Post-breeding migration of four Long-tailed Skuas (Stercorarius longicaudus) from North and East Greenland to West Africa

Benoît Sittler, Adrian Aebischer, Olivier Gilg

Post-breeding migration of four Long-tailed Skuas (*Stercorarius longicaudus*) from North and East Greenland to West Africa

Benoît Sittler[12], Adrian Aebischer[13] and Olivier Gilg[14]

[1] Groupe de Recherche en Ecologie Arctique, 16 rue de Vernot, 21440 Francheville, France

[2] Institut für Landespflege, University of Freiburg, Tennenbacherstraße 4, 79106 Freiburg, Germany

[3] Museum of Natural History, Chemin du Musée 6, 1700 Fribourg, Switzerland

[4] Lab. Biogéosciences, UMR CNRS 5561, Université de Bourgogne, 21000 Dijon, France and Department of Biological and Environmental Sciences, University of Helsinki, 00014 Helsinki, Finland (corresponding author: olivier.gilg@gmail.com; tel/fax: +33 3 80 35 09 23).

Abstract

The Long-tailed Skua is a specialist predator of lemmings during summer and hence an important component of the Tundra ecosystems, but most of its life cycle takes place offshore and remains largely unknown outside of the breeding season. Using 9.5g solar-powered satellite transmitters, we could document for the first time the post-breeding movements of the Long-tailed Skua, from its high-Arctic breeding- grounds in North and Eastern Greenland, to the tropical waters of West Africa. The birds travelled the ca. 10.000 km of this migration in only 3-5 weeks, covering 800-900 km/day during active migration, which also occurred during night time. Leaving their breeding areas in August (except for one failed breeder), the Long-tailed Skuas first moved south along the coast of East Greenland towards a staging area off the Canadian Great Banks where they stayed for 1-3 weeks. From there, they crossed the Atlantic Ocean eastwards in just one week and entered the African waters near the Madeira Archipelago in September. Although we only monitored four birds for 1.5 to 3 months, migration routes were relatively similar between birds breeding in different locations and in different years.

Keywords

Satellite tracking, post-breeding migration, staging area, upwelling, rates of travel, Long-tailed Skua, *Stercorarius longicaudus*, Greenland.

Zusammenfassung

Der Zug von vier Falkenraubmöwen (*Stercorarius longicaudus*) von den Brutgebieten in Nord- und Ostgrönland bis nach Westafrika.

Falkenraubmöwen ernähren sich während der Brutzeit hauptsächlich von Lemmingen und stellen somit ein wichtiges Glied in Tundren-Ökosystemen dar. Da sie aber den Großteil ihres Lebens auf hoher See verbringen, ist über ihre Lebensweise außerhalb der Brutsaison nur wenig bekannt. Mit Hilfe von 9.5 g schweren, solarbetriebenen Satellitensendern konnten nun erstmals die Zugbewegungen von den hocharktischen Brutplätzen in Nord- und Ostgrönland bis in die tropischen Gewässer vor der westafrikanischen Küste dokumentiert werden. Innerhalb von 3 bis 5 Wochen legten die Vögel etwa 10000 km zurück. Die Tagesetappen betrugen 800 bis 900 km, wobei die Vögel auch nachts zogen. Nach dem Verlassen der Brutgebiete im August flogen die Vögel zunächst entlang der ostgrönländischen Küste bis zum Festlandsockel vor Neufundland, wo sie 1 bis 3 Wochen blieben. Sie überquerten anschließend in nur einer Woche den Atlantik in südöstlicher Richtung und gelangten über Madeira und die Kanaren bis in die Nähe der Kapverdischen Inseln. Bislang konnten wir nur 4 Vögel über einen Zeitraum von 1.5 bis 3 Monate verfolgen, jedoch wiesen die Zugrouten aus unterschiedlichen Brutgebieten in beiden Untersuchungsjahren ähnliche Muster auf.

Introduction

The Long-tailed Skua (*Stercorarius longicaudus*) is an important component of the Arctic terrestrial vertebrate community. Across most of its breeding range, it depends on cyclic lemming densities to breed (Andersson 1971, 1976, 1981; Larson 2007; Maher 1970; Meltofte and Høye 2007) and both species strongly interact (Gilg et al. 2003). Along with a few other predators, the Long-tailed Skua regulates the Collared Lemming (*Dicrostonyx groenlandicus*) dynamics in Northeast Greenland (Gilg et al. 2006; Schmidt et al. 2008), especially during the peak phase of the lemming cycle when, along with the Snowy Owl (*Nyctea scandiaca*) and the Arctic Fox (*Alopex lagopus*), it is responsible for the rapid summer decline in lemming numbers (Gilg 2002).

Conditions experienced by seabirds during migration and on their wintering grounds are assumed to impact their subsequent reproductive performance (Furness et al. 2006). De Korte (1985) has shown that Long-tailed Skuas breeding in Northeast Greenland arrive with maximal fat reserves in spring. The pelagic habitats they use during the non-breeding period (9-10 months of the year) must hence provide them with sufficient food resources to initiate breeding but are also, in turn, indirectly impacting the lemming population dynamics. Little is known, however, about the flyways and wintering grounds used by the species, the most pelagic of all Skuas (Furness 1987; Olsen and Larsson 1997). With the exception of some local concentrations reported from the Benguela upwelling (Lambert 1980; Ryan 1989), a cold nutrient rich current off the coasts of Namibia and South-Africa, there are nearly no ring recoveries for the species during the non-breeding period and flyways have been inferred from only a limited number of offshore observations.

Recent developments in satellite telemetry, with transmitters weighing less than 10g, have opened new perspectives for the study of medium sized bird (between 300 and 500g). Because it breeds in remote Arctic areas and spends the rest of the year in similarly remote offshore waters, the Long-tailed Skua is a perfect candidate species for these new research techniques. The present study presents the timing, duration, and flyways of four Greenlandic Long-tailed Skuas during their post-breeding migration, as part of a comprehensive long-term research of terrestrial vertebrates in Northeast Greenland (Gilg et al. 2003; Sittler 1995).

Material and methods

Four Long-tailed Skuas were captured and fitted with satellite transmitters (PTTs) in 2006 and 2007 in the “North and East Greenland National Park” (Table 1). All birds were breeding. In 2007 we captured the birds on the nest using a bow net, while in 2006 they were captured within a few meters of the

nest, using a small mist net (ca. one square meter) fixed on two handhold poles and rapidly raised in front of attacking birds.

All birds were equipped with 9.5g solar-powered PTTs from Microwave Telemetry Inc (Columbia, USA). Transmitters were attached to the birds as a backpack using Teflon ribbon and four silver rings to build the harness. The PTT and harness (ca. 2g) weighted less than12g, which was on average 3.9% (±0.15 SD) of the body mass of the birds. The PTTs fitted on the two birds in 2006 were set to a constant duty cycle of 7/38h (on/off, respectively), the two PTTs attached in 2007 had a constant duty cycle of 7/25h on/off.

PTTs were located using the Argos positioning system (CLS 2008) that provides positions in seven precision classes. The location errors of the classes called LC3, LC2, LC1 and LC0 follow a normal distribution with a standard deviation of <150, <300, <1000 and >1000 m respectively. There is no accuracy estimate associated with the remaining classes (i.e. LCA, LCB and LCZ) but LCA have been showen to have the same accuracy as LC1 (Hays et al. 2001; Vincent et al. 2002). We used orthodromic distances to estimate the "daily rates of travel" of the birds (Imboden and Imboden 1972; James et al. 2005) for time scales of 45±7 hours (in 2006) and 32±7 hours (in 2007). For these calculations, we used successive "best daily location" (i.e. in order of preference: LC3, LC2, LC1, LCA, LC0) produced during the 7 hour transmitting period. We never used LCB and LCZ in the calculations. We also estimated "hourly rates of travel" using successive high accuracy fixes (LC3, LC2 and LC1) for time periods between 0.5-2 hours (for more details see Gilg et al. 2010).

Results

Altogether, the four PTTs produced 1019 Argos positions and the birds could be monitored for 45 to 86 days (mean 66 days; Table 1). Only one third (i.e. 376) of these locations were LC3, LC2, LC1 or LCA, but more than 70% of the "best daily positions" (i.e. 93 out of 131) were high accuracy fixes (LC3, LC2 and LC1).

Since 2006 and 2007 were two years with very low lemming densities in Mestersvig and Karupelv Valley, no Long-tailed Skuas bred successfully in either of these study sites during these years (Gilg et al. 2009; Benoît Sittler, unpublished data). The three birds monitored from this region left their breeding grounds 36-43 (Papikk), 42-43 (Niilar) and 12 days after they had been released (Table 1). The bird from Bliss Bugt (Blissy), the only bird that had possibly raised young (considering a fledging period of 25 days: Cramp and Simmons 1983), left its territory 31 days after release.

Hence, the start of the fall migration (i.e. the date of departure from the breeding grounds) occurred between July 19th and August 15th, in line with previous studies (Korte 1984; Wiley and Lee 1998; Benoît Sittler and Olivier Gilg, unpublished data).

After departure, all birds moved southward following the outer coast (note that "Blissy" did not take the shortest route over the Greenland icecap), passing between southeast Greenland and Iceland, towards a large (ca. 500.000 km²) staging area located off the Great Banks of Newfoundland in Canada (Figure 1). The first bird (Lucy) arrived there by the end of July, the others by the end of August. With the exception of Blissy, which was lost 20 days after it had started its migration (i.e. shortly before reaching this area), it took the birds 1-2 weeks to travel the 3.000 km from their breeding grounds in Northeast Greenland to this staging area (Figure 1). The three birds then stayed in this area for 8-20 days.

Two of the remaining birds could be further followed while they crossed the Atlantic Ocean towards North-West Africa. It took them one week to travel the 2500-3000 km from the staging area to the African waters, north of the Madeira Archipelago, where they arrived on September 12th (Papikk) and 23rd (Niilar), i.e. 21 and 39 days respectively after they had left their breeding grounds. From there, the last bird we monitored (Papikk) continued to move south, flying a few 100's of km offshore, and was finally lost one week later and 2500 km further south, off the coast of Guinea (ca. 10° Lat. N).

After they had left their breeding grounds, the rate of travel of the birds was usually between 100-400 km/day, with maximum rates of 800-900 km/day (Figure 2: upper panel). When adding together the daily legs of this route, the length of the post-breeding flyway, from Greenland to Guinea (through the Canadian waters -off the Great Banks- and the Madeira Archipelago) is about 10.000 km (Figure 2: central panel), and is 1500 km longer for birds like "Blissy" breeding in North Greenland. The remaining distance to the main known wintering grounds (see Discussion) off South Africa is about 5000 km on a direct route crossing the Gulf of Guinea (according to Lambert (2006), some migrating Long-tailed Skuas follow the coast of Angola while other cross the Gulf of Guinea offshore).

The hourly rate of travel calculated during migration with 63 successive pairs of high accuracy fixes was 14 km/h on average (maximum values: 53, 56 and 61 km/h). In several instances, we also found evidence of active nocturnal migration, as already suspected by Lambert (1988). Two such cases presented in detail in Table 2 (using four and six LC0 fixes) indicate that distances travelled during such events (i.e. >200 km), are not anecdotal when compared with the mean daily rate of travel (Figure 2: upper panel).

Discussion

Although our results are inferred from only four individuals, the consistency in the routes followed by these birds, and the fact that they originated in three different locations over two different years, supports the idea that the Long-tailed Skuas breeding in East and North Greenland use a specific post-breeding flyway and make use of a staging area off the Canadian Great Banks between ca. 48-51° Lat. N (Figure 1 and Figure 2: see plateau on lower panel). This pelagic region is well known for its high productivity (see e.g. http://oceancolor.gsfc.nasa.gov/SeaWiFS) and has also recently been suggested as a "hot-spot" for other seabird species (Egevang et al. 2010; see also historical data in Wyne-Edwards 1935). Staging in this area probably allows the Long-tailed Skuas to restore fat reserves after the demanding breeding season before heading to the southern hemisphere through the low productive tropical waters off West Africa.

From this staging area, Long-tailed Skuas head eastward, crossing the Atlantic Ocean north of the Azores Islands and reaching Northwest Africa between mid August and late September. Only few autumn observations have been made from the coasts of West Africa, probably because the migrating birds pass far offshore (see Papikk and Niilar on Figure 1), but seawatching from the Cape Verde Peninsula in Senegal has provided an average of 18 birds per day in October between 1995 and 2008 (111 days of monitoring and 1988 birds counted; Dubois et al. 2009), with a maximum of 123 birds on 27 October 2007 (Nilsson 2008). Numbers are probably even higher in late August and September (e.g. 69 Long-tailed Skuas counted in a single day the 31st of August 1990; Baillon and Dubois 1991; see also Fig. 2 lower panel) but no regular monitoring has yet been undertaken during this period (Dubois et al. 2009).

At first glance, our results would suggest that the Greenland birds migrate to the South-African wintering zone, where large concentrations of this species have been reported in the past, rather than to South-America, as previously thought by some authors (Harrison 1989; Olsen and Larsson 1997; but see below). Lambert (1980) for example found great numbers of Long-tailed Skuas off the coast of Namibia (> 200 birds some days) and Ryan (1989), working off the South African coast, gave an estimate of 75.000 Long-tailed Skuas wintering between 34 and 44° Lat. S. (see also observations from Lambert (2006) who counted up to 26 birds per day in October/November off the coast of Angola). Whether overestimated or not, these figures are at least suggesting that this region, a highly productive marine area due to the Benguela upwelling system (Hutchings 1992), is a key wintering area for the species. It probably hosts birds from many different origins, and possibly most if not all of the western Palaearctic populations.

However, we can't yet rule out the possibility that some at least of the Greenland birds continue their migration towards the other main wintering area reported in the Southern Atlantic Ocean: the Falkland current off Argentina. Up to 1500 birds were seen daily in this region in early November 1920 (Cramp 1985; Olsen and Larsson 1997), though later visits always provided much smaller numbers (Brown et al, 1975; Murphy 1936; Veit 1985; Wetmore 1926) or even failed to record the species at all (see e.g. Orgeira 2001; Tuck 1985). Among all known wintering areas for this species, the remaining ones only host small numbers of wintering birds and are less likely to be used by Greenland Long-tailed Skuas. For example the east coast of Africa (Lambert 2005) and the south-western coast of South America (Harrison 1989; Howell and Webb 1995; Johnson 1965; Tuck and Heinzel 1985), another region with productive upwelling zones, are thought to host birds originating from central Siberia (Lambert (2005) suggested that these birds use overland migration) and from eastern Siberia-Alaska, respectively. A few additional wintering areas may exist, e.g. off Australia and New Zealand, as suggested by irregular but repeated observations (Harrison 1989; Lewis 1991; Marchant and Higgins 1996; Melville 1985; Olsen and Larsson 1997; Wood 1989), and the species may even winter in the sub-Antarctic region where it has been seen from boats (Kampp 2001).

Both on migration routes and on wintering grounds, the Long-tailed Skua is often associated with the Sabine's Gull (*Larus sabini*; Olsen and Larsson 1997), which has a similar circumpolar breeding range. It is also interesting to note that the post-breeding flyway of the East Greenland Long-tailed Skuas greatly overlaps with the one recently documented for 11 Arctic Terns (*Sterna paradisaea*) originating from the same region (Egevang et al. 2010). While most of these birds (n= 7) moved along the African Coast heading to South Africa, four of these Terns crossed the Atlantic using an alternate flyway towards the coast of Brazil. Such a bi-directional migration pattern might also exist for the Long-tailed Skuas originating from the North Atlantic sector and would explain the records made off South America (see above). Indeed and as suggested above, after reaching the tropical waters off West Africa, some birds could make use of favourable easterly winds to continue westward (see Felicísimo et al. 2008), hence following a "S-shape" flyway from breeding to wintering grounds.

Based on this review and considering our limited knowledge of the migration patterns and wintering areas of the Long-tailed Skua, it is obvious that if we want to document the different flyways and assess the exact borders and respective importance of the different wintering grounds, we should continue our efforts and initiate sister projects over the entire breeding range of the species. To date, Southwest Africa and Southeast South-America appear to be the two main wintering grounds for this species, but the relative importance of these areas is still unclear.

Unfortunately, and for reason that are still unknown, the PTTs we used were only working for a few weeks. Overcoming these difficulties, for example using geolocators (Egevang et al. 2010), would open new perspectives and may also shed new light on the spring migration which, according to Lambert's (1980) observations (he still noticed adult birds off Namibia in early May, i.e. one month only before they arrive on their breeding grounds), could be much faster than the autumn migration (i.e. ≥ 12.000 km in only one month).

Acknowledegments

We are grateful to the Groupe de Recherche en Ecologie Arctique and the Musée d'histoire naturelle de Fribourg for financial support, to Pascal Grand, Brigitte Sabard and Luc Hardy for their help in the field, to the Government of Greenland (Ministry of Domestic Affairs, Nature and Environment) for granting access and research permits in the "North and East Greenland National Park", and to Ross Bartley for his comments on an earlier draft of the manuscript.

Bibliography

Andersson M (1971) Breeding behaviour of the Long-tailed Skua *Stercorarius longicaudus* (Vieillot). Ornis Scand 2:35-54

Andersson M (1976) Population ecology of the Long-Tailed Skua (*Stercorarius longicaudus* Vieill.). J Anim Ecol 45:537-559

Andersson M (1981) Reproductive tactics of the long-tailed skua *Stercorarius longicaudus*. Oikos 37:287-294

Baillon F, Dubois P (1991) Seawatching from Cape Verde, Senegal. Birding World 4:440-442

CLS (2008) Argos User's Manual. CLS, Toulouse

Coyne MS, Godley BJ (2005) Satellite Tracking and Analysis Tool (STAT): an integrated system for archiving, analyzing and mapping animal tracking data. Marine Ecology-Progress Series 301:1-7

Cramp S (1985) Handbook of the birds of Europe, the Middle East and North Africa. Volume IV Terns to woodpeckers. Oxford University Press, Oxford

Cramp S, Simmons KEL (1983) Handbook of the birds of Europe, the Middle East and North Africa. Volume III Waders to Gulls. Oxford University Press, Oxford

Dubois JP, Holmström N, Verneau A (2009) La péninsule du Cap-Vert à Dakar, Sénégal, est-elle la "Mecque" du seawatching? Ornithos 4/2009:220-232

245 Egevang C, Stenhouse IJ, Phillips RA, Petersen A, Fox JW, Silk JRD (2010) Tracking of Arctic terns
246 *Sterna paradisaea* reveals longest animal migration. PNAS 107:2078-2081
247 Felicísimo AM, Munñoz J, González-Solis J (2008) Ocean Surface Winds Drive Dynamics of
248 Transoceanic Aerial Movements. PLoS ONE 3:e2928
249 Furness RW (1987) The Skuas. Poyser, Calton
250 Furness RW, Crane JE, Bearhop S et al (2006) Techniques to link individual migration patterns of
251 seabirds with diet specialization, condition and breeding performance. Ardea 94:631-638
252 Gilg O (2002) The summer decline of the collared lemming (*Dicrostonyx groenlandicus*) in high arctic
253 Greenland. Oikos 99:499-510
254 Gilg O, Hanski I, Sittler B (2003) Cyclic dynamics in a simple vertebrate predator-prey community.
255 Science 302:866-868
256 Gilg O, Sittler B, Hanski I (2009) Climate change and cyclic predator-prey population dynamics in the
257 high-Arctic. Global Change Biol 15:2634–2652
258 Gilg O, Sittler B, Sabard B, Hurstel A, Sané R, Delattre P, Hanski I (2006) Functional and numerical
259 responses of four lemming predators in high arctic Greenland. Oikos 113:196-213
260 Gilg O, Strøm H, Aebischer A, Gavrilo MV, Volkov A, Miljeteig C, Sabard B (2010) Post-breeding
261 movements of the northeast Atlantic ivory gull *Pagophila eburnea* populations. Journal of
262 Avian Biology 41:532-542
263 Harrison P (1989) Seabirds. Christopher Helm, London
264 Hays GC, Åkesson S, Godley BJ, Luschi P, Santidrian P (2001) The implications of location accuracy
265 for the interpretation of satellite-tracking data. Anim Behav 61:1035-1040
266 Howell SNG, Webb S (1995) Noteworthy bird observations from Chile. Bull Brit Orn Club 115:57-66
267 Hutchings L (1992) Fish harvesting in a variable, productive environment — searching for rules or
268 searching for exceptions? S Afr J Mar Sc 12:297-318
269 Imboden C, Imboden D (1972) Formel für Orthodrome und Loxodrome bei der Berechnung von
270 Richtung und Distanz zwischen Beringungs- und Wiederfundort. Vogelwarte 26:336-346
271 James MC, Eckert SA, Myers RA (2005) Migratory and reproductive movements of male leatherback
272 turtles (*Dermochelys coriacea*). Mar Biol 147:845-853
273 Johnson AW (1965) The birds of Chile and adjacent regions of Argentina, Bolivia and Peru. Vol. 1.
274 Platt Establecimientos Gráficos, Buenos Aires

Kampp K (2001) Seabird observations from the South and Central Atlantic Ocean, Antarctica to 30°N, March-April 1998 and 2000. Atlantic Seabirds 3:1-14

Korte Jd (1984) Ecology of the Long-tailed Skua (*Stercorarius longicaudus* Vieillot, 1819) at Scoresby Sund, East Greenland. Part two: Arrival, Site tenacity and Departure. Beaufortia 34:1-14

Korte Jd (1985) Ecology of the Long-tailed Skua, *Stercorarius longicaudus* Vieillot, 1819, at Scoresby Sund, East Greenland. Part three: clutch size, laying date and incubation in relation to energy reserves. Beaufortia 35:93-127

Lambert K (1980) Ein Überwinterungsgebiet der Falkenraubmöwe, *Stercorarius longicaudus* Vieill. 1819, vor Südwest- und Südafrika entdeckt. Beitr Vogelkunde 26:199-212

Lambert K (1988) Nächtlichte Zugaktivität von Seevögeln im Golf von Guinea. Beitr Vogelkunde 34:29-35

Lambert K (2005) The spatial and seasonal occurence of seabirds (Aves) off southern Mozambique. Durban Museum Novitates 30:45-60

Lambert K (2006) Seabird sightings in the waters off Angola, 1966-1988. Marine Ornithology 34:77-80

Larson R (2007) Site tenacity of the Long-tailed Skua *Stercorarius longicaudus* - a study of the population at Stekenjokk. Ornis Svecica 17:81-89

Lewis M (1991) The status of long-tailed jaeger *Stercorarius longicaudus* in Australian waters. Austr Bird Watcher 14:119-122

Maher WJ (1970) Ecology of the Long-tailed Jaeger at Lake Hazen, Ellesmere Island. Arctic 23:112-129

Marchant S, Higgins PJ (1996) Handbook of Australian, New Zealand and Antarctic birds. Vol. 3. Pratincoles to Pigeons. Oxford University Press, Melbourne

Meltofte H, Høye TT (2007) Reproductive response to fluctuating lemming density and climate of the Long-tailed Skua *Stercorarius longicaudus* at Zackenberg, Northeast Greenland, 1996-2006. Dansk Orn Foren Tidsskr 101:109-119

Melville DS (1985) Long-tailed skuas *Stercorarius longicaudus* in New Zealand. Notornis 32:51-73

Murphy RC (1936) Ocean birds of South America. Macmillan, New York

Nilsson K (2008) Senegal - Havsfågelskådning i världsklass. Vår Fågelvärld 5/2008:18-21

Olsen KM, Larsson H (1997) Skuas and Jaegers. Pica Press, Sussex

306 Orgeira JL (2001) Distributión especial de densidades de aves marinas en la platforma continental
307 Argentina y Océano Atlantico sur. Ornitologia Neotropical 12:45-55
308 Ryan PG (1989) The distribution and abundance of Long-tailed Skuas off southern Africa. Ostrich
309 60:89-90
310 Schmidt NM, Berg TB, Forchhammer M, Hendrichsen DK, Kyhn LA, Meltofte H, Høye TT (2008)
311 Vertebrate predator-prey interactions in a seasonal environment. Adv Ecol Res 40:345-370
312 Sittler B (1995) Response of stoat (*Mustela erminea*) to a fluctuating lemming (*Dicrostonyx*
313 *groenlandicus*) population in North East Greenland: preliminary results from a long term
314 study. Ann Zool Fennici 32:79-92
315 Tuck G (1985) A guide to seabirds on the ocean routes. Collins, London
316 Tuck G, Heinzel H (1985) Guide des oiseaux de mer. Delachaux et Niestlé, Neuchâtel
317 Veit RR (1985) Long-tailed jaegers wintering along the Falkland Current. Amer Birds 39:873-878
318 Vincent C, McConnell BJ, Ridoux V, Fedak MA (2002) Assessment of Argos location accuracy from
319 satellite tags deployed on captive gray seals. Mar Mamm Sci 18:156-166
320 Wetmore A (1926) Observations on the birds of Argentina, Paraguay, Uruguay, and Chile. US Natl
321 Mus Bull 133
322 Wiley RH, Lee DS (1998) Long-tailed Jaeger (*Stercorarius longicaudus*). In: Poole A (ed) The Birds
323 of North America Online, Cornell Lab of Ornithology; Retrieved from the Birds of North
324 America Online: http://bna.birds.cornell.edu/bna/species/365, Ithaca
325 Wood KA (1989) Seasonal abundance, marine habitats and behaviour of skuas of central New South
326 Wales. Corella 13:97-104
327 Wyne-Edwards VC (1935) On the habits and distribution of birds on the North Atlantic. Proceedings
328 of the Boston Society of Natural History 40:233-346
329
330

Table 1: Summary data for the four studied Long-tailed Skuas and timing of their post-breeding migration

Birds' names (mass)	***Trapping location*** *(deg. Lat.N / Long. W)*	***Release date***	***Duration of tracking***	***Start date of fall migration in Greenland[1]***	***Duration of staging off Canada***	***Arrival off NW Africa***
Papikk (300g)	Karupelv Valley (72.50°/24°)	30-6-2006	81 days	5-12 August	8 days	12-9-06
Niilar (280g)	Karupelv Valley (72.50°/24°)	3-7-2006	86 days	14-15 August	16 days	23-9-06
Lucy (278g)	Mestersvig (72.25°/24°)	2-7-2007	45 days	19 July[2]	20 days	n.d.
Blissy (295g)	Bliss Bugt (83.57° /30°)	8-7-2007	52 days	8 August	n.d.	n.d.

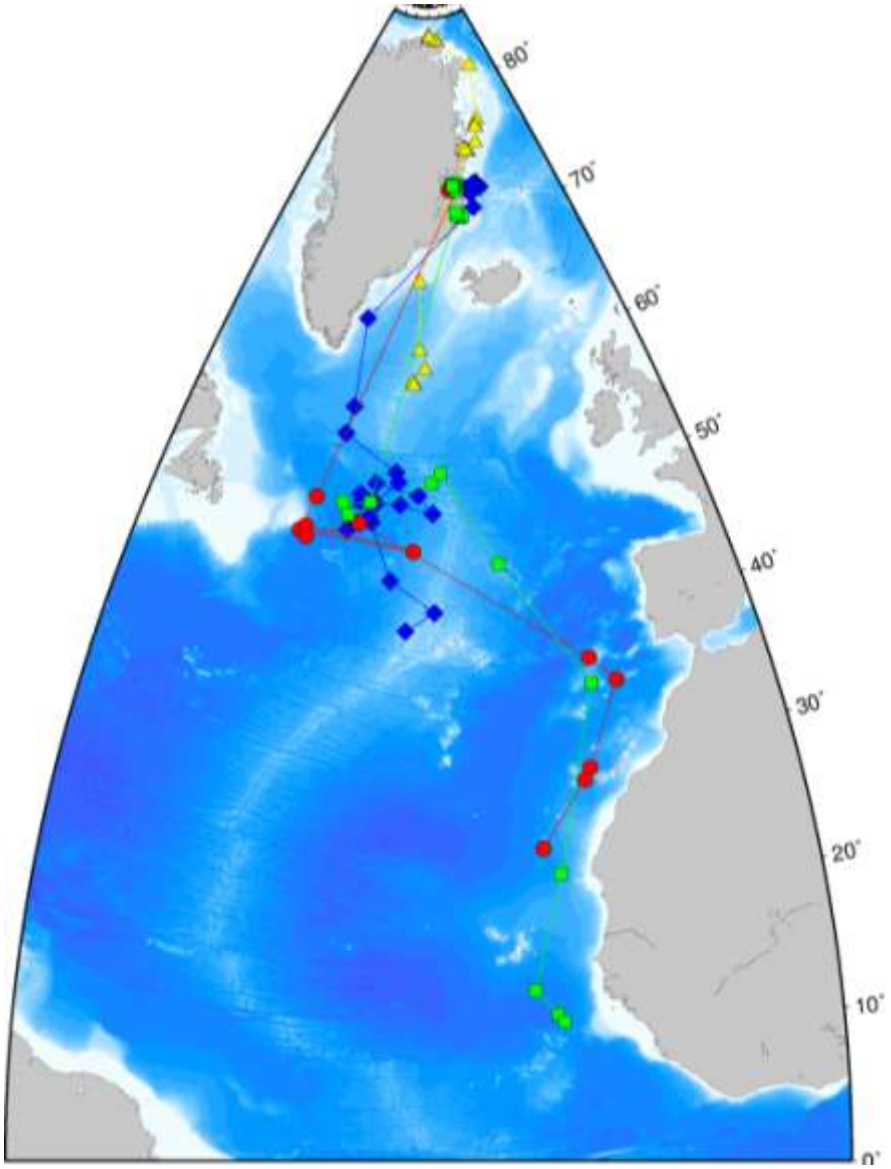
[1] the earliest and latest possible departure dates from breeding grounds are given when the exact data could not be documented

[2] this bird left its breeding territory on the 9th of July but remained within 50-100km of this area until July 18.

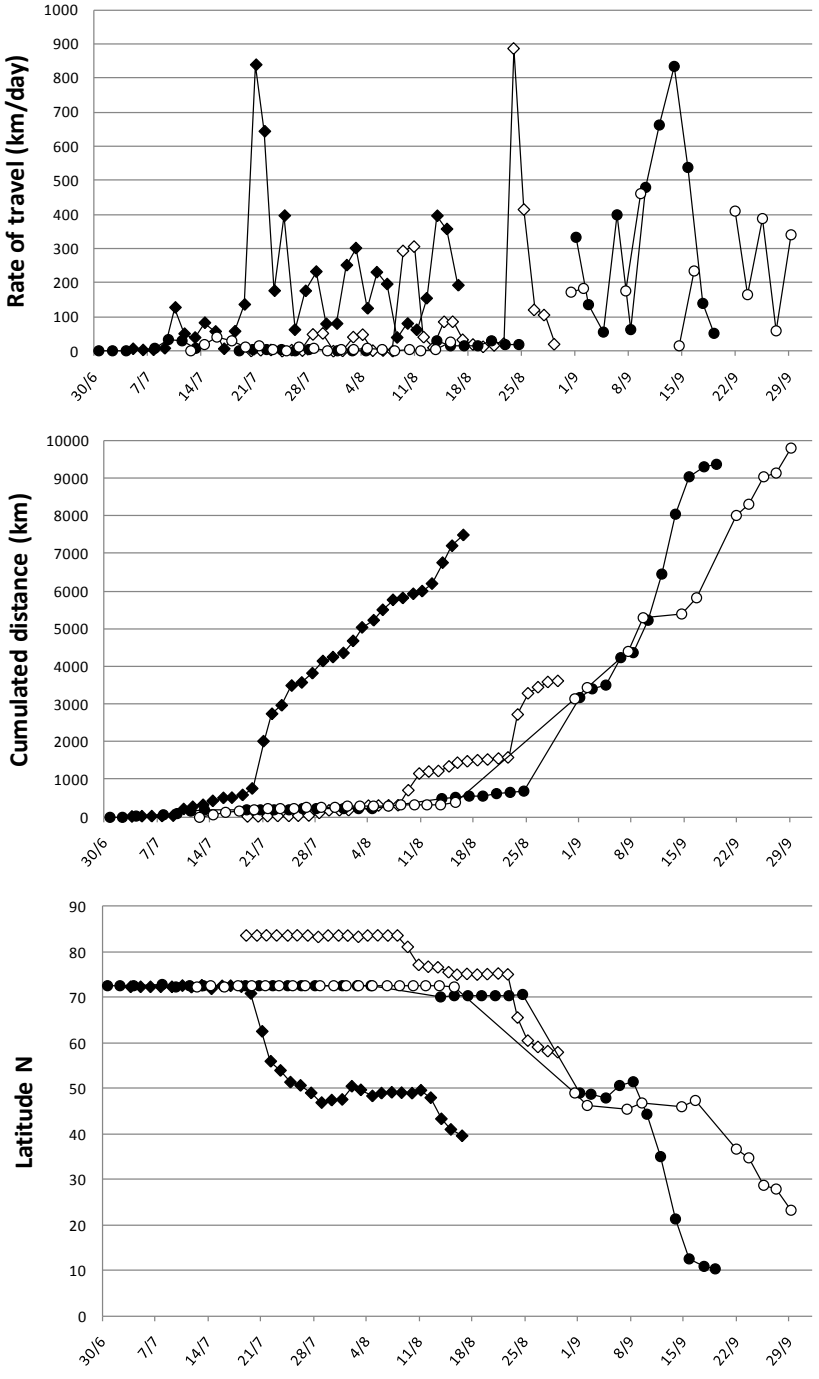
Table 2: Evidences for nocturnal migration of Long-tailed Skua.

Bird	**Date**	**Latitude** (deg. N)	**Longitude** (deg. W)	**Solar time**	**Solar angle** (deg./horizon)	**Distance** (km)	**Speed** (km/h)
Papikk	12-13/09/06	35.29°	15.16°	22:12:37	-43		
		34.87°	15.33°	23:51:30	-51	50	30
		34.10°	15.06°	01:33:29	-46	89	53
		33.30°	14.70°	03:07:38	-32	96	62
Lucy	14-15/08/07	43.63°	33.28°	19:59:43	-10		
		43.23°	32.74°	21:41:41	-24	62	37
		43.17°	32.62°	22:00:59	-26	12	37
		42.84°	32.00°	23:26:00	-32	62	45
		42.76°	31.84°	23:44:34	-33	16	55
		42.58°	31.19°	01:20:42	-30	57	36

Fig. 1: Post-breeding flyway of four Long-tailed Skuas from North and East Greenland to West Africa (Papikk: square; Niilar: circle; Lucy: diamond and Blissy: triangle; details in Table 1). The background map is a transverse mercator projection between 0-85° Lat. North and 0-60° Long. West (www.seaturtle.org/maptool; Coyne and Godley 2005). Only the best daily locations (i.e. one position per day per bird) presented on the tracks (see Methods).



352 **Fig. 2**: Movements of four Long-tailed Skuas (Papikk: black circle; Niilar: open circle; Lucy: black diamond and
353 Blissy: open diamond) between Greenland and Africa. Time scales used for the calculations are 45±7
354 hours (in 2006; circles) and 32±7 hours (in 2007; diamonds; see Methods).
355
356



357