might also have caused the declines in the North Atlantic region if observers tended to concentrate surveys in periods when more birds were present. We evaluated this hypothesis by calculating the mean number of surveys per site in each region and year of the study (Fig. 2). The mean number of surveys per site increased during the first decade of the program and decreased during the most recent decade, but the trend is similar in the two regions. Thus, the hypothesis that variation in the number of surveys per site caused the decline in the North Atlantic region is not supported by the data.

If species are much less common in the Midwest region, then even if trends there are positive, this could not account for declines in the North Atlantic region. This hypothesis was difficult to evaluate rigorously because we do not have a complete list of the important sites for each region and sites were not selected randomly. Nonetheless, some indication of relative abundance may be obtained by comparing mean numbers of birds recorded per survey in the two areas (Table 5). Means for three species – black-bellied plover, Hudsonian godwit, and semipalmated sandpiper-were much higher in the North Atlantic region than in the Midwest region, and the mean for killdeer was much higher in the Midwest, suggesting that movements between the two regions could not account for the declining trends exhibited by these species in the North Atlantic region. Means per survey for the other species, however, were in the same order of magnitude. For those species, we cannot rule out the movements hypothesis as an explanation for the declining means per survey in the North Atlantic region.

A final variation of the movements hypothesis is that birds moved through the North Atlantic region faster in recent years than in early years of the study. Such a trend might result from a general decline in the quality of habitat in the North Atlantic region or from changes on the breeding or wintering areas. We were unable to evaluate this hypothesis with existing data. Investigations into the declines observed in western sandpiper in British Columbia have suggested that increased turnover rates have indeed occurred in recent years and may account for the observed overall declines (Ydenberg et al. 2004). Principal southward migration passage dates of the shorebird species we evaluated precede Atlantic coast migration dates of the raptors that commonly hunt shorebirds in the North Atlantic region (Veit and Petersen 1993).

Table 4. Proportion of species declining in the North Atlantic region that are increasing in the Midwest region.

Trend in North Atlantic	N species	Proportion increasing in the Midwest	P-value
All species	20	0.70	0.15
Significant decrease	9	0.67	0.51
Non-significant decrease	11	0.73	0.23

Table 5. Grand mean of the mean number of birds recorded per site for species that declined significantly in the North Atlantic region. Only American golden plover and killdeer increased significantly in the Midwest.

Species	North Atlantic	Midwest
BBPL	89.9	2.7
AGPL	1.9	1.8
KILL	1.7	45.9
SOSA	0.6	1.1
UPSA	0.1	1.7
HUGO	6.2	0.2
SESA	3406.6	1.1
PESA	9.6	34.1
STSA	5.9	10.5

The change in detection hypothesis

The change in detection hypothesis is that the reduction in numbers reported is due to a long-term decline in the "regional index ratio", the ratio of the mean number of birds reported, in a given year, to the mean number present in the region during the study period. Such a decline might be caused by a decline in the proportion of birds present at the sites at the times of the survey that were detected by the observer; by a shift in the timing of surveys (e.g., from a few surveys at peak times to more evenly spaced surveys throughout the study period); or by a net shift of birds within the region from surveyed to non-surveyed sites. We evaluate each of these possibilities below.

The hypothesis that declines in the North Atlantic region were caused by declines in the detection rates would be supported if the most important sites showed declines among most or all species. It would not be supported if within-site trends varied substantially among species, especially species that would be expected to have similar detection rates. We addressed this issue by calculating the proportion of the estimates that were negative at all sites in the North Atlantic region with estimates from 5+ species each based on means of 10+ birds per survey (Fig. 3). The results showed that negative and positive trend estimates frequently occurred within a given site. For example, the proportion of negative

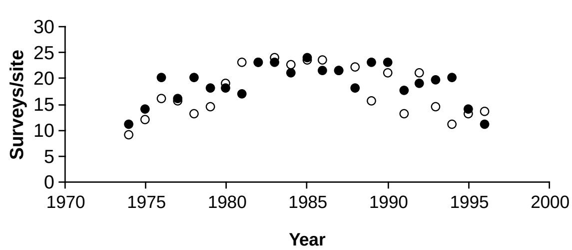

Fig. 2. Trend in mean number of surveys per site during the fall at International Shorebird Survey and Maritimes Shorebird Survey locations (closed circles = Atlantic region; open circles = Midwest region).

estimates was between 0.25 and 0.75 at 9 of the 21 sites. Thus, there was no evidence for a general decline in detection rates at sites in the North Atlantic region.

A shift in the timing of surveys is possible, but trends in the number of surveys in the North Atlantic and Midwest region were so similar (Fig. 2) that a change in timing in the North Atlantic region, but not the Midwest region, seems extremely unlikely. We therefore did not pursue this hypothesis.

The hypothesis of a net shift from surveyed to non-surveyed sites would be supported if most individuals of the species that showed declines occurred at a few sites. If these individuals were widely distributed among many sites, then it is difficult to imagine that a net shift between surveyed and non-surveyed sites occurred. We therefore determined how many sites hosted the majority of the species that declined in the North Atlantic region. To minimize effects of sampling error we used only those species that declined significantly. We identified the 5 sites that each species was most abundant at, and then determined whether these sites were the same for most species. A total of 21 sites were included on the top five species-specific lists. Thus, the species showing declines were not concentrated in just a few sites and, accordingly, the hypothesis of a net shift from surveyed to non-surveyed sites in the North Atlantic region is not supported.

The population change hypothesis

The population change hypothesis is that the reduction in numbers recorded is due to a reduction in size of the breeding population. This hypothesis would be supported by independent evidence that population size is declining and would be undermined by independent evidence that the breeding populations are stable or increasing. Evidence on trends for each of the species that declined significantly in the North Atlantic region is summarized briefly below. The estimates in this report update Howe et al. (1989) and Morrison et al. (1994), and these reports are therefore not described below.

Several reports suggest changes in the size of populations on arctic breeding grounds. Substantial declines in the number of shorebirds breeding at Churchill, Manitoba, have been described by Gratto-Trevor (1994) and Lin and Jehl (1998). Declines were reported for semipalmated plover, lesser yellowlegs, whimbrel, semipalmated sandpiper, least sandpiper, dunlin, stilt sandpiper, common snipe, and red-necked phalarope, while increases occurred in American golden plover, hudsonian godwit, and short-billed dowitcher. Stilt sandpiper numbers have declined 75% at Churchill since the 1960s and some evidence exists for a westward shift (Klima and Jehl 1998). Gratto-Trevor et al. (1998) compared population sizes of shorebirds on Rasmussen Lowlands in the mid-1970s and mid-1990s. They found significant decreases for black-bellied plovers and American golden plovers and about the same numbers of pectoral and semipalmated sandpipers. Pattie (1990) reported an increase of American golden plovers during 1978–1989 on Devon Island, with a concomitant decrease in black-bellied plovers. In temperate breeding areas, a recent analysis of Breeding Bird Survey (BBS) data indicated that a majority of shorebird species detected by the surveys declined, with decreases being most pronounced over the last 20 years (Sauer et al. 2000; Morrison 2001b). Over the entire period of the surveys, 11 of 14 species declined; statistically significant declines occurred for killdeer, lesser yellowlegs, and Wilson's phalarope. A significant increase occurred in upland sandpipers. Page and Gill (1994) noted declines in shorebirds breeding in temperate areas of western North America, especially species nesting in upland habitats. Counts from migration areas in eastern Canada have also indicated many species appear to be declining, with significantly disproportionate numbers of species declining in the Ontario Shorebird Surveys (Ross et al. 2001) and in the Étude des populations d'oiseaux du Québec checklist program (Aubry and Cotter 2001). Butler and Lemon (2001) reported declines in the two most abundant species of shorebirds, western sandpiper and dunlin, passing through the lower Fraser River Delta. In New Jersey, significant declines were found during northward migration for two shorebird species in Delaware Bay (Clark et al. 1993, Baker et al. 2004), and Harrington (1995) has also drawn attention to declines in shorebird populations in eastern North America

Trends among wintering populations in or south of the North Atlantic region may also indicate trends in population size. Sauer et al. (1996) analyzed Christmas Count data collected during 1959–1988. They reported increases for black-bellied plovers (4.6, $P < 0.01$), and significant decreases for semipalmated sandpipers (-15.0, $P < 0.01$). Killdeer declined non-significantly in 8 of 12 eastern seaboard States. Recent work on the main wintering grounds of red knots in South America-as well as on migration areas in northern Canada-has suggested a substantial decrease in numbers (Morrison et al. unpubl. data).

While results are mixed for some species, the overall picture indicates a disproportionate number of declines across many shorebird species in North America, for regions where data exist, particularly eastern Canada and the northeastern

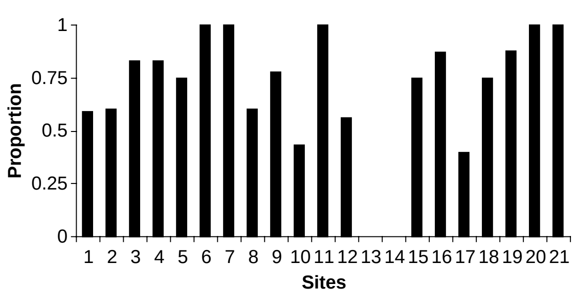

Fig. 3. Proportion of estimates that were negative at all shorebird survey locations in the ISS and MSS programs with 5+ estimates each based on means of 10+ birds.

United States (Morrison 2001a; Morrison et al. 2001). Declines have been detected using a variety of methods in a variety of areas: volunteer survey schemes (MSS, ISS, Ontario Shorebird Surveys), checklist programs (Quebec), roadside counts (BBS, USA and Canada), aerial surveys (North and South America), counts made during research projects (Western Canada) and arctic breeding ground surveys. While further research is needed to determine whether changes in numbers may be caused by changes in routes or turnover rates during migration, the wider picture currently lends support to the hypothesis that changes are occurring owing to decreases in population size.

Future studies

It appears that shorebird declines observed at sites in the North Atlantic region were caused by declines in population size, but we cannot exclude the hypothesis that the changes were due to a change in movements during migration, such as passing through the region more quickly. An urgent need exists for more long-term data sets, especially from northern breeding grounds and from western North America and at a sufficient number of locations that trends can be estimated by sub-species and distinct population segments. Surveys were conducted at several locations in the arctic during the mid-1970s. Repeating these surveys would provide the best indication we are likely to obtain of whether population size has declined. Surveys in the western parts of North America would indicate whether numbers in these areas have also declined as would surveys on the wintering areas.

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Appendix 1. Common and scientific names (American Ornithologists' Union 1998) of species mentioned in the text.

Code	Common name	Scientific name
BBPL	Black-bellied plover	*Pluvialis squatarola*
AGPL	American golden plover	*Pluvialis dominica*
SEPL	Semipalmated plover	*Charadrius semipalmatus*
PIPL	Piping plover	*Charadrius melodus*
KILL	Killdeer	*Charadrius vociferus*
GRYE	Greater yellowlegs	*Tringa melanoleuca*
LEYE	Lesser yellowlegs	*Tringa flavipes*
SOSA	Solitary sandpiper	*Tringa solitaria*
WILL	Willet	*Catoptrophorus semipalmatus*
SPSA	Spotted sandpiper	*Actitis macularia*
UPSA	Upland sandpiper	*Bartramia longicauda*
WHIM	Whimbrel	*Numenius phaeopus*
HUGO	Hudsonian godwit	*Limosa haemastica*
MAGO	Marbled godwit	*Limosa fedoa*
RUTU	Ruddy turnstone	*Arenaria interpres*
REKN	Red knot	*Calidris canutus*
SAND	Sanderling	*Calidris alba*
SESA	Semipalmated sandpiper	*Calidris pusilla*
WESA	Western sandpiper	*Calidris mauri*
LESA	Least sandpiper	*Calidris minutilla*
WRSA	White-rumped sandpiper	*Calidris fuscicollis*
BASA	Baird's sandpiper	*Calidris bairdii*
PESA	Pectoral sandpiper	*Calidris melanotos*
DUNL	Dunlin	*Calidris alpina*
STSA	Stilt sandpiper	*Calidris himantopus*
SBDO	Short-billed dowitcher	*Limnodromus griseus*
LBDO	Long-billed dowitcher	*Limnodromus scolopaceus*
COSN	Common snipe	*Gallinago gallinago*
WIPH	Wilson's phalarope	*Phalaropus tricolor*
RNPH	Red-necked phalarope	*Phalaropus lobatus*