Rapid long-distance migration in Norwegian Lesser Black-backed Gulls along the eastern flyway

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We studied the long-distance migration of Lesser Black-backed Gulls *Larus fuscus fuscus* breeding in northern Norway along the eastern flyway using geolocators in 2009 and 2010. The majority of birds wintered in lakes in East Africa and southeast Mediterranean was the most important stopover area. *L. f. fuscus* along the eastern flyway travelled at a net travel speed of 399 and 177 km/day during the autumn and spring migration, respectively, and this was faster than published travel speeds for *L. f. graellsi* migrating along the western flyway. The results suggest that the long-distance migratory Norwegian *L. f. fuscus* seek to minimize time spent in transit rather than maximizing energy, whereas slower travel speed during northerly spring migration compared to southerly autumn migration may reflect differences in wind patterns or food conditions between spring and autumn.

Keywords: animal movements, migration strategies, migratory stopover

Many bird species are believed to minimize the time spent on migration rather than the associated energetic costs (Alerstam & Lindström 1990). Possible explanations include the high risks encountered en route to wintering grounds (Strandberg *et al.* 2010), the need to allocate time to other activities (Buehler & Piersma 2008), or because of the benefits of early arrival in breeding and winter areas (Norris *et al.* 2004). However, there is large variation in flight modes (e.g. flapping, soaring) and migration strategies (e.g. speed, distance, routes) between species, , but also within bird families (reviewed by Klaassen *et al.* 2012). This includes the gulls (Laridae), which are considered to master l flapping flight as well as thermal- and ridge soaring flight (Rayner 1988). In addition, they are feeding generalist foragers that may find food in almost any habitat along the migration route (Olsen & Larsson 2004), which may affect time spent on migration (e.g. Klaassen *et al.* 2012).

Lesser Black-backed Gulls *Larus fuscus graellsi* breeding in the Netherlands were expected to show a time-minimizing migration strategy with birds taking the shortest possible route, having few stopovers and travelling at a high speed (Klaassen *et al.* 2012). Instead, using satellite transmitters Klaassen *et al*. (2012) found that the gulls made substantial detours from the shortest route and travelled at low speeds due to long stopovers, such that their net travel speed (44 and 98 km/day in autumn and spring, respectively) was the lowest yet recorded in any migrating bird. The authors concluded was that these gulls minimized energy expenditure during their short migration (500 – 2800 km) and that it is not known if such a migration strategy is commonplace among gulls, and whether other populations of Lesser Black-backed Gulls with different migration routes, such as those from Scandinavia, behave similarly.

The nominate subspecies of the Lesser Black-backed Gull *Larus fuscus fuscus* breeds in Norway and around the Baltic Sea, and winters in east-central Africa (Kilpi & Saurola 1984, Helberg *et al.* 2009). They therefore have the longest migration of any Lesser Black-backed Gull population (up to 7600 km), but until our study there was no detailed information on the route or travel speed of individual gulls. We examined the migration movements of Lesser Black-backed Gulls from northern Norway, using light and temperature data from geolocators (Global Location Sensor or GLS loggers). Because Scandinavian gulls travel over much longer distances and probably cross areas with little food (Helberg *et al*. 2009, Kylin *et al.* 2011) we predicted that their migration strategy would be different, i.e., higher travel speed and fewer stopovers, from that recorded for the much shorter distance migrants from the subspecies breeding in the Netherlands (Klaassen *et al.* 2012).

METHODS

Lesser Black-backed Gulls were caught at Horsvær (65º 19’ N 11 º 37’ E), a small archipelago at Helgeland (Nordland County) in northern Norway. Up to 400 pairs of gulls breed on seven small islands when conditions are good. At our arrival in the study area in mid-June, we marked all occupied nests and trapped incubating birds using walk in traps (Bustnes *et al.*, 2008). The birds were ringed with steel and alphanumeric colour rings, and geolocators were fitted to the colour rings by cable ties.

Geolocators

Using geolocators it is possible to calculate the position of birds (twice per day) from light level readings with reference to calendar date, with an average error of ~185 km (Phillips *et al.* 2004). In June 2009 and 2010, 8 and 12 GLS loggers (mk15, 2.5g; British Antarctic Survey, Cambridge, UK) were mounted on breeding birds. Five GLS loggers were retrieved in 2010, and two in 2011. Six loggers had been on for one year and contained data for the complete migration. One logger had been on from 2009 to 2011, and contained data until 27 March 2011. The data were downloaded and processed with the BASTrak software package (Fox 2010). Following Frederiksen *et al.* (2012), we calculated positions initially using a range of sun elevation angles between -1.5 and -4.5°. Birds were assumed to stay close to the colony at the end of the breeding season (25 July-5 Aug), and the smallest bias in latitude was obtained with a light-treshold of 10 and a sun elevation angle of -2.5°. Hence, this angle was used for all loggers. Furthermore, it provided the best results for the remainder of the year, including a distribution at the end of the spring migration that was centred on the breeding colony.

Although longitudes were unaffected, estimates of latitude were unreliable for ~two weeks before and after the equinoxes. However, the loggers recorded temperature when being in salt water (one record after 20 minutes continuous submersion and a second and last record after 40 minutes) , which can be used to improve latitude estimation where there are differences between water masses or a clear latitudinal gradient in sea surface temperatures (Bost *et al.* 2009). Therefore, we compared temperature readings from the loggers (95 % confidence intervals of the mean) with weekly sea surface temperatures (SST) extracted from 1° grids in the Norwegian Sea (65-66º N, 11-12º E), Baltic Sea (55-56º N, 18-19º E), Gulf of Bothnia (62-63º N, 19-20º E), Black Sea (42-43º N, 30-31º E), Mediterranean Sea (32-33º N, 32-33º E), Gulf of Suez (28-29º N, 32-33º E) and Red Sea (26-27º N, 34-35º N) obtained from the IRI/LDEO Climate Data Library (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.EMC/.CMB/.GLOBAL/.Reyn_SmithOIv2/.weekly/).

Stopovers where identified when birds rested on sea water and the loggers recorded temperature. Depending on whether this occurred outside or within the equinox periods the stopover sites were located to one of the above mentioned ocean regions based on information on latitude, longitude and SST or longitude and SST, respectively.

We calculated the geographic mean, using spherical trigonometry, for all positions in December –January to identify individual wintering areas (Fig. 1). We used a conservative approach when calculating distances, using great circle distances between the colony and the wintering areas, via the stopover sites (Fig. 1). We therefore focused on the net travel distance and speed (net travel distance divided by number of days) of the tracked birds, as we could not obtain reliable daily travel estimates because parts of the migration occurred during the equinoxes.

During the equinoxes we used the longitude estimates and sea surface temperatures to aid the determination of the timing of migration. Timing of departure from the breeding grounds and arrival at the Mediterranean (including stopovers), was successfully determined for all seven birds, except one during autumn (Table 1). Timing of arrival and departure in East Africa, however, could only be determined for three and two birds (out of six), respectively. All these birds, except one, arrived or departed outside the equinox periods when both latitude and longitude estimates were reliable. Timing of departure from East Africa for one bird that departed during the spring equinox, could be determined because this bird wintered in a salt water lake, and sea temperatures were used to determine the timing of departure. These birds spent on average 4 (3-5) and 11.5 (10-13) days migrating between the Mediterranean and the wintering areas during autumn and spring, respectively. These values were applied to the remaining birds in order to estimate the total time spent on migration. Although this reduces the variance in net migration speeds, it is unlikely to have more than a marginal effect on the overall mean.

RESULTS

The final destination of all Lesser Black-backed Gulls that were tracked was East Africa (Uganda or South Sudan), except for one that spent the entire winter in the southeast Mediterranean Sea (Fig. 1). For the birds wintering in East Africa, the mean net migratory distance from the breeding colony to the individual wintering areas was 7239 km (se = ± 133, *N*=5) and 6632 km (se = ± 378, *N*=2) in 2009 and 2010, respectively (Table 1, Fig. 1). The birds took about three weeks to reach their wintering areas in East Africa, including brief stopovers in the Baltic Sea and/or the Black Sea, and 9 days in the Mediterranean (Fig. 1, Table 1). The mean net travel speed between Norway and East Africa was 399 km/day (se = ± 20, *N*=4) and 315 km/day (se = ± 52, *N*=2) in 2009 and 2010, respectively (Table 1).

The gulls departed on the spring (return) migration from East Africa in March or April and reached the Mediterranean by end March to mid-April. In 2010, the Mediterranean was the main stopover site, with birds staying there on average for 20 days (se = ± 2.1, *N*=5, Table 1), compared with periods of 0-2 and 2-12 days in the Black Sea and the Baltic Sea/Gulf of Bothnia, respectively. In 2011, in contrast, the one tracked bird spent only 3 days in the Mediterranean, compared with 16 days in the Black Sea and 13 days in the Baltic Sea. The overall spring migration lasted six weeks, with mean net travel speeds of 177 km/day (se = ± 12, *N*=5) in 2010, and net travel speed of 141 km/day (*N*=1) in 2011 (Table 1).

DISCUSSION

This study revealed that the majority of Lesser Black-backed Gulls from Norway are long-distance migrants, estimated conservatively to travel at least 6,295-7,585 km to reach wintering grounds in east Africa (Table 1). The only other long-distance transequatorial migrants among the 43 species of gulls in Europe, Asia and North America are Sabine's Gull *Larus sabini* and Franklin's Gull *L. pipixcan* (Olsen & Larsson 2004, Stenhouse *et al.* 2012). The migration strategies of the birds we tracked were very distinct from those of Lesser Black-backed Gulls from the Netherlands (Klaassen *et al.* 2012). However, it is important to keep in mind that the two populations belong to different subspecies, travel over different habitats and have different flight distances from their breeding sites. Hence, variation in flight strategies might be expected. , Nevertheless, gulls in our study seemed to follow the shortest route from Norway to East Africa, including long overland flights, whereas the Dutch gulls predominantly followed the coast. Moreover, Norwegian gulls had only a few stopovers (2-3), the longest being up to 12 and 24 days in autumn and spring, respectively. The Dutch gulls, in contrast, stopped frequently, most individuals on at least one occasion for > 14 days, and on average for 77 days in total (Klaassen *et al*. 2012). The use of coastal areas and long stopovers enabled the latter to take advantage of feeding opportunities along the route, which was less of a possibility for Norwegian gulls as they fly mainly over forests and deserts (see also Schmaljohann *et al.* 2008). As a result, the Norwegian gulls had a much higher net migratory speed (399 and 315 km/day in autumn 2009 and 2010, respectively) than Dutch gulls (44 km/day). The complete autumn migration (~7000 km) of Norwegian gulls took three weeks. In spring, the Norwegian gulls migrated substantially slower than in autumn, yet still almost twice as fast as the ones from Netherlands. The slower speeds during spring could perhaps reflect less favourable wind patterns for northern migration along the eastern flyway (Shamoun-Baranes *et al*. 2003, Kemp *et al.* 2010), and birds may postpone departure until wind conditions are optimal for northern flight. Alternatively, it could reflect a greater need to build up body reserves before returning to the breeding colony. Indeed, food availability in their breeding areas may be unpredictable, and often scarce (Bustnes *et al.* 2010, 2011), and the gulls have no way to assess feeding conditions beforehand.

One issue regarding the comparison between the two studies is the use of different technology. Whereas Klaassen *et al.* (2012) used GPS loggers with very high accuracy which transmits using the Argos satellite system; we used geolocators, which provide locations of much lower spatial and temporal resolution. We did not calculate daily point-to-point travel speeds, but instead calculated great circle distances between the colony and the wintering areas via the stopover sites, divided by migration duration. This conservative approach seems justified; there is little reason given the lack of feeding opportunities to expect that the gulls would have diverted much from the shortest routes, and hence distances and speeds are unlikely to be greatly underestimated. Moreover, according to an unpublished study, one Finnish gull with a satellite-transmitter flew 3500 km nonstop from the Nile Delta to Lake Victoria in 92 h (J. Kube *et al.* unpublished data), which is similar to the time taken by the Norwegian birds (3-5 days) for the same journey. This suggests that our estimates of flight speed are reasonable. One great advantage of GLS loggers is, however, the small size, which makes interference with flight capability highly unlikely.

In conclusion, this study highlights a striking intraspecific difference in migration strategy in the Lesser Black-backed Gull, depending on the distance travelled. Birds from the Netherlands, with short travel distances, seem to minimize energy expenditure, *i.e.* they can “afford” to migrate slowly and take advantage of feeding opportunities along the route, and to move only when conditions are favourable (Klaassen *et al.* 2012). On the contrary, the long-distance migrants from northern Scandinavia travel rapidly in order to reach the productive freshwater habitats of East Africa. This suggests that they are minimizing the time on migration, and as such the population conforms more closely to accepted theories on the evolution of bird migration patterns (Alerstam & Lindström 1990). Furthermore, time spent on migration seems to be modulated by additional factors. For example if wind patterns are favourable it may be beneficial to reduce the duration, whereas good feeding conditions at stopover sites may make it better to stay longer to increase nutrient reserves. An example of potential modulation of migration strategy is that Dutch and Norwegian gulls, respectively, increased and decreased speeds during spring migration.

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Table 1. Migration distance, speed and timing of Lesser black-backed gulls *Larus fuscus fuscus* breeding in North Norway

		Net migratory distance (km)	Net migratory speed (km/d)		Time spent on migration incl. stopovers (d)		Time spent in the Mediterranean Sea (d)	
Bird	Year	Autumn/spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
A	2009/10	7585	379	170	20	44.5	9	22
B*	2009/10	6860	-	163	-	42	-	22
C†	2009/10	4208	373	316	11	13	198	
D	2009/10	7097	355	222	20	32	12	12
E	2009/10	7496	416	148	18	50.5	7	24
F	2009/10	7158	447	181	16	39.5	8	19
F*	2010/11	6970	367	-	19		7	-
G	2010/11	6295	262	141	24	44.5	11	3

*Timing and speed of autumn migration could not be estimated for bird B. The logger attached to bird F stopped in spring 2011 and parameters for spring migration could not be obtained

† Bird C spend the entire winter (198 d) in the Mediterranean Sea

Figure 1. Stylised migration route of Lesser Black-backed Gulls *Larus fuscus fuscus* from a Norwegian colony via stopover sites (red circles) to the wintering grounds in East Africa and the Mediterranean Sea (filled circles, each colour representing a different individual). The path is shown for the individual wintering farthest south, and represents the net migratory distance.