Bird migration and species diversity under polar conditions: the Siberian – American migration systems

Alerstam, Thomas; Bäckman, Johan; Gudmundsson, GA; Hedenström, Anders; Henningsson, Sara; Karlsson, Håkan; Rosén, Mikael; Strandberg, Roine

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Project leader

Thomas Alerstam
Department of Animal Ecology
Lund University

Project participants

Johan Bäckman
Sara Henningsson
Håkan Karlsson
Mikael Rosén
Roine Strandberg
Deptartment of Animal Ecology
Lund University

Gudmundur A. Gudmundsson
Icelandic Institute of Natural History
Reykjavik, Iceland

Anders Hedenström
Department of Theoretical Ecology
Lund University

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Background and objectives

Extensive studies of bird migration patterns based on field observations and tracking radar registrations have been conducted during earlier expeditions to Siberia in 1994, the central Arctic Ocean in 1996 and arctic Canada in 1999 (e.g. Gudmundsson and Alerstam 1998, Alerstam and Gudmundsson 1999 a, b, Alerstam and Jönsson 1999, Alerstam et al. 2001, Gudmundsson et al. 2002, Hedenström et al. 2002, Green et al. 2004). Among the significant results of these studies are the discovery of important bird migration syst-ems between Siberia and Alaska/Canada across the Arctic Ocean, and the demonstration that flight routes closely resemble great circles, as predicted if the birds use for their orientation a sun compass without compensating for the longitudinal time shift. In addition biogeographical analyses have indicated that possibilities and const-raints associated with the birds' migratory performance have an important influence on the biodiversity and distribution of arctic birds (Henningsson and Alerstam 2005 a, b).

We had two main objectives for our studies during the Beringia 2005 expedition:

1. To study and document bird species richness and relative species abundance by intensive field observations during the entire journey of the icebreaker Oden and at the coastal field sites that were visited during this journey. The route of the icebreaker provided an excellent and unique opportunity to explore and compare biogeographical features of pelagic bird diversity in little explored and remote areas of the Arctic.
2. To investigate the extent and exact routes of bird migration in the Siberian–Alaskan region by the use of tracking radar on-board the expedition ship. This would fill in the gap in such studies from the Beringia region that was not covered on our earlier expeditions to Siberia and Canada, respectively. These radar measurements will be used to test hypotheses about orientation principles and to evaluate flight conditions, including the effects of weather and wind, for the unique bird flights across wide expanses of the Arctic Ocean.

Methods

The number of species and individuals of birds were recorded from the outer deck daily. Special emphasis was put on counting birds in the mornings in a standardized way so as to be able to compare days. Birds were detected and identified with the aid of binoculars and spotting scopes (20–60X). The start and finish times of each standardized count were then translated to positions and distances travelled with the aid of the ships' navigation system.

Counts were performed both when the ship was stationary and when it was moving. In addition to this, a daily species list was kept, including all species observed during the standardized counts as well as all additional species observed.

On land sites the observers recorded species and counted the number of individuals along a path walked. The position and time at each start-, finish- and turning point were noted.

Two tracking radar stations were installed on the 4th deck of Oden, on the port and starboard sides respectively, with a partly overlapping horizontal field view of about 240° each. The two stations (type PV 301 and PV 882) had similar technical performances, with wavelength 3 cm, peak power about 200 kW and a pencil beam width of about 1.65°. New software was developed to record and store radar data every second, along with simultaneous information from two tilt sensors recording the levelling of the ship and updating the position, direction and movement of the ship every 5 seconds from the Oden network. Winds at different altitudes were measured by releasing and tracking helium balloons that carried an aluminium foil reflector. Both radar stations were sometimes operated simultaneously, but this was not possible in poor visibility when only one of the stations could be used because of interference with the ship's radar system. The radars permitted tracking of individuals or flocks of birds, mostly in the range of 3–10 km from the ship, up to maximum ranges of 15–20 km. Targets were tracked for at least 20 seconds and normally for 60–300 seconds. Altitude, speed and direction of movement were calculated based on position data averaged during 10 seconds intervals, after taking into account the levelling, direction and movement of the ship. The overall mean altitude, ground speed, and vertical speed for each target were obtained by averaging the data for all available 10 second intervals. Track directions were calculated as mean vectors in a corresponding way. Samples of echo signatures, allowing analysis of wingbeat patterns, were also obtained for many targets.

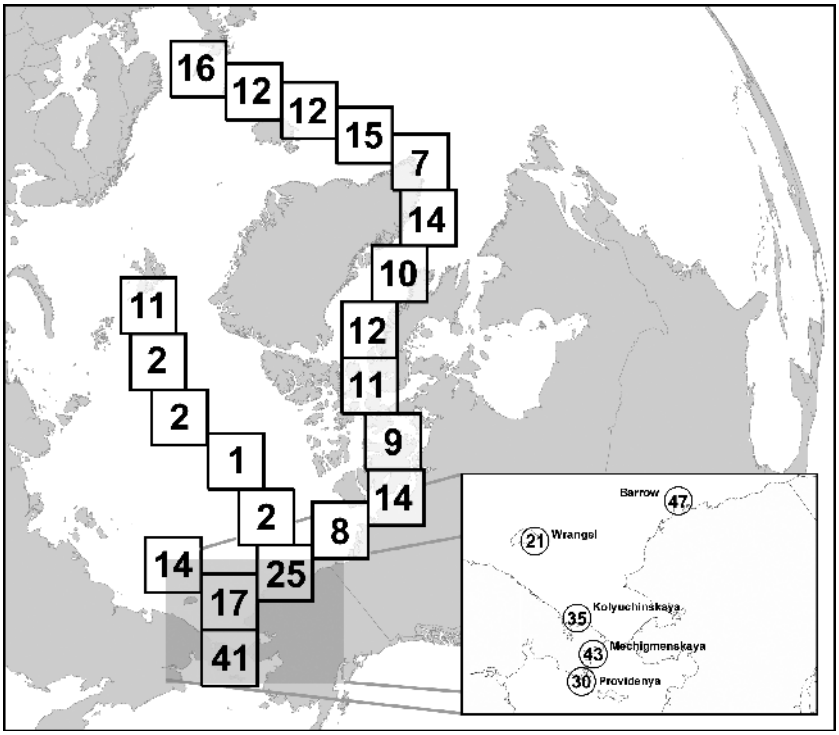


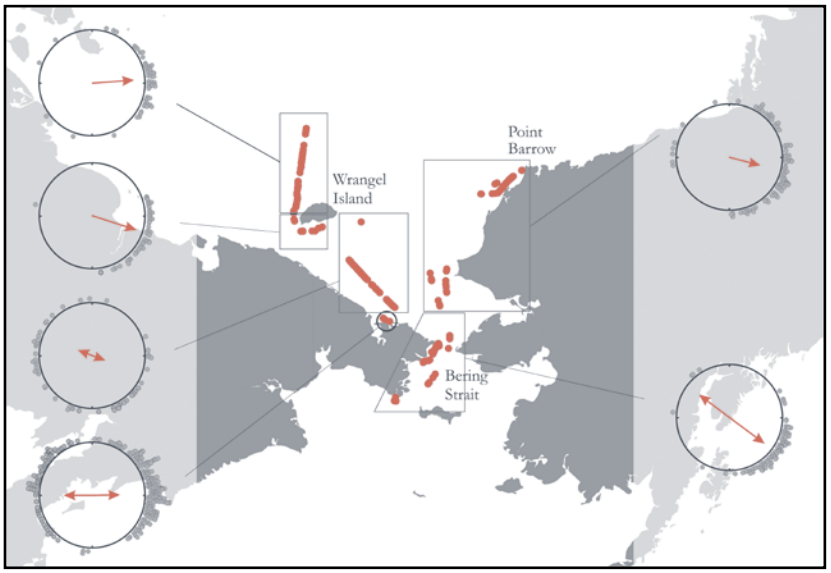
Figure 1
Total number of bird species observed from Oden along different segments of the entire expedition journey from Sweden to Svalbard. The inserted map shows the number of species recorded at five tundra sites visited for field work during the Oden journey.

Preliminary results

Pelagic bird diversity

An overview of the variation in numbers of species along the entire passage is shown in figure 1. Enclosed in the boxes are the numbers of species observed along the track corresponding to each box. Although each box represents different amounts of counts and days, the figure gives an idea of the broad structure of the species richness variation along the track. Particularly high numbers of species were detected in the area of the Bering Strait and southern Chukchi Sea. This region is characterized by highly productive waters and may therefore host a diverse pelagic bird community. A spill-over effect from the more southerly Bering's sea, which is even more nutrient rich and known as one of the most diverse regions in the Northern Hemisphere for alcids and other pelagic species, may also contribute to the high diversity observed in the Bering's strait and Chukchi sea. Furthermore, the region is transected by a massive autumn migratory highway of birds, particularly shorebirds, skuas and passerines. These are migrants of both Siberian and American origin who also contribute to the high diversity in the Bering Strait area.

Especially noticeable are the low numbers of both local birds and transient migrants across the Arctic Ocean interior. The only species observed along the route across the vast pack-ice of the central polar basin were singleton individuals of glaucous gull,



Left - Figure 2
Locations and numbers of grey phalaropes *Phalaropus fulicarius* recorded from Oden during the entire expedition journey.

Right - Figure 3
Locations and flight directions of migrating birds as recorded in the Beringia region by tracking radars placed onboard Oden. Black dots on the map show locations of tracks (often overlapping locations when the ship was stationary or moving very slowly), and circular diagrams show flight directions in different regions (dots on the circle peripheries refer to track directions of individual targets, and mean directions or axes are indicated by arrows). This preliminary overview is based on 569 radar tracks of migrating birds (mostly flocks but also single birds).

grey phalarope, northern fulmar, black-legged kittiwake and snow bunting.
A dramatic increase of both individuals and species occurred only at the very edge of the pack-ice. The hostile environment and low food availability in the pack-ice are the likely reasons why so few species are encountered there. Radar studies from earlier expeditions have also shown a striking absence of migratory activity in the central polar basin. Although the distance across the pack-ice would be theoretically possible to fly, at least for some shorebirds, evolution has not favoured the establishment of such routes. The birds often need to reach more favourable habitats further south to fuel up during early stages of autumn migration. Northern tundra sites may not provide enough resources to build up fat reserves for a direct barrier crossing such as a trans-Arctic Ocean flight. There may also be orientation and navigation difficulties associated with migration near the magnetic and geographic poles.

The relatively low numbers of birds seen in northwest Canada are likely a result of particularly heavy ice situation in this area during the passage.

Our observations reflect the well differentiated avifauna between the Atlantic and the Beringia side of the Northwest Passage. The ship-based observations on the Beringia side included a total of 52 species, compared to 43 on the Atlantic side. The Bering's Sea and the Atlantic had 22 species in common. Relatively higher diversity of petrels and shearwaters was recorded on the Atlantic side, while relatively higher diversity of auks was recorded on the Beringia side.

Birds at coastal wetland sites

The total numbers of species (including both local birds and transient migrants) observed on the five different land sites in the Beringia region are illustrated in the lower right corner of figure 1. Although the number of days spent on each site differs, the observations give a general idea of the between-site variation in species occurrence during early stages of autumn migration. For instance, the most abundant shorebird species at each site were quite variable. The three most dominant shorebirds for each site were

1. western sandpiper, red-necked stint, and common plover on the southern Chukotka sites,
2. grey phalarope, western sandpiper and dunlin on the northern Chukotka site,
3. dunlin, red knot and ruddy turnstone on the Wrangel Island site and
4. grey phalarope, red-necked phalarope and long-billed dowitcher on the north Alaskan site.

Shorebirds constitute the largest part, in both diversity and number of individuals, of the migratory activity in these regions, as observed both on land and at sea. However other groups, such as long-distance migrant species of passerines, skuas and terns, were also represented in good numbers.

Grey phalaropes on migration

Grey phalarope was frequently encountered from the icebreaker and on land sites in the Bering Strait region. Several observations of this species were also made outside this area on leg 1 and 3. Figure 2 illustrates the location and numbers of

grey phalaropes seen from the ship during the entire passage. An intense migratory activity of grey phalaropes was observed from the ship just north of the Bering Strait. During the most intensive passage, the numbers passing the ship were estimated to 11,000 birds/hour. The majority of these flocks migrated in a south-easterly direction. Grey phalaropes were also encountered in fair numbers further north in both the Chukchi and Beaufort Sea, with some extreme individuals as far north as 77°N. Most of these individuals probably had a Siberian origin and were on route to America and, like the Alaskan populations, to winter in the Pacific Ocean off the coast of South America. However the grey phalaropes encountered in Baffin Bay and Lancaster Sound (as well as on Svalbard) may belong to a different flyway with a migratory destination in wintering areas off-coast Africa in the Atlantic Ocean.

Radar records of flight patterns of birds in the Beringia region

Distributions of flight directions in six different areas of the Beringia region are illustrated in figure 3, based on a total number of 569 radar tracks (≥ 20 seconds) that were recorded during the period 30 July–19 August. Most migrants were travelling in easterly directions from Siberia towards Alaska, as expected for many shorebird species. It is interesting to note how the mean direction changes from almost due east in the area north of Wrangel Island to southeast in the Bering Strait area. This pattern offers promising possibilities to extrapolate flight directions according to different orientation principles and to evaluate the full extent of the shorebird flyway system from Siberia towards Alaska. However to make this analysis complete it is required that the impact of wind on the birds' orientation is calculated and also that data from earlier expeditions to Siberia and Canada are included in the overall evaluation, which are the next steps in our analysis work. The easterly migration was usually occurring at considerable heights, with mean altitudes between 1 300 and 1 800 m above sea level in the northerly offshore areas and also over the Bering Strait. Maximum altitudes were between 3 500 and 4 600 m in these areas. The mean altitude of the easterly migrants was lower at the Siberian coast (the Kolyuchinskaya site), at about 900 m above sea level. In addition many tracks were easterly rather than south-easterly at this site, possibly reflecting a response by the migrants flying at moderate heights to travel parallel along the coastline which extends almost due west-east at this site.

A novel discovery was the existence of a regular and important migration in westerly directions (mean track direction about 280°). Many of these migrants were passerines, as determined from their characteristic radar echo signatures. The most probable species in this migratory movement were e.g. wheatear, yellow wagtail, arctic warbler, red-throated pipit and other "Old World"-species with breeding ranges extending into Alaska and with winter quarters in southern Asia and in Africa. We are looking forward to proceed with detailed analyses of the directions of these migrants in relation to the effects of wind and to the orientation principles and possible routes towards their distant wintering quarters.

The mean flight speed (ground speed) varied in different areas between 12 and 18 m/s, and this variation will be further analysed in relation to wind to reveal the true airspeeds of the migrating birds.

Conclusion

Our project has obtained a rich harvest of highly interesting and valuable field and radar observations during the Beringia 2005 expedition. On the basis of these results we hope to add new knowledge about the biodiversity and migratory behaviour of arctic birds, particularly about the evolutionary causes and orientation principles for the intriguing crossroad migration patterns in the Beringia region.

Acknowledgements

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The two primary methods of the project were intensive and standardised visual observations and tracking radar registration, respectively. Photos: Johan Bäckman and Mikael Rosén.

Near Bering Strait seabird abundance reached peak levels and Oden sailed through huge flocks of short-tailed shearwater Puffinus tenuirostris, consisting of several tens of thousands of birds. Photo: Thomas Alerstam.

Phalaropes were among the most abundant shorebirds recorded on migration, particularly the grey phalarope *Phalaropus fulicarius* (see Fig. 2). These photos from Barrow show a flying flock of mixed grey and red-necked phalaropes and a flock of swimming and foraging adult grey phalaropes in different stages of post-breeding moult. Photos: Thomas Alerstam.

Secretariat and the crew of Oden, from whom we received full support during the entire expedition.

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Fåglarnas flyttning och artdiversitet i polarmiljö: flyttningssystemen mellan Sibirien och Amerika.

Omfattande fält- och radarstudier av de arktiska fåglarnas flyttning, orientering och förekomst har bedrivits under tidigare expeditioner i Nordostpassagen 1994, Norra Ishavet 1996 och Nordvästpassagen 1999. Projektets målsättning 2005 var att genomföra utvidgade studier i Beringia-regionen för att fylla kunskapsluckan från detta område som inte besökts tidigare, och som dessutom är centralt för att förstå utvecklingen av fåglarnas flyttningssystem i ett cirkumpolärt perspektiv.

De arktiska fåglarnas artdiversitet och förekomst studerades genom systematiska fältobservationer från Oden längs hela expeditionsrutten. Två radarstationer för målföljning installerades på Oden och användes för att följa flyttande fåglar och mäta flyghöjd, hastighet och riktning. Varje individ eller flock följdes oftast under 1–5 min på 3–15 km avstånd från fartyget. Heliumfyllda ballonger användes för mätning av vindens riktning och hastighet på olika höjder.

Antalet fågelarter längs expeditionsrutten och vid fältlokaler på tundran visas i Figur 1. Artrikedomen var särskilt stor vid Berings sund, i bjärt kontrast till det extremt fattiga fågellivet i de centrala packisfyllda delarna av Norra Ishavet. Som exempel på förekomsten av en enskild art visas i Figur 2 observationerna av den brednäbbade simsnäppan. Många av simsnäpporna flyttar via Berings sund-området till vinterkvarter i södra Stilla havet, medan östligare bestånd flyttar från arktiska Kanada till Atlanten. Fördelningen av flyttfåglarnas flygriktningar enligt radarföljningar inom olika delar av Beringia-området visas i Figur 3. Bilden visar fågelflyttning på bred front i östliga riktningar från Sibirien mot Alaska (främst vadarfåglar med medelhöjder 1 300-1 800 meter över havet, upp till 4 600 m för enstaka flockar) men även västriktad flyttning från Alaska mot Sibirien (till stor del tättingar med medelhöjd omkring 900 meter över havet). Dessa resultat ger ett mycket värdefullt underlag för att närmare analysera fåglarnas kursförändringar, vindberoende och orienteringsmekanismer. Dessutom hoppas vi bidra till förståelsen av hur de storskaliga och korsande fågelflyttningssystemen i Beringia-regionen, som vi på detta sätt upptäckt och kartlagt, har utvecklats.