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Spring arrivals of migrant waders in Iceland in the 20th century

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Records of first sightings of Icelandic-breeding waders and high-Arctic passage migrants have been made in most parts of Iceland since 1902. Two sets of records of first sightings are used here to analyse temporal changes in arrival dates during the 20th century and the effects of weather conditions. First sightings became earlier in the first half of the 20th century, as local spring temperatures increased. They ceased to do so after 1960, when temperatures were decreasing slightly, though the associations between arrival dates and annual temperatures were weak. In years with more than five records for a species, the earliest sightings were 5–9 days before the median dates of all first sightings. Though earliest sightings were delayed in cool Icelandic springs, those median dates showed little correlation with local spring temperatures. Six species arrived later when the winter or spring values of the North Atlantic Oscillation (NAO) were high, but seven species showed no significant associations with the winter NAO. Sightings tended to be later in springs in which westerly or cyclonic systems were prevalent over Ireland and Scotland. First sightings in Iceland were substantially later than in the Outer Hebrides, though in closer synchrony with the peaks of passage there than with arrival and passage dates in Shetland and north Norway. Sustained observations at a few key sites should be useful in tracking the responses of waders to variations in climate and other environmental changes.

Iceland is a small country (of 103,000 km^2), of which nearly half is covered by glaciers and deserts of gravel, boulders or volcanic lava and only one-seventh is well vegetated. Eleven species of waders breed there regularly, several in large numbers (Table 1). Few of them winter in the country; most emigrate to western Europe and some as far south as West Africa (Table 2). Records of first sightings of summer resident migrants in Iceland were kept during most of the 20th century, though the numbers and distribution of reporters varied widely. Thorough study of the annual patterns of arrival of any species requires sustained and intensive effort and seems to have been attempted for waders in Iceland only in a few places and for short periods (Whitfield & Magnusson 1987, Morrison & Wilson 1992, Tiedemann 1992a, b).

The largest collection of first-sighting records, now held in the Icelandic Institute of Natural History, was begun by Finnur Gudmundsson, first director of the Museum of Natural History which is now incorporated in the Institute. His own first records were made in 1919, when he was ten years old, but he found records from other observers going back to 1902. In the mid 1930s, Finnur assembled a network of volunteers who continued, in dwindling numbers, to report arrival dates until about 1970. In 1998, the Institute set up a new network. In some years as many as 20 people noted their first sighting of an abundant and widespread species, but for most waders in most years there were few records, often only one. The original handwritten records were recently converted into computer-readable files.

A second collection of first-sighting records consists of those published for nearly all years since 1950 in the May issue of *Veðrattan*, the journal of record of Veðurstofur Islands, the Icelandic Meteorological Service. These printed records are limited to the first sighting of each species at any weather station (*ie* to a single record of each species in any year). These 'censored' records are especially useful for the period 1950–96, when few records from other observers are known. In recent years, as people have become more mobile, it has been difficult to recruit and keep weather observers. For weather observations, that problem has been overcome by the establishment of automatic weather stations, but these do not note bird arrivals, so that records from this source are becoming fewer. Additional records that may exist in the archives are not readily available.

Here, these two sets of records of first sightings are used, first, to see whether there have been substantial changes in arrival dates over time and, second, if weather conditions in Iceland, or in wintering and spring staging areas, seem to have influenced arrival times. Haphazard

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Table 1. Waders in Iceland: species and subspecies, estimated numbers of breeding pairs, wintering individuals and peak numbers of passage migrants (from Petersen 1998).

Breeding in Iceland	Breeding pairs	Wintering individuals
Oystercatcher *Haematopus ostralegus*	10,000	2,000–3,000
Ringed Plover *Charadrius h hiaticula*	30,000–50,000	
Golden Plover *Pluvialis apricaria*	300,000	
Purple Sandpiper *Calidris maritima littoralis*	10,000	10,000–100,000
Dunlin *Calidris alpina schinzii*	300,000	
Common Snipe *Gallinago g faeroeensis*	300,000	10–100
Black-tailed Godwit *Limosa l islandica*	7,000–10,000	
Whimbrel *Numenius phaeopus islandicus*	200,000	
Redshank *Tringa totanus robusta*	50,000–100,000	500–1,000
Red-necked Phalarope *Phalaropus lobata*	50,000–100,000	
Grey Phalarope *Phalaropus fulicarius*	50	
Passage migrants	**Peak spring count**	**Wintering individuals**
Knot *Calidris canutus islandica*	270,000	10–50
Sanderling *Calidris alba*	17,000	
Turnstone *Arenaria interpres*	40,000	2,000–5,000

Table 2. Wintering ranges of waders breeding in Iceland, or seen there regularly on spring passage. After Petersen (1998), Snow & Perrins (1998) and Wernham *et al* (2002). Secondary areas are shown in parentheses.

	Wintering range	Length of spring migration
Breeding in Iceland		
Oystercatcher	British Isles, (western Europe)	short
Ringed Plover	Britain, western Europe, northwest Africa	short/medium
Golden Plover	Ireland, (southern Britain, western Europe)	short
Purple Sandpiper	Iceland, west coasts of Europe, east coast of Canada	short/medium
Dunlin	Coasts of Iberia and northwest Africa	medium
Common Snipe	Ireland, (Britain, west France, Portugal)	short/medium
Black-tailed Godwit	England, (northwest France, Portugal)	short/medium
Whimbrel	West African coasts	long
Redshank	British Isles, (North Sea coasts)	short
Red-necked Phalarope	At sea, north Atlantic areas still unknown	long
Grey Phalarope	At sea, Atlantic, possibly west of Africa	long
Passage migrants		
Knot	British Isles, (European Channel coasts)	short
Sanderling	West African coasts (British Isles)	long
Turnstone	British Isles, west coasts of Europe & Africa	short/long

collections of arrival records cannot be expected to yield strong inferences, but may be sufficient to identify broad patterns. The principal questions addressed here are: (1) have the many waders breeding in Iceland shown similar changes in arrival dates during the 20th century to those of the four summer resident passerines (Boyd 2003); (2) have high-Arctic passage migrants also changed their times of arrival; (3) have waders been influenced by the same weather factors, locally and in western Europe, that have affected the arrivals of passerines; and (4) have different wader species tended to appear first in different parts of the country. Arrival dates in Iceland are also compared with those at similar latitudes in north Norway and with the periods of peak passage through the Outer Hebrides and Shetland.

METHODS

Data for first-sighting records consisted of those held by the Icelandic Institute of Natural History and records published by the Icelandic Meteorological Service since 1950 in the May issue of *Veðrattan*. Data for earliest sightings and estimated dates of peak wader passage for the Outer Hebrides were obtained from *Outer Hebrides Bird Reports* (Boyer *et al* 1991–2004). Other published data sources are referred to in the text.

The influence of climate on arrival dates is treated here in a very limited way. Variations in spring warmth in Iceland are described by mean monthly temperatures at Stykkisholmur, on the west coast, in March–May (Boyd 2003). Conditions in the British Isles, where many Icelandic waders overwinter, and over which most of them must pass in spring, are summarised by mean winter (December–February) temperatures in Ireland and in Central England, and by estimates of the daily state of the near-surface atmosphere in the spring months (after Lamb 1972 and Mayes 1991). Weather data for Britain and Ireland were obtained from the Climatic Research Unit, University of East Anglia (www.cru.uea.ac.uk) and Met Éireann (www.met.ie), respectively.

As the winter distribution of the long-distance migrants cannot be defined precisely, no attempt was made to relate their spring movements to winter conditions south of the British Isles. The possible effects on arrival dates of weather conditions (temperature and wind) and large-scale seasonal changes in the lower atmosphere were explored by seeking correlations (Pearson's correlation coefficients) between annual arrival dates and weather variables, and between arrival dates and the North Atlantic Oscillation (NAO; Hurrell 1995) in the winter and spring months. The NAO is measured by the differences in mean monthly sea-level pressure (MSLP) between stations near the Azores High (Ponta Delgada) and the Iceland Low (Reykjavik). These data were also obtained from the Climate Research Unit (www.cru.uea.ac.uk/cru/data/nao.htm).

Table 3. Regional distribution of observers, within Iceland, reporting wader sightings in different periods of the 20th century.

	NW	NE	SE	SW	Total
Museum/IINH observers					
1902–25	3	1	0	0	4
1926–50	12	17	16	15	60
1951–97	2	12	4	12	30
1998–2000	5	37	14	48	104
All years	22	67	34	75	198
Weather observers					
1950–2000	12	14	5	16	47

RESULTS

Numbers and distribution of observers and records

Table 3 shows the regional distribution of observers at different times during the century. For simplicity, the country has been divided into four quadrants: north or south of 65°N, and west or east of 19°W. An early bias to the north was reversed in recent years, when 70% of the human population had settled in or near Reykjavik, in the southwest.

The scatter of observers influenced the distribution of sightings (Table 4), which were also affected by changes, during the century, in the abundance of several species, including a prolonged increase in Oystercatchers and a decline in Dunlins. The numbers of sighting records in

Table 4. Regional distribution of first sighting records of eight abundant breeding waders in Iceland in 1902–50 and 1951–2000.

	1902–50					1951–2000				
	NW	NE	SE	SW	Total	NW	NE	SE	SW	Total
Oystercatcher	8	8	15	22	53	10	20	44	94	168
Ringed Plover	25	35	12	2	74	6	43	10	20	79
Golden Plover	28	61	27	28	144	13	45	42	108	208
Dunlin	15	52	21	20	108	4	48	9	10	71
Common Snipe	35	51	20	24	130	8	34	22	92	156
Whimbrel	38	53	17	26	134	17	42	37	79	175
Redshank	50	44	13	21	128	17	48	44	68	177
Red-necked Phalarope	13	45	21	13	92	15	42	17	6	80
Rank	2	1	4	3		4	2	3	1	
Total sightings	**212**	**349**	**146**	**156**	**863**	**90**	**322**	**225**	**477**	**11**

recent years are consistent with the estimates of their present abundance, in Table 1. During the first half of the century 65% of the records were from the north, in the second half only 37%. Dividing the number of sightings in each quadrant by the number of reporters there (from Table 3), there were more sightings per observer before 1950 than in 1951–2000, especially in the northwest (Table 4). The penultimate line in Table 4 shows that, over the first half of the century, the sightings were widely distributed. In the second half, the northwest was poorly represented.

Earliest dates of sighting of summer residents

The simplest measure of arrival is the earliest date on which a member of a species was first seen, though it is unlikely that the first individual seen was the first to reach Iceland. Table 5 shows the dates of earliest sighting for each species through the 20th century. There was substantial variation in the first sighting dates for most species, with the earliest dates most often being in 1935–50, the period in which there were most observers. Yet the changes were not due simply to greater searching effort. Table 6 shows a comparison of the earliest and median sighting dates in 1935–37 with 1998 and 2000, the years with the greatest effort. There were wide differences between the earliest and median sighting dates of nearly all species. Most of the distributions were right-skewed, so that some of the earliest dates appear as outliers (defined as more than two standard deviations ahead of the mean). No consistent patterns in the within-season distributions of sightings were found. The inter-annual differences were as great for the median sightings as for the earliest ones. Because of the method of selection, there is no tally of the total numbers of records from the weather stations, which provide the great majority of the earliest sightings used between 1950 and 1997. Consequently, earliest sighting dates have been used here with no adjustments for varying effort.

Records from individual sites

At Heimaey, in the Westmann Islands, off the south coast, arrivals were noted every year from 1952 to 2000. First sightings of Oystercatcher (mean 30 March, standard deviation [sd] 7.8 days), Golden Plover (10 April, sd 7.1 days) and Whimbrel (2 May, sd 7.6 days) showed no significant trends. Common Snipe (mean 15 April, sd 7.1 days) tended to be seen earlier in the 1950s than in the 1990s. The Ringed Plover (6 May, sd 15.2 days) was noted only until 1962. Arrivals of the Redshank (20 April, sd 5.0 days), which was not seen regularly until 1972, showed no trend over the subsequent thirty years.

At Kelduhverfi, in the northeast, sightings of seven species were made in 1907–14, 1935–37 and 1947–58. Five of them were seen earlier in 1935–37 than in either the first or the third periods.

Sightings of high-Arctic passage migrants

There were few records of passage migrants in the first half of the century. In 1951–2000, 18/21 of Red Knot and 24/29 of Turnstone records were from Þorvaldsstadir, on

Table 5. Mean earliest sighting dates of waders in Iceland in 1902–34, 1935–50 and 1951–2000. N = number of years with records, na = insufficient records during period. Under 'change': + = days earlier, - = days later.

	1902–34 (1)			1935–50 (2)			1951–2000 (3)			change	
	N	mean	sd	N	mean	sd	N	mean	sd	1→2	2→3
Breeding in Iceland											
Oystercatcher	6	6 Apr	7.8	13	28 Mar	12.7	50	21 Mar	9.3	+9	+7
Ringed Plover	22	10 May	5.6	16	28 Apr	6.3	43	28 Apr	9.6	+12	0
Golden Plover	24	20 Apr	7.6	16	31 Mar	9.1	50	4 Apr	7.7	+21	-4
Purple Sandpiper		na		10	2 May	9.3	14	27 Apr	12.4		+5
Dunlin	15	4 May	8.6	16	24 Apr	8.7	45	30 Apr	7.1	+10	-6
Common Snipe	22	30 Apr	9.4	16	12 Apr	7.3	50	10 Apr	5.4	+18	+2
Black-tailed Godwit		na		14	25 Apr	8.4	42	28 Apr	9.0		-3
Whimbrel	22	10 May	4.5	16	27 Apr	8.8	50	26 Apr	8.0	+13	+1
Redshank	22	21 Apr	6.9	16	8 Apr	5.8	50	12 Apr	5.1	+13	-4
Red-necked Phalarope	16	22 May	5.1	16	11 May	6.1	42	16 May	6.3	+11	-5
Passage migrants											
Knot		na			na		30	9 May	8.0		
Turnstone		na		8	11 May	6.8	50	30 Apr	10.6		+11
Mean earliest sightings		1 May			21 Apr			23 Apr		+10	-2

Table 6. Ordinal dates (from 1 January) of earliest sighting (E) and mean of all first sightings (M) of waders in Iceland in years with most records (1935–37, 1998 and 2000). N = number of records, D = days between earliest and mean first sighting.

Year	Oystercatcher				Ringed Plover				Golden Plover				Dunlin			
	N	E	M	D	N	E	M	D	N	E	M	D	N	E	M	D
1935	12	79	115	36	11	100	127	27	18	83	110	27	13	107	123	16
1936	8	87	114	27	10	119	124	5	17	80	99	19	10	97	124	27
1937	10	86	92	6	9	114	126	12	15	80	101	21	9	103	122	19
1998	7	79	88	9	9	99	109	10	15	85	93	8	7	99	107	8
2000	14	64	85	21	10	104	108	4	15	83	93	10	12	84	107	23

	Common Snipe				Whimbrel				Redshank				Red-n. Phalarope			
	N	E	M	D	N	E	M	D	N	E	M	D	N	E	M	D
1935	23	94	115	21	25	105	124	19	18	95	109	14	16	113	135	22
1936	15	94	102	8	14	108	125	17	15	80	103	23	10	129	141	12
1937	15	95	105	10	14	101	120	19	12	92	103	11	9	112	133	21
1998	8	71	94	23	4	113	119	6	8	97	104	7	–			
2000	25	91	107	16	12	111	116	5	13	84	107	23	9	131	135	4

the northeast coast. Red Knots were seen in 30 years, with a mean first sighting date of 8 May (sd 11.4 days) and outliers of 26 March 2000 (next earliest 19 April 1998) and 23 May 1978. The decadal mean first sighting of Turnstones was earliest (21 April) in 1951–60, the warmest decade, and latest (14 May) in 1931–40, the next warmest; their arrivals became later after 1960. For these passage migrants, the intervals between earliest and median sighting dates decreased: for the Knot from 9.4 days in 1931–40 to 4.8 in 1991–2000, for the Turnstone from 4.8 to 2.5 days. The only Sanderlings reported were in 2000, when records from six sites occurred between 1 and 13 May.

First sightings and spring weather in Iceland

It has become customary to use records from Stykkisholmur, on the mid-west coast, to represent conditions over the whole of Iceland, though temperatures are usually lower and precipitation less in the east than in the west. Mean spring temperatures at Stykkisholmur were much lower in 1901–20, and higher from 1922 to 1945, than they were in most later years. During most of the 20th century the decadal means were well above those in the second half of the 19th century. Precipitation was also lower in 1901–20 than in any subsequent decade except 1971–80. Warm springs were usually wet ($r = 0.609$, $P < 0.02$).

The sightings in the cold early years tended to be late. In each half of the 20th century five species seem to have arrived earlier in warm springs (Table 7), but, when time trends in the data are allowed for, these relationships cease to be statistically significant. Associations with spring precipitation were even weaker. The Red Knot and Red-necked Phalarope, which do not reach Iceland until well into May, showed no response to spring warmth.

First sightings and weather in wintering areas

In 1951–2000, the earliest sighting dates showed few clear associations with winter temperatures in Ireland or Central England (Table 8). Many Icelandic Golden Plover and Common Snipe winter in Ireland (Petersen 1998) and their arrival dates were more strongly associated with Irish winter temperatures than with those in Central England or in western Europe as a whole. The arrivals of three of the four species seen regularly on Heimaey, though not those of the Golden Plover, were better correlated with winter temperatures in their wintering areas than those of the same species in other parts of Iceland.

Many Icelandic Ringed Plover, Dunlin and Black-tailed Godwit are believed to winter in West Africa. Their earliest sighting dates seemed not to be linked to winter conditions in the British Isles. Though the pelagic wintering areas of Icelandic Red-necked Phalaropes have not yet been identified, they are likely to be well south in the Atlantic Ocean, so that the absence of links between their return dates and onshore winter conditions in western Europe was also to be expected.

Table 7. Correlation coefficients of earliest sighting dates in 1902–50 and 1951–2000 and mean spring temperatures at Stykkisholmur. * $P < 0.05$.

	1902–50 All sites	1951–2000 All sites	Heimaey
Breeding in Iceland			
Oystercatcher	-0.388	0.349 *	-0.022
Ringed Plover	-0.374 *	-0.352	
Golden Plover	-0.371 *	-0.367 *	-0.018
Purple Sandpiper	-0.619 *		
Dunlin	-0.391 *	-0.081	
Common Snipe	-0.252	-0.007	-0.099
Black-tailed Godwit		0.328	
Whimbrel	-0.359 *	-0.363 *	0.292
Redshank	-0.284	-0.366 *	-0.004
Red-necked Phalarope		-0.424 *	-0.361*
Grey Phalarope	-0.076		
Passage migrants			
Turnstone	0.387	-0.546 *	

Table 8. Correlation coefficients of earliest sighting dates of waders in Iceland in 1951–2000, with winter (Dec–Feb) and spring (Mar–May) temperatures in Ireland and Central England (CET). Records from all sites and, for four species, from Heimaey only (in italic). N = number of years with sightings, *$P < 0.05$, **$P < 0.01$, otherwise $P < 0.1$. No value indicates $P > 0.1$.

	Winter		Spring	
	Ireland	CET	Ireland	CET
Breeding in Iceland				
Oystercatcher				
Ringed Plover				
Golden Plover	-0.419 *		-0.327	*0.427***
Purple Sandpiper			0.430	
Dunlin				
Common Snipe	-0.303 *	*-0.418* **	*-0.396* **	
Whimbrel	*0.372* *			
Redshank		*-0.387* *	*-0.421* **	
Red-necked Phalarope				
Passage migrants				
Knot		-0.436 *		

Arrivals in Iceland tended to be delayed in years when westerly and cyclonic conditions were frequent over the British Isles in spring (Table 9). In the few years in which southerlies were frequent, most arrivals were early.

What routes do migrants to Iceland follow?

Most of the Icelandic waders wintering in Ireland and Britain presumably fly directly to Iceland and many of those wintering further south are also likely to cross the British Isles. Table 10 compares the earliest sightings and estimated dates of peak passage in Iceland in the 1990s with those in the Outer Hebrides and with the periods of peak passage in Shetland (from Pennington *et al* 2004). Though all species were first seen much earlier in the Hebrides, most of the earliest sightings in Iceland were on dates close to the apparent peaks of passage through the Hebrides. In contrast, the peaks of passage of several species through Shetland were later than most arrivals in Iceland, suggesting that the birds involved were not travelling to Iceland.

Table 9. Correlation of earliest sightings of waders in Iceland in 1951–95 with airflow patterns over the British Isles and over Ireland only (shown in italic) in March, April and May. Airflow summaries are from Mayes (1991), with unpublished additions. Dates are correlated against the monthly total of days with seemingly unhelpful conditions for migration: W = westerlies, C = cyclonic, Z = west to southwesterlies and/or cyclonic. Coefficients shown only when $P < 0.1$; *$P < 0.05$; **$P < 0.01$; # Heimaey only. Positive coefficients imply later arrival.

	March	April	May
Breeding in Iceland			
Oystercatcher	Z -0.345*		
Ringed Plover	*W -0.270*	C 0.306*	C 0.389*
Golden Plover		C 0.367*	
Purple Sandpiper	W 0.613*, Z 0.571*, *W 0.665**	C 0.610*, Z -0.375*, *C 0.444*,	
Dunlin	W 0.414*, Z 0.425**, *W 0.411**	C 0.253, *C 0.289*	
Common Snipe		W 0.323#, C 0.316, Z 0.372*, *W 0.355**	C 0.241#
Black-tailed Godwit		W 0.331, C 0.379*	
Whimbrel		W 0.339*, C -0.326#, Z 0.364*	C -0.275#
Redshank		*W 0.249*	
Red-necked Phalarope	W 0.302, Z 0.339*		
Passage migrants			
Turnstone	W 0.506*, Z 0.363*, *W 0.466**	W -0.362	

Table 10. Mean earliest sighting dates of waders in Iceland in 1989-2002, compared with mean earliest sighting dates and peak passage in the Outer Hebrides, Scotland, and with periods of peak passage through Shetland (after Pennington *et al* 2004).

	Iceland earliest	**Outer Hebrides earliest**	**Outer Hebrides peak**	**Shetland peak**
Breeding in Iceland				
Oystercatcher	17 Mar	28 Feb	8 Apr	late Mar–early Apr
Ringed Plover	28 Apr	11 Mar	1 May	2nd week May
Golden Plover	4 Apr	11 Mar	12 Apr	late Mar–early May
Purple Sandpiper	28 Apr	11 Mar	4 May	1st week May
Dunlin	1 May	6 Mar	26 Apr	mid May
Common Snipe	9 Apr	4 Mar	18 Apr	mid Mar–early May
Black-tailed Godwit	27 Apr	28 Mar	5 May	late Apr–early May
Whimbrel	23 Apr	9 Apr	29 Apr	May
Redshank	11 Apr	11 Mar	11 Apr	Apr–early May
Passage migrants				
Knot	5 May	4 Mar	26 Apr	mid May
Turnstone	30 Apr	6 Mar	28 Apr	late Mar–early Apr
Mean dates	18 Apr	11 Mar	23 Apr	

Table 11. Mean earliest and median dates of first sightings of waders in Iceland, and in Troms, Norway, in 1970–2000 (Barrett 2002).

	Earliest sighting Iceland	**Earliest sighting Troms**	**Median sighting Iceland**	**Median sighting Troms**	**Main arrivals in Troms**
Oystercatcher	5 Mar	3 Mar	28 Mar	16 Mar	20–25 Mar
Golden Plover	24 Mar	5 Apr	5 Apr	4 May	1–10 May
Common Snipe *G g faeroeensis*	30 Mar		16 Apr		
Common Snipe *G g gallinago*		7 Apr		25 Apr	1–6 May
Whimbrel *N p islandicus*	9 Apr		4 May		
Whimbrel *N p phaeopus*		30 Mar		18 Apr	15 Apr–10 May
Redshank *T t robusta*	2 Apr		17 Apr		
Redshank *T t totanus*		28 Mar		26 Apr	1–10 May

Arrivals of five species that breed in both Iceland and north Norway were reported from Troms (*c* 68°N 10°E) in 1970–2000 by Barrett (2002). The Golden Plover, Snipe and Redshank reach Iceland earlier than north Norway, the Whimbrel much later (Table 11). That three of the species in the two regions have been described as different subspecies suggests that their breeding populations have been separated for a long time and are unlikely to mingle in the later stages of spring migration.

Has the North Atlantic Oscillation influenced wader arrivals in Iceland?

The NAO summarises the seasonal and monthly frequency and intensity of weather systems moving across the eastern Atlantic Ocean and western Europe. Positive winter values of the NAO, with pressure markedly higher over the Azores than over Iceland, are associated with more and stronger storms crossing the North Atlantic and on a more northerly track, resulting in relatively warm and wet conditions in western Europe. Negative values of the NAO correspond to cold winters and springs in northern Europe (Hurrell 1995). Positive values have been dominant in both winter and spring since about 1970.

There were few significant correlations between earliest sighting dates of waders and either the winter or spring values of the NAO (Table 12). The Red-necked Phalarope was the only species to show significant correlations in both halves of the 20th century, while the Purple Sandpiper was the only one showing strong association with both the winter and spring NAO. The correlations are predominantly positive in sign, implying later arrival in years when the NAO was positive and high. Many of the coefficients are trivially small, especially those among the responses to the winter NAO in 1951–2000.

Table 12. Correlation of earliest sighting dates of waders breeding in Iceland with the winter and spring values of the North Atlantic Oscillation in the periods 1902–50 and 1951–2000. *$P < 0.05$, **$P < 0.01$.

	1902–50	1951–2000
Winter		
Oystercatcher	0.124	-0.167
Ringed Plover	0.265	0.156
Golden Plover	0.254	-0.035
Purple Sandpiper	0.418 *	
Dunlin	0.330	0.071
Common Snipe	0.247	0.181
Black-tailed Godwit	0.060	
Whimbrel	0.291	-0.001
Redshank	0.016	-0.291 *
Red-necked Phalarope	0.109	-0.059
Spring		
Oystercatcher	0.464 *	-0.223
Ringed Plover	0.347 *	0.099
Golden Plover	0.263	0.102
Purple Sandpiper	0.500 *	
Dunlin	0.231	0.277
Common Snipe	0.233	0.075
Black-tailed Godwit	0.253	
Whimbrel	0.305	0.120
Redshank	-0.216	0.117
Red-necked Phalarope	0.356 *	0.355 *

It seemed possible that associations between arrival dates and the MSLP at Reykjavik might be stronger than those with the NAO. That proved not to be the case.

DISCUSSION

The arrival times of waders in Iceland during the 20th century seem to have varied in much the same ways as those of the summer resident passerines (Boyd 2003). In the second half of the century, they failed to match the advances in arrival times shown by four of five species of geese (Boyd *et al* 2000), perhaps because of major differences in the performance of goose and wader populations. The 20th century was a good time to be an Icelandic goose, or Oystercatcher, but a bad time for some other breeding waders, such as the Dunlin and the two phalarope species.

That the associations between weather conditions and the earliest sightings were stronger than those with the median sighting dates may mean no more than that the median sighting date has no biological significance. Much larger samples, over many years, would be needed to determine the extent to which the arrivals of each species are bunched or dispersed, by date and by area, in different years. Sustained daily watches and counts at sites favourable for observing seem likely to be far more informative than further haphazard recording of sightings.

The first years of the 21st century have been unusually warm in Iceland (Trausti Jonsson, pers comm). Temperature change scenarios for Europe have suggested increases in mean summer temperatures in Iceland of about 0.75°C by the 2020s and 1.5°C by the 2080s (Hulme & Carter 2000, Houghton *et al* 2001). Should that happen, waders may again find it advantageous to arrive earlier.

Other modelling studies suggest, in strong contrast, that major climatic cooling in Iceland may be imminent (Houghton *et al* 2001), if continuing increases in concentrations of greenhouse gases elicit large non-linear responses in the thermohaline circulation (THC) in the North Atlantic Ocean. The resulting changes in thermal and freshwater forcing could lead to the complete shutdown of the North Atlantic THC, though probably not before 2100, and to earlier shutdown in the Labrador and Greenland Seas (Stouffer & Manabe 1999). That would reduce, or eliminate, the warming 'Gulf Stream' effect that at present causes Iceland to be remarkably mild for a country at latitude 64–66°N. Though neither the probability nor the timing of major circulation changes in the North Atlantic can yet be predicted with confidence, simulations run by Stouffer & Manabe (1999) suggest that a regional shutdown could occur quite early in the 21st century, and happen in less than a decade.

These conflicting scenarios for Iceland are not unusual, as climate modelling is developing rapidly. Uncertainty about the behaviour of the oceans is still far greater than about changes in the atmosphere. Whatever changes in climate come about, it seems likely that Iceland will continue to be an important breeding place for waders. The several distinctive subspecies found there suggest that the summer resident waders have been able to withstand harsher climatic conditions than those of the 20th century, though perhaps in smaller numbers.

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