Wader populations at Zackenberg, high-arctic Northeast Greenland, 1996-2005

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(Med et dansk resumé: Vadefuglebestandene ved Zackenberg i Nordøstgrønland, 1996-2005)

Abstract At Zackenberg Research Station (74°30' N, 20°30' W) in central Northeast Greenland monitoring of wader populations and their breeding performance have taken place since 1996 in a 19.3 km^2 census area as part of the BioBasis climate effects monitoring programme. Six species of waders breed in the area totalling an average of 260-300 pairs. In spite of notorious difficulties in monitoring tundra waders in such a large area, the evaluation of the data indicates relatively limited interannual fluctuations between most years. Common Ringed *Plover Charadrius* hiaticula and Red Knot *Calidris canutus* have varied most, with up to a factor two between adjacent years, while Ruddy Turnstone *Arenaria interpres*, Sanderling *Calidris alba*, Dunlin *Calidris alpina* and Red-necked Phalarope *Phalaropus lobatus* have varied less. Only Common Ringed Plover showed a significantly decreasing trend over the study years, which is in accordance with declining numbers on the wintering grounds in West Africa. Waders breeding at Zackenberg appear largely to be site tenacious. There were few correlations with environmental conditions that could explain the observed variations in numbers. Especially interesting was a positive correlation between Red Knot and Ruddy Turnstone numbers and July temperatures two years previously, suggesting that chick survival influences population sizes two years later, when the young birds mature.

Introduction

Few long-term programmes monitor arctic waders on their breeding grounds (Soloviev & Tomkovich 2005), which means that we have limited knowledge of the factors, operating during the breeding season, that influences the population trends we see on staging and wintering areas (International Wader Study Group 2004, Stroud et al. 2004).

On order to have at least a 'foothold' in high-arctic Greenland, Zackenberg Research Station (74°30' N, 20°30' W) was established in 1995 to facilitate long-term research and monitoring of biotic as well as abiotic factors influencing the dynamics of this high-arctic ecosystem in relation to climate variability and trends (Meltofte 2002). The biological part of the programme, BioBasis, is monitoring a wide range of parameters within plant communities and reproduction, invertebrate occurrence, and bird and mammal populations and breeding performance (Meltofte & Berg 2005).

Since waders make up the dominating group of tundra birds, both concerning species numbers and population densities, they constitute an important part of the BioBasis monitoring programme. Hence, population size together with breeding phenology and nest success are monitored within a 19.3 km^2 census area, as are the numbers of juveniles turning up at the coast in late summer.

In this paper, the size and variability of wader populations during the first 10 years of the programme are presented, analyzed and discussed. Since breeding waders are notoriously difficult to census on the extensive arctic tundras (Meltofte 2001a), the present paper does not claim to give absolute figures. The accuracy varies from species to species, but at the very least the figures should provide reliable, relative values.

Data on breeding phenology and success together with food availability etc. are presented in

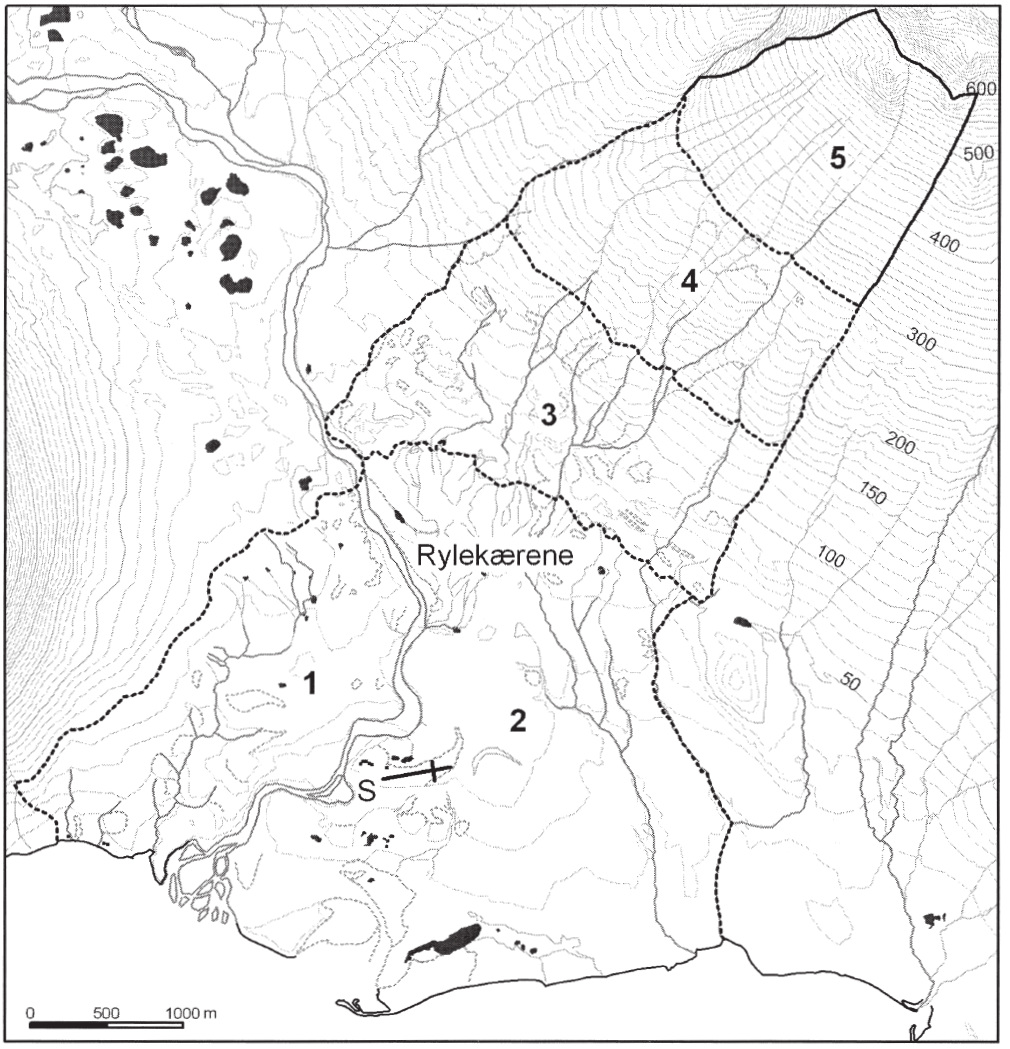

Fig. 1. Map of the study area at Zackenberg with demarcation of sections 1-5, showing streams, lakes and ponds (black), and contour curves (m a.s.l.). The research station (S) and runway are at the lower left centre.
Kort over optællingsområdet ved Zackenberg med afgrænsning af sektionerne 1-5 samt elve, søer og damme (sort), landskabskonturer og forskningsstationen (S) med landingsbanen.

annual reports (e.g. Rasch & Caning 2005) and analysed by Meltofte & Sittler (in print) and Meltofte et al. (submitted a).

Study area and methods

The 19.3 km^2 bird census and study area at Zackenberg stretches from the coast of Young Sund and up the slopes of Aucellabjerg to an altitude of 600 m. Below 50 m a.s.l., most of the land is relatively flat with extensive areas of dwarf scrub heath (mainly mountain avens *Dryas* spp., white arctic bell-heather *Cassiope tetragona* and arctic willow *Salix arctica*) and wet fens, but also with areas of more or less barren gravel and stones, which have no or little snow cover in winter. This part of the study area is divided into an intensive study area of 3.47 km^2 (section 1; Fig. 1 and Table 1) west of the main river, Zackenbergelven, and a 7.77 km^2 area east of the river (section 2). Between 50 and 150 m a.s.l. (section 3; 3.33 km^2) the terrain is more hilly with barren moraine ridges, Oksebakkerne ("Musk Ox Hills"), but also with extensive fens and grass-

During mid/late June an initial mapping is made of all waders present on snow-free areas. Photo: Inger Meltofte.

lands. Smooth slopes with an inclination of 7°-13° prevail above 150 m a.s.l., the area below 300 m a.s.l. (section 4; 2.51 km^2) being dominated by mountain avens heath, whereas the area up to 600 m a.s.l. (section 5; 2.24 km^2) has more extensive areas of barren clay and gravel, but also stretches of grassland with scattered mountain avens (see Bay 1998 for map of plant communities).

Each year, the waders and other birds present are mapped in the entire census area during mid/late June, i.e. from 10-12 June onwards, when most birds are displaying and are concentrated on the snow-free areas. Ideally, this is during the period of settlement, i.e. following dispersal from pre-breeding areas and before the birds start living a more secluded life during incubation – or even disappear from the area following depredation of nests or other failure (see Meltofte & Berg 2005 for description and Meltofte 2001a for discussion of the method). Since some pairs begin incubation before many other birds are dispersed, it is not fully possible to map all birds during settlement. Particularly during recent years, egg-laying has been so early that most pairs have been incubating during the initial census. However, the census cannot take place earlier, since many other birds are unsettled in early June. In addition, it takes at least a week to cover the entire area, which means that some areas, especially on the upper slopes, have been covered too late. All this means that the accuracy of the census results varies between years, between species, and between sections, as discussed more fully in the species accounts below.

In most years, snow cover by 10 June is about 80% (Table 2), but it decreases rapidly during the census period. During the census, we strive to cover all snow free areas so that the census taker passes within 100 m of all important patches. All birds present are plotted using codes for birds appearing in pairs, birds singing or displaying, and birds giving alarm calls or other vocalisation. During the rest of the season we try to find as many nests and broods as possible, and follow up on the initial census. The follow-up has been much more intensive in the lowland and on the lower slopes than above 200-300 m. Also, a 1 km wide goose protection zone along the coast east of the old delta of Zackenbergelven (the spit in Fig. 1) has been covered much less intensively during the post-laying season than has the rest of the lowland. Almost all fieldwork has been performed between 9 hrs and 18 hrs local sun time, when the birds are most active.

After the season, the records are evaluated to produce maps of pairs/territories. In so doing, all birds

present during the initial census are considered as belonging to the local population. This even applies to birds outside typical nesting habitat, meaning that the evaluation results in numbers and location of potential breeding pairs, of which some may actually have been visitors or non-breeders.

Birds occurring in pairs and singing or otherwise vocal individuals are taken as representing pairs/territories, while silent individuals are added as representing possible pairs/territories. Records from the rest of the season may possibly upgrade 'possible pairs' to 'pairs', or add new pairs in places where no birds were recorded previously (see Discussion).

The minimum figures in Tables 2-6 are the pairs as defined above, while maximum figures include the possible pairs. In addition, the total number of individuals recorded during the initial census in mid/late June is given.

Since the evaluated numbers of pairs involve some subjectivity, the extent of which may have varied over the years, both the evaluated population sizes and the total numbers of birds recorded during the initial censuses are presented and tested. For population sizes, the median between minimum and maximum numbers of pairs/territories were used in the statistical tests. Conditions during the initial census have been similar in all years except 1999 (extensive snow cover) and 2001 (snow storm in the middle of the census period) (Meltofte 2000, 2003). In these two years many birds were concentrated and easy to record in the limited snow free areas, where even birds from neighbouring areas may have been present. Therefore, the data are tested both with and without these two years. Trends were tested using linear regression, while correlations with early season snow cover (10 June), and with June and July mean temperatures, were tested using Pearson's correlation coefficient. Tests were made with snow cover and June temperatures in the same year, and with snow cover and June and July temperatures one and two years earlier. Annual snow cover and temperature data are presented in Table 2.

The censuses were performed by the author during 1996-2003, by Ole Thorup and the author in 2004, and by Jannik Hansen and the author in 2005. Ole Thorup's evaluation of the 2004 data have been revised according to the methods used in the other years, reducing the totals of Common Ringed Plover and Ruddy Turnstone by 13% and 10%, respectively, compared with Ole Thorup's evaluations. In addition, the data from the first two years were re-evaluated in 1998, yielding higher figures than originally estimated. However, the results from 1996 may still be too low for some of the species.

Species accounts

Six species of waders breed in the 19.3 km^2 bird census area, averaging a total of 260-300 pairs. The species have different habitat preferences as illustrated by the distribution within different sections of the census area (Table 1). Common Ringed Plovers are found on poorly vegetated gravel expanses in the lowland and particularly in areas above 300 m a.s.l., but always close to vegetated areas. Red Knots and Sanderlings are mainly found on mesic dwarf scrub heath with low topographic profile – the Sanderling apparently on less stony ground than the Red Knot – in the lowlands and particularly on the slopes between 150 m and 300 m a.s.l. Dunlins breed exclusively in and around wet fens, which primarily are found in the lowland. Ruddy Turnstones breed on gravelly and stony sites, often with hills and ridges, which is why most are found in Oksebakkerne between 50 m and 150 m a.s.l., where very few Sanderlings occur. Finally, one or a few pairs of Red-necked Phalaropes breed at the ponds in the fens close to the research station. Surprisingly, the total densities of waders are very similar between regions up to 300 m a.s.l. (Table 1).

Common Ringed Plover *Charadrius hiaticula*. Common Ringed Plovers are particularly problematic to census because they may run or fly around the observer and give alarm calls several hundred metres from the nest, and may join alarm-calling individuals more than one kilometre away, so that several birds may perform alarmist behaviour simultaneously around the census taker (Meltofte 1979 and unpubl.). As a consequence the population is easily overestimated. Furthermore, Common Ringed Plovers breed commonly on higher ground than other wader species (Table 1), indicating that unsettled individuals may be present in the lowlands (sections 1, 2 and 3) until the high-lying slopes become sufficiently snow-free. Particularly in 1999 and 2001 when there was much snow in mid June, many Common Ringed Plovers were recorded in the lowlands in habitats where most of them did not breed (Table 2; see also Dunlin and Discussion below). Hence, both pairs/territories and individuals recorded during the June census show significant positive correlations with the 10 June snow cover, but these correlations disappear when excluding 1999 and 2001.

Table 1. Area size (km^2) and average population densities (pairs/territories) of waders in five sections of the 19.3 km^2 study area at Zackenberg 1996-2005 (see Fig. 1 for position of sections).
Størrelse (km^2) og det gennemsnitlige antal par/territorier af vadefugle i de fem sektioner af optællingsområdet ved Zackenberg 1996-2005 (se Fig. 1 for placering af sektionerne; C. hia. Stor Præstekrave, C. can. Islandsk Ryle, C. alb. Sandløber, C. alp. Almindelig Ryle og A. int. Stenvender).

Section	Area	*C. hia.*	*C. can.*	*C. alb.*	*C. alp.*	*A. int.*	All
5 (300-600 m)	2.24	4.78	0.31	2.28	0.58	0.04	7.99
4 (150-300 m)	2.51	4.04	2.51	5.00	0.88	0.94	13.37
3 (50-150 m)	3.33	1.23	2.66	1.13	4.31	5.29	14.62
2 (0-50 m)	7.77	1.18	1.38	3.67	7.08	2.98	16.29
1 (0-50 m)	3.47	2.19	0.73	3.16	7.41	1.47	14.96
Total	19.32	2.15	1.53	3.16	5.10	2.51	14.45

We have no explanation for the low numbers in 2003 and 2005, but pairs have clearly disappeared from areas where they bred in earlier years. Particularly low numbers were found in the lowland and on the slopes between 150 and 300 m a.s.l. in section 4, which resulted in a statistically significant decrease both of pairs/territories (r = -0.740, P = 0.014) and of individuals recorded in June (r = -0.821, P = 0.012; 1999 and 2001 excluded).

Furthermore, there is a highly significant negative correlation, both of pairs/territories and of individuals recorded in June, with the June temperature the year before (r = -0.822, P = 0.007 and r = -0.776, P = 0.014, respectively), but this is probably coincidental. The same may be said of the positive correlation between both pairs/territories and individuals recorded at the June census with snow cover in the previous year (1999 and 2001 excluded) (r = 0.850, P = 0.015 and r = 0.810, P = 0.027, respectively). These correlations reflect the decreasing spring snow cover and the increasing June temperatures during the study years, factors that are probably unrelated to the population decline (see Discussion).

The slopes above 300-400 m a.s.l. often become covered temporarily by new snow during the summer season, but we have no data to show if this has any effect on the birds breeding up there.

The population has probably ranged around 40 pairs in 1996-2002 and 2004 (Table 2).

Red Knot *Calidris canutus*. Red Knots are very secretive near their nest, and the incubating bird often stays put until approached within a few meters or less. The off-duty bird, on the other hand, defends a radius of 500 m around the nest and often feeds in communal feeding areas up to 2 km away from the territory (Whitfield et al. 1996, Niles et al. 2001). Hence, most records were of pairs or individuals feeding or singing – often in flight pursuits with conspecifics. This mainly occurred on breeding habitat, but each year single individuals and pairs were also recorded in areas where they did not breed. Although these birds were considered

Table 2. Census results (pairs/territories) for Common Ringed Plover *Charadrius hiaticula* in the 19.3 km^2 study area at Zackenberg 1996-2005. "Individuals" denotes the number of birds recorded during the initial census in mid-late June each year. Also per cent snow cover on 10 June and mean June and July temperatures (ºC) are given.
Optællingsresultater (par/territorier) for Stor Præstekrave i det 19,3 km^2 store optællingsområde ved Zackenberg 1996-2005. "Individuals" angiver antallet af fugle optalt under den indledende totale dækning af området i juni hvert år, mens "Nests and broods" angiver det totale antal reder og ungekuld, som blev fundet. Også snedækket (%) 10. juni og middeltemperaturerne (ºC) for juni og juli er angivet.

Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5 (300-600 m)	14	9-10	8	12	16	11	12	8	9-11	6-7
4 (150-300 m)	14-15	9-11	10	13	7	12	13-14	11	6-9	3
3 (50-150 m)	8	5-6	4-5	9-11	5	4	1	2	1	0
2 (0-50 m)	8	7-11	7-11	11-18	6	18-20	4-6	4	10	6-8
1 (0-50 m)	10-11	10	9-11	6-11	7-9	6-7	7-8	4	9	2
Total	54-56	40-48	38-45	51-65	41-43	51-54	37-41	29	35-40	17-20
Individuals	69	61	62	104	68	103	63	48	44	30
Nests & broods	2	6	4	4	3	4	1	3	3	0
Snow 10 June	82	76	80	91	53	84	79	83	48	28
June temp.	1.9	2.2	0.9	1.5	1.9	2.1	2.6	2.2	2.5	2.9
July temp.	5.8	3.7	4.7	6.2	5.3	4.9	5.7	7.7	7.2	7.1

Table 3. Census results (pairs/territories) for Red Knot *Calidris canutus* in the 19.3 km^2 study area at Zackenberg 1996-2005. "Individuals" denotes the number of birds recorded during the initial census in mid-late June each year. *Optællingsresultater (par/territorier) for Islandsk Ryle i det 19,3 km^2 store optællingsområde ved Zackenberg 1996-2005. "Individuals" angiver antallet af fugle optalt under den indledende totale dækning af området i juni hvert år, mens "Nests and broods" angiver det totale antal reder og ungekuld, som blev fundet.*

Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5 (300-600 m)	0	0	1	1	1	0	0	1	1	2
4 (150-300 m)	5-6	5-10	3-6	6-10	3-4	9	5-6	6-7	4-6	8
3 (50-150 m)	13-17	11-12	10-11	12-13	10	5-6	6	4	5-7	6-9
2 (0-50 m)	12-16	15-17	10-11	5-6	9-10	11-13	10-11	11	5	12-14
1 (0-50 m)	3-4	4-5	3	1-3	1-2	2	3-4	2	1	2-3
Total	33-43	35-44	27-32	25-33	24-27	27-30	24-27	24-25	16-20	30-36
Individuals	54	60	38	44	27	59	35	24	27	44
Nests & broods	2	2	4	4	3	4	1	3	4	1

as belonging to the local population, some of them may have been visitors from neighbouring areas.

In 2003, an intensive search was made for incubating Red Knots by 'roping' 4 km^2 of the slopes between 100 and 400 m a.s.l. (Piersma et al. in print). Here, only two nests and an additional two broods were found in an area where I had previously estimated the population to be 8-9 pairs. The discrepancy may be due to a combination of factors: the rapid assessment may overestimate the population, incubating birds may have been missed by the roping count, some nests were probably depredated before the roping, and non-breeding pairs/individuals may have been present. For example, 35-40% of active wader nests were missed during roping in Alaskan studies (Gill 2004).

On this background the number of pairs/territories and individuals recorded (Table 3) may not reflect actual population sizes but merely provide a population index. The estimated number of pairs shows a weak but statistically significant decrease ($r = -0.650$, $P = 0.042$). This is also the case for the number of individuals recorded during the June census (Thorup & Meltofte 2005), but only if the high numbers from 2005 are excluded. There is also a significant positive correlation between numbers of individuals in June (excluding 1999 and 2001) and July temperatures two years earlier ($r = 0.833$, $P = 0.040$), which seems to make sense because Red Knots are two years old when mature (Cramp & Simmons 1983). However, more data are needed before the existence of such a correlation can be firmly established (see also Ruddy Turnstone). It is noteworthy that Red Knot numbers on the slopes above 150 m a.s.l. have remained largely unchanged, while most of the decrease has taken place in section 3.

In 2004, Ole Thorup re-evaluated all our field maps and found that the population decreased only slightly during 1996-2004 (Thorup & Meltofte 2005). This re-evaluation excluded all records of singing males made within 500 m of another singing male, a technique that could prune relatively more records from the early years with dense populations than from later years. I have therefore chosen to rely on my field records of individuals present at the June census, which are unaffected by later evaluations (Table 3). The breeding population has probably ranged around 20-30 pairs in most years.

According to Rosenberg et al. (1970) only nine pre-breeding Red Knots were seen in Zackenbergdalen during two visits on 10-17 June and in early July 1964. However, according to diaries from that expedition, kept at the Arctic Institute in Copenhagen, singing individuals were recorded in the southern parts of the study area (both in late May and in mid June), and no survey trips were made to areas north and east of the present research station, where the vast majority of the Red Knots are found today.

Sanderling *Calidris alba*. Sanderlings generally breed a little later than the other species and are often seen in pairs far into the general incubation period (Meltofte 2001a), which makes this segment of the population easy to census, while birds already sitting on eggs most often are very secretive. This means that the census efficiency decreases markedly during June, with the likely result that the population on the upper slopes, which are covered latest, is underestimated. This was confirmed in 2003, when the intensive programme of 'roping' for incubating Red Knots was performed on 4 km^2 of the slopes. Here, 15 nests and a further seven broods of Sanderlings were found in an area where my rapid assessment had resulted in an estimate of 13-17 pairs (Piersma et al. in print). It is also noteworthy that much higher numbers were found

Table 4. Census results (pairs/territories) for Sanderling *Calidris alba* in the 19.3 km^2 study area at Zackenberg 1996-2005. "Individuals" denotes the number of birds recorded during the initial census in mid-late June each year.
Optællingsresultater (par/territorier) for Sandløber i det 19,3 km^2 optællingsområde store ved Zackenberg 1996-2005. "Individuals" angiver antallet af fugle optalt under den indledende totale dækning af området i juni hvert år, mens "Nests and broods" angiver det totale antal reder og ungekuld, som blev fundet.

Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5 (300-600 m)	4	3	5	12-14	6	1-4	3	7	6-7	1
4 (150-300 m)	12-15	14	10-11	10	16-17	11-13	12-13	17	10-12	8-9
3 (50-150 m)	2-3	6-11	3-5	5	2	5	0-1	4-5	1	4-5
2 (0-50 m)	22-29	22-32	32-36	21-25	20-26	31-37	25-29	26-30	37-44	19-27
1 (0-50 m)	10-12	10	12-13	12-13	14-15	10-13	9	13-15	7-9	6-7
Total	50-63	55-70	62-70	60-67	58-66	58-72	49-55	67-74	61-73	38-49
Individuals	94	103	98	109	92	103	61	109	98	78
Nests & broods	8	9	14	17	13	11	9	34	17	7

on the uppermost slopes in the late breeding season of 1999 than in years with earlier snowmelt (Table 4). Hence, the population is likely to be underestimated on the upper slopes. Nevertheless, the numbers of Sanderlings recorded during the initial census, and the resulting estimates of pairs/territories, have been relatively stable in all sections over the study years, except for the lower figures in 2005. My best estimate is a population of about 70 pairs in most years.

A weak positive correlation was found between numbers of individuals recorded in June and snow cover two years earlier ($r = 0.726$, $P = 0.042$), but this is clearly a nonsense correlation.

We do not know to what extent Sanderlings at Zackenberg are involved in 'double-clutching', where a female produces two clutches and incubates one herself while leaving the other to the father (Parmelee & Payne 1973, Tomkovich & Soloviev 2001). Other populations in Northeast Greenland have been shown to predominantly use a more traditional breeding strategy (Pienkowski & Green 1976, Meltofte 1979). At Zackenberg we have many examples of two birds attending a nest, but also some with only one (Piersma et al. in print). This may indicate that the majority of our Sanderlings incubate pairwise and that our results are not significantly biased by double-clutching.

Sanderlings were "sparse" at Zackenberg in 1964 (Rosenberg et al. 1970), but numbers reported in the diaries are not much different from what can be seen in the same areas at present.

Dunlin *Calidris alpina*. Dunlins have caused much concern over the years, since it is often difficult to distinguish between pairs and single individuals, and because I considered the marked increase in census numbers during 1996-2002 unreliable.There has been a significant increase over the study years, both in the estimated numbers of pairs/territories ($r = 0.764$, $P = 0.010$) and in the numbers of individuals recorded during the June census ($r = 0.644$, $P = 0.044$, or $r = 0.792$, $P = 0.019$ when excluding 1999 and 2001). The most likely reason for the increase is that, initially, I did not believe that there could be so many Dunlins in

Table 5. Census results (pairs/territories) for Dunlin *Calidris alpina* in the 19.3 km^2 study area at Zackenberg 1996-2005. "Individuals" denotes the number of birds recorded during the initial census in mid-late June each year. The separation between sections 2a and 2b is an east-west line on top of the figure 2 on the map Fig. 1.
Optællingsresultater (par/territorier) for Almindelig Ryle i det 19,3 km^2 store optællingsområde ved Zackenberg 1996-2005. "Individuals" angiver antallet af fugle optalt under den indledende totale dækning af området i juni hvert år, mens "Nests and broods" angiver det totale antal reder og ungekuld, som blev fundet. Adskillelsen mellem sektion 2a og 2b er lige over tallet 2 på kortet Fig. 1.

Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5 (300-600 m)	1	0	0	3	1	2	2	2	2	0
4 (150-300 m)	3	3	1	1	2	3	2	2	2	3
3 (50-150 m)	20-23	14-16	9-10	11-12	17-19	13-15	15-16	10-11	15-16	12-13
2b (0-50 m)	9-14	18-20	24-34	16-20	25-26	31-33	44-50	36-42	35-39	25-29
2a (0-50 m)	12-13	18-26	21-24	25-31	27-28	26-28	27-29	30-31	30-35	33-37
1 (0-50 m)	24-27	22-26	20-25	24-27	26-27	29-30	30-33	25-26	26-28	19-20
Total	69-81	75-91	75-94	80-94	98-103	104-111	120-132	105-114	110-122	92-102
Individuals	74	102	120	100	120	166	138	128	132	125
Nests & broods	11	17	25	22	27	12	13	20	27	11

the area, and that the most densely populated part, Rylekærene ("the Dunlin fens") in the northern part of section 2, was covered insufficiently and inefficiently in the early study years. To facilitate an evaluation of the figures from this area, I have split section 2 into a southern, well covered area (2a) and a northern, problematic area (2b in Table 5). It appears that the population estimates have been rather stable in the intensive study area west of river Zackenbergelven (section 1), while the population may have been underestimated considerably in the lowland (section 2) east of the river during the first years, and particularly so in Rylekærene (section 2b). On the other hand, numbers were high between 50 and 150 m a.s.l. in 1996. Taken together, my best estimate is that the population has numbered around 100 pairs/territories in most years, and that this figure is more likely to be an underestimate than an overestimate.

The exceptionally high number of individuals recorded during mid/late June 2001 was the result of a snow storm in mid June that year, concentrating many birds in the fens of the census area (Meltofte 2003).

Dunlins were also the numerically dominating waders at Zackenberg in 1964, where up to 100 were recorded during late May (Rosenberg et al. 1970).

Ruddy Turnstone *Arenaria interpres*. Ruddy Turnstones are relatively easy to census, most often showing their presence by giving alarm calls or chasing Long-tailed Skuas *Stercorarius longicaudus*. Still, they may behave very secretively at their nests like the other wader species (Meltofte 1979 and unpubl.). However, there is no doubt that pre-breeding pairs/individuals have been recorded in areas where no birds bred, but probably to a limited extent only. Consequently, the figures presented in Table 6 are probably quite representative for the real population, and the low numbers in 2002 and 2003, as well as the high numbers in 2005, must be considered real. It is noteworthy, however, that we found 24 and 23 nests and broods in 1998 and 2000, respectively, without any particular effort, while we have only managed to find 13-15 nests and broods in recent years in spite of focused efforts. This could indicate that the population has actually dropped in recent years, despite the fact that there are no significant trends in the recorded numbers.

As with the Red Knot, there is a significant positive correlation between numbers of individuals recorded in the June census and July temperatures two years previously, both including ($r = 0.753$, $P = 0.031$) and excluding ($r = 0.855$, $P = 0.030$) data from 1999 and 2001. Again, this makes sense because Ruddy Turnstones are two years old when mature (Cramp & Simmons 1983).

According to Rosenberg et al. (1970), up to 25 individuals were recorded at Zackenberg during 11-14 June 1964, at which point they disappeared, and no indication of breeding was found. However, according to the expedition diaries kept at the Arctic Institute in Copenhagen, single pairs were seen both west and east of the river during the same period. Later, in mid July, 3-4 pairs giving alarm calls were encountered between Zackenberg and Daneborg.

Red-necked Phalarope *Phalaropus lobatus*. Zackenberg is the northernmost known regular breeding site of Red-necked Phalaropes in East Greenland (Boertmann 1994), and a few individuals have turned up each year and performed mating behaviour at the many ponds in the fen areas

Table 6. Census results (pairs/territories) for Ruddy Turnstone *Arenaria interpres* in the 19.3 km^2 study area at Zackenberg 1996-2005. "Individuals" denotes the number of birds recorded during the initial census in mid-late June each year.
Optællingsresultater (par/territorier) for Stenvender i det 19,3 km^2 store optællingsområde ved Zackenberg 1996-2005. "Individuals" angiver antallet af fugle optalt under den indledende totale dækning af området i juni hvert år, mens "Nests and broods" angiver det totale antal reder og ungekuld, som blev fundet.

Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5 (300-600 m)	0	0	1	0	0	0	0	0	0	1
4 (150-300 m)	1-3	0	2	4	6	1	0	0	2	6-7
3 (50-150 m)	19-22	19-22	18-20	17-19	15	11-13	10	14	21	25-27
2 (0-50 m)	15-19	23-27	29-31	18-21	24-26	27-30	18-23	17	19	28-32
1 (0-50 m)	6-7	7-9	6-9	4-5	3	6-7	3-4	2-3	3	5-7
Total	41-51	49-58	56-63	43-49	48-50	45-51	31-37	33-34	45	65-74
Individuals	66	87	83	69	69	78	55	63	73	98
Nests & broods	10	18	24	13	23	13	13	14	15	13

around the research station. Most years, it has been either two females and one male or two males and one female (Hansen & Meltofte in print). Nests or young were found in four seasons.

The species was also present in mid June 1964, when three pairs occurred at the ponds in the fens west of the river ("Vestkærene") – where we have never seen the species – in addition to two pairs at the ponds north of the research station ("Gadekæret") and three males and four females in the pond area south of the research station ("Sydkærene") (Rosenberg et al. 1970 and diaries kept at the Arctic Institute, Copenhagen). Later, in mid July, one pair and a female were seen in fens at the coast ("Kystkærene"). In June, the birds in the different fen areas were never seen at the same time, but nevertheless, the observations point to a population 2-4 times the size of the present.

Besides the common wader species discussed above, a European Golden Plover *Pluvialis apricaria* gave alarm calls in the census area in June 2001, and pairs or single individuals of Red Phalarope *Phalaropus fulicarius* have visited the area for shorter periods in June 1998, 2001, 2003 and 2005, without any firm indication of breeding (Meltofte 1999, 2003, Hansen & Meltofte in print). Also in 1964, a few Red Phalaropes were seen at Zackenberg (Rosenberg et al. 1970).

Discussion

Possible reasons for the population fluctuations

The apparent decline in Common Ringed Plover is difficult to explain from local conditions. During the last years, spring and summer have been particularly warm with fast snowmelt. This has made it possible for the waders to breed very early (Hansen & Meltofte in print) and should have favoured their reproduction (Meltofte et al. in print). Locally, breeding was hampered by unfavourable conditions during 1999, 2000 and 2001. In 1999, snow cover was unusually extensive in early June delaying egg-laying and causing many Ruddy Turnstones to refrain from breeding (Meltofte 2000). In 2000 and 2001 snowstorms raged in mid July and mid June, respectively, destroying eggs and chicks, but this had little or no impact on the number of juveniles showing up on the coast in August, when birds from a larger region are involved (Meltofte 2001b, 2003). After the late 1999 season only low numbers of juvenile Ruddy Turnstones occurred on the coast, but this was also the case in 2004, when Ruddy Turnstones bred very successfully. Unfortunately, we have no good data on Red Knot juveniles.

In this connection, the significant correlation between recorded numbers of Red Knots and Ruddy Turnstones and July temperatures two years before is noteworthy since it could indicate an effect of chick survival on the population size two years later, when the young mature. Waders are normally long-lived birds, and population stability is generally more sensitive to changes in adult survival than to recruitment (e.g. Hitchcock & Gratto-Trevor 1997). However, in a number of studies recruitment has been shown to influence population fluctuations, i.e., fledging success influenced population size in the following year(s) or during more extended periods (Ryabitsev 1993, Troy 1996, Boyd & Piersma 2001, Atkinson et al. 2003). Furthermore, a significant positive correlation was previously found between July temperatures and juvenile production in the Siberian Arctic (Schekkerman et al. 1998, Soloviev et al. in print).

Since snow cover was very limited, or snowmelt very fast, in recent years (Thorup & Meltofte 2005, Hansen & Meltofte in print), a wider dispersal of the population to neighbouring areas was possible. Such a dispersal is unlikely, however, because the species involved are very site tenacious (Cramp & Simmons 1983). Even in Sanderlings, exhibiting partly opportunistic strategies in other arctic regions (Tomkovich & Soloviev 2001), we have recovered adults as well as chicks ringed in previous years.

The early snowmelt has resulted in earlier egg-laying (Meltofte et al. submitted a) so that more birds incubate inconspicuously during our censuses. This could have led to increasingly underestimated populations, particularly of Sanderlings and Red Knots which are the most inconspicuously nesting species. However, recorded Sanderlings have not decreased – if we exclude 2005 – and the decrease in Red Knots took place already during the first years.

The Zackenberg study area is probably a prime breeding area, which means that it should 'fill up' before more marginal breeding areas are occupied. This means that the observed changes could reflect regional trends. In this connection, it is noteworthy that we have seen exceedingly few juvenile Red Knots at Zackenberg during autumn migration (Meltofte & Berg 2004), although they are otherwise commonly seen along arctic coasts in August (Meltofte 1985).

The population of Ruddy Turnstone has varied by a factor two at Zackenberg during 1996-2005. Photo: Hans Meltofte.

Comparison with other parts of Greenland

With a total density of 14-15 pairs or territories of waders per square kilometre, densities at Zackenberg are among the highest densities recorded in Northeast and North Greenland (Meltofte 1985, Boertmann et al. 1991, Mortensen 2000). To some extent this is a result of the census method aiming at 'potential breeding pairs' early in the season, but it does not change the fact that there have been many breeding waders at Zackenberg during the last decade.

As our data indicate, population changes at Zackenberg were not dramatic between most years. In the longer term, marked changes may occur, as indicated by the higher numbers of Red-necked Phalaropes at Zackenberg in 1964 and the low numbers of some of the species in the last few years. At Danmarkshavn, 265 km north of Zackenberg, numbers of Ruddy Turnstones and Sanderlings underwent marked changes during the 1970s and 1980s, while the Common Ringed Plover and Dunlin populations remained stable (Boertmann et al. 1991). Red Knots and Ruddy Turnstones also appear to have shown considerable population changes in high-arctic Greenland earlier in the 20th century (Meltofte 1985).

The densities found at Zackenberg are typical for well vegetated high-arctic tundra in other parts of the Arctic, while much higher densities are found in parts of the North American and Siberian low-arctic (Meltofte et al. in print). Breeding densities 50 times higher than at Zackenberg have been found in Alaska.

Relation to recent total population trends

The Red Knots and Ruddy Turnstones breeding in high-arctic Greenland winter in Northwest Europe (Lyngs 2003), where the populations are relatively well monitored (Stroud et al. 2004). The last published data are from the 2000-2001 (Britain) and 2001-2002 (Netherlands) winters, however. On the main wintering grounds on the British Isles, Ruddy Turnstones have been decreasing since the late 1980s, while Red Knots have been rather stable during the 1990s (Pollitt et al. 2003). Numbers of Red Knots have gone down in the Dutch Wadden Sea, but it is unclear whether this is just the result of redistribution after over-harvest of the preferred bivalve food of the Red Knots (van Roomen et al. 2005).

The Common Ringed Plovers and Dunlins together with many of the Sanderlings from high-

arctic Greenland winter in West Africa, where monitoring is much less complete. Here, Common Ringed Plover populations wintering in Banc d'Arguin in Mauritania have halved from 1980 to 2000, but besides the Greenlandic birds this winter population involves the large Icelandic *psammodroma* as well as the North Eurasian *tundrae* populations (Stroud et al. 2004, C. Smit in litt.). Sanderlings show no reliable trends in the West African wintering areas, and the *arctica* Dunlins from Northeast Greenland make up such a small fraction of Dunlins in the area that we have no trend information (Stroud et al. 2004).

No significant trends were found in numbers of Common Ringed Plover or Red Knot passing Blåvandshuk on the west coast of Denmark during 1964-2003, while Sanderlings and Ruddy Turnstones have been decreasing over the last 10-15 years (Meltofte et al. submitted b). Many of these birds are believed to originate in Greenland, but other populations are involved as well.

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Resumé

Vadefuglebestandene ved Zackenberg i Nordøstgrønland, 1996-2005

Der eksisterer kun få langtidsstudier over bestandsstørrelser og yngleresultater for vadefugle i Arktis. Som led i bestræbelserne på at få indsigt i effekterne af klimaændringer og -variationer i højarktisk Grønland, er vadefuglebestandene ved Zackenberg Forskningsstation blevet fulgt siden stationens oprettelse i 1995-96, ligesom det er sket med en lang række af andre biologiske og fysiske parametre. Ud over bestandsstørrelserne omfatter undersøgelserne ynglefænologi, klækningssucces og forekomsten af flyvedygtige ungfugle i sensommeren (Meltofte 2002, Meltofte & Berg 2004, 2005, Meltofte et al. submitted a, Meltofte & Sittler in print).

I denne artikel rapporteres og analyseres de årlige variationer i vadefuglebestandene og deres fordeling i et 19,3 km^2 undersøgelsesområde i Zackenbergdalen (Fig. 1). Området er delt ind i fem sektioner, som strækker sig fra havniveau op til 600 meters højde på skråningerne af Aucellabjerg. Lavlandet i op til 50 meters højde i sektionerne 1 og 2 er overvejende fjeldhede, men også med store kærområder samt mere eller mindre vegetationsløse afblæsningsflader. Sektion 3 udgøres af morænebakker op til 150 meter over havniveau, sektion 4 af mere jævnt stigende fjeldhede, som går over i sektion 5's mere sparsomt vegetationsdækkede grus- og lerskråninger i 300-600 meters højde.

Hvert år fra 10-12. juni gennemføres en 7-8 dages total kortlægning af fuglene på alle snefrie dele af undersøgelsesområdet. Fuglenes sang og territoriale adfærd topper omkring dette tidspunkt (Meltofte 2001a). Siden forsøger vi at finde så mange reder og ungekuld som muligt for at følge yngleforløbet og følge op på den indledende kortlægning. Hvert år evalueres alle feltkortene for dels at bestemme det samlede antal af registrerede individer under kortlægningen i juni og dels at estimere antallet af par/territorier i hver sektion. I denne evaluering regnes alle registreringer af par og syngende, varslende eller på anden måde vokale individer som repræsenterende lokale par/territorier, mens registreringer af tavse enkeltindivider regnes som repræsenterende mulige lokale par/territorier. Denne 'liberale' evaluering bruges, fordi vadefugle kan optræde meget diskret i deres yngleområder, og fordi en varierende andel af fuglene allerede ruger på tidspunktet for optællingerne. Hensigten er at få et tal for de potentielt ynglende bestande i området, uanset om fuglene faktisk yngler eller ej.

Seks vadefuglearter yngler i undersøgelsesområdet ved Zackenberg med sammenlagt 260-300 par som middel for undersøgelsesårene. Stor Præstekrave findes på sparsomt vegetationsdækkede ler- og grusflader i lavlandet og specielt over 300 m på Aucella-skråningerne (Tabel 1). Islandsk Ryle og Sandløber findes spredt på fjeldhederne i lavlandet og især på fjeldhedeskråningerne mellem 150 og 300 m højde. De Almindelige Ryler yngler næsten udelukkende i kærområderne i lavlandet, mens Stenvenderne fortrinsvis yngler på stenet og gruset fjeldhede, især i Oksebakkerne i 50-150 m højde. Endelig yngler nogle få par Odinshøns omkring dammene nær forskningsstationen.

Stor Præstekrave overestimeres let, da ynglefugle gerne varsler adskillige hundrede meter fra deres territorier og deltager i varsling på fremmede territorier mere end en kilometer væk. Hertil kommer, at fugle fra de høje skråninger ofte opholder sig i lavlandet i forår med udbredt snedække i højderne. På den baggrund vurderer jeg, at bestanden var på omkring 40 par i årene 1996-2002 og 2004, hvorimod den af ukendte årsager var væsentligt lavere i 2003 og specielt i 2005 (Tabel 2). Ændringerne er især foregået i lavlandet og på fjeldhedeskråningerne i sektion 4, og den samlede nedgang er statistisk signifikant. Det er ganske bemærkelsesværdigt, idet der også er konstateret en betydelig bestandsnedgang i Vestafrika, hvor disse fugle overvintrer (Stroud et al. 2004). Der er tillige en signifikant positiv korrelation mellem bestanden de enkelte år og snedækket året før, samt en signifikant negativ korrelation med juni-temperaturerne, men disse korrelationer synes meningsløse.

Islandsk Ryle er ikke mindre vanskelig at optælle, da fuglene stik modsat præstekraverne opfører sig uhyre diskret nær reden. Og når de ikke er på reden, synger eller

strejfer de over store områder. Derfor bør tallene højst tages som et indeks for antallet af fugle i området; de var høje de to første år, hvorefter de aftog signifikant frem t.o.m. 2004 (Thorup & Meltofte 2005) for så at stige igen i 2005 (Tabel 3). De største ændringer er sket i bakkeområderne mellem 50 og 150 m i sektion 2, mens tallene i kerneområdet i sektion 3 mellem 150 og 300 m har været mere stabile. Den samlede bestand har formentlig været på omkring 20-30 par de fleste år.

Sandløberne er blandt de letteste vadefugle at tælle, vel at mærke når man gør det helt tidligt på sæsonen, hvor de færdes parvis. Så snart de begynder at ruge, opfører de sig næsten lige så diskret som de Islandske Ryler. Derfor er tallene øverst på Aucella-skråningerne – som tælles sidst – givetvis for lave, undtagen i 1999, hvor sneen forsvandt sent (Tabel 4). Ellers er der ikke nogen systematiske ændringer mellem sektionerne, og jeg vurderer den samlede bestand til at have været omkring 70 par de fleste år undtagen 2005.

Almindelig Ryle yngler i så tætte bestande i lavlandets kærområder, at de er vanskelige at få gode tal på. Især er det vanskeligt at skelne mellem par og enkeltindivider, idet hun og han ofte optræder hver for sig, og mange fugle flyver syngende rundt over kærene. Bestanden blev givetvis underestimeret i de første år, mens den siden har ligget på omkring 100 par de fleste år (Tabel 5). De relativt stabile tal i det særligt intensivt dækkede område vest for elven (sektion 1) understøtter formodningen om, at der var tale om underestimater især i Rylekærene de første år (sektion 2b i Tabel 5). Det specielt høje antal individer registreret i juni 2001 skyldes en snestorm, som koncentrerede mange af fuglene i de mest føderige kærområder.

Stenvenderne er relativt lette at optælle, idet de oftest varsler kraftigt, når man opholder sig i deres territorium, eller når der er Små Kjover i nærheden. Men de kan faktisk godt opføre sig meget diskret selv ved besøg direkte ved reden. Formentlig afspejler tallene ganske godt den virkelige bestand, også de lave tal i 2002 og 2003 og de rekordhøje tal i 2005 (Tabel 6). Det er dog bemærkelsesværdigt, at jeg uden nogen speciel indsats kunne finde 24 og 23 reder og ungekuld i hhv. 1998 og 2000, mens vi de senere år ikke har kunnet finde mere end 13-15 kuld trods ihærdig indsats.

Odinshønsene i Zackenberg udgør de nordligste regelmæssige ynglefugle i Østgrønland, og bestanden er kun på 1-2 'par' (Thorup & Meltofte 2005). Dette er kun mellem halvdelen og en fjerdedel af, hvad der blev fundet i området under det eneste tidligere besøg af dedikerede ornitologer i 1964 (Rosenberg et al. 1970). Thorshane og Hjejle har også optrådt i området visse år, men der har ikke været nogen overbevisende tegn på yngel.

Tætheder af vadefugle i Zackenberg er omkring 14-15 par/territorier pr km^2, hvilket er i den høje ende af hvad der er kendt for højarktisk Grønland (Meltofte 1985, Boertmann et al. 1991, Mortensen 2000). Dette skyldes til dels den 'liberale' optællingsmetode, dels at der rent faktisk er relativt mange vadefugle i området. Tæthederne er ganske typiske for tilsvarende relativt frodige højarktiske områder i andre dele af Arktis, mens væsentligt større tætheder findes i lavarktisk Sibirien og Nordamerika, hvor op til 50 gange så store tætheder er fundet specielt i Alaska (Meltofte et al. in print).

Vadefugle er relativt længelevende fugle, og de fleste af de arter, der yngler i Zackenberg, er ganske stedtro. Derfor kan der ikke forventes store år-til-år-variationer i bestandstallene. På denne baggrund er det bemærkelsesværdigt, at bestandsvariationerne af både Islandsk Ryle og Stenvender viser statistisk signifikant positiv korrelation med juli-temperaturen to år tidligere. Disse to arter er netop to år om at blive kønsmodne, så ungeoverlevelsen i juli, hvor langt de fleste dununger vokser op, ser ud til at have indflydelse på bestandsstørrelsen to år senere. Men dataserien er kort, og vi behøver flere års data, før der kan drages en sikker konklusion.

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