SEABIRDS IN THE CENTRAL NORTH ATLANTIC, SEPTEMBER 2006: FURTHER EVIDENCE FOR AN OCEANIC SEABIRD AGGREGATION AREA

DAVID BOERTMANN

Institute of Bioscience, Aarhus University, P.0. Box 358, DK-4000 Roskilde, Denmark (dmb@dmu.dk)

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SUMMARY

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From 12 to 17 September 2006 a "snapshot" of seabird densities in the northern Atlantic between Greenland and the Azores was obtained using the strip-transect method. Relatively high densities of seabirds in the Greenland shelf and subpolar waters as well as very low densities in the oceanic subtropical waters, described by early authors, were confirmed. Highest oceanic densities (average 21 individuals/km^2 per sub-transect) were observed on 15 September approximately 200 km south of the subpolar front at about 50°N and approximately 600 km west of the Mid-Atlantic Ridge. Most numerous in this area were Leach's Storm-Petrel (552 on-transect), Great Shearwater (317 on-transect) and Cory's Shearwater (125 on-transect), and noteworthy were small numbers of Arctic Terns and Long-tailed Skuas. This high-density site was located in the centre of the stopover site/foraging area recently discovered by tracking Arctic Terns, Long-tailed Skuas, Sooty Shearwaters and Cory's Shearwaters. This combined aggregation area seems to be associated with the subpolar front between the Grand Banks and the Charlie–Gibbs fracture zone.

Key words: North Atlantic, strip sampling, oceanic seabird aggregation area, Leach's Storm-Petrel, Great Shearwater, Cory's Shearwater, Arctic Tern, Long-tailed Skua

INTRODUCTION

Descriptions of seabird occurrences in the oceanic part of the North Atlantic Ocean are few and date back to the early and mid-1900s (Jespersen 1924, 1930, Wynne-Edwards 1935, Mayr 1938, Baker 1947, Wiley 1959). Jespersen (1924, 1930), who conducted the most extensive surveys, described a marked divide between southern, warm waters with very few seabirds and northern, cooler waters with higher densities. More recent seabird-at-sea surveys have been carried out in the North Atlantic, but these have focused on the shelf areas or on oceanic parts to the northeast, where seabirds are generally more abundant than in the central oceanic parts (Danielsen *et al.* 1990, Skov *et al.* 1995, Garðarsson 1999, Reid *et al.* 2001, Gjerdrum *et al.* 2008). Surveys applying modern systematic sampling methods are therefore lacking in the central oceanic parts of the North Atlantic.

In recent years, tracking of seabirds with satellite transmitters and geo-locators has provided insight into seabird occurrence in these remote parts of the ocean (Magelhães *et al.* 2008, Egevang *et al.* 2010, Paiva *et al.* 2010, Hedd *et al.* 2010, Sittler *et al*. 2010). Common to these studies is that the studied species tend to stage for periods in their life cycles in a particular part of the central North Atlantic. This stopover site has been termed a "hot-spot" (Egevang *et al.* 2010), a phenomenon poorly known in the North Atlantic, but well known in other parts of the world's oceans, such as fronts in Antarctic waters (Bost *et al*. 2009). I report on systematic observations of seabirds made in September 2006 along a north–south route in the mid-Atlantic Ocean that passes through the stopover site.

METHODS

Data were collected on 12–17 September 2006 between Nuuk in Greenland and Ponta Delgada on the Azores, Portugal, (Fig. 1) on leg 4 of the Danish Galathea 3 expedition on the naval ship HDMS *Vædderen*, a 368-foot frigate. Data from this leg filled a gap in seabird-at-sea information in Greenland waters, kept in a database at my institution. The cruise was in the central part of the North Atlantic and, apart from the shelf waters off southwest Greenland, covered very deep oceanic waters, crossing the Mid-Atlantic Ridge on 16 September (Fig. 1, Appendix 1).

Observations were carried out throughout daylight hours (interrupted by meals, ship stops and, on 14 September, by adverse weather) from an observation box placed on top of the bridge with an eye level of 14 m above the sea surface. Cruising speed was 17 knots (31.5 km/h, for 88.3% of the transect length), but observations were also made during mapping of the seabed at 14 knots (25.9 km/h, 4.4% of the total time) and when hauling oceanographic equipment at 9 knots (15.7 km/h, 3.8%) or 10 knots (18.5 km/h, 3.5%).

Data were collected by strip sampling, applying a 300 m wide transect on one side of the ship (Tasker *et al.* 1984), using the detailed guidelines of Webb & Durinck (1992). Distance sampling (Buckland *et al.* 2001) with six 50 m wide transect bands was also used; however, as almost all observed birds — even the alcids — were flying, distance calculations were not possible (Ronconi & Burger 2009). Flying birds were recorded in "snapshots" adjusted to the speed of the ship (Webb & Durinck 1992). The transect was divided into sub-transects when observations were interrupted or

when the ship changed course. Observations were carried out in 2 min observation periods/bins corresponding to 1.05 km at 17 knots (31.5 km/h). Seabirds observed outside the 300 m transect width, following the ship or outside observation periods were recorded as "off-transect."

Salinity and sea-surface temperature (SST) data were collected continuously, together with ocean depth, throughout the entire leg. These "Ferry Box" data are available on http://galathea.dtu.dk/GE_data.html. Aqua Modis SST data (composite of nighttime temperatures for 14–21 September 2006) and chlorophyll *a* (composite of data for 29 August to 29 September 2006) were downloaded from the NASA site "OceanColor Web" (http://oceancolor.gsfc.nasa.gov/) and used as background in Figs. 2 and 3.

RESULTS

On 12 and 13 September, the weather was relatively calm, overcast, with high visibility, and sea state was low (Beaufort number < 5), creating good observation conditions. On 14 September and part of 15 September we passed just west of the remains of hurricane Florence, associated with strong winds, high sea state and reduced visibility. It was, however, possible to carry out observations during some periods, as the wind and waves came in from behind. On 16 and 17 September the weather was again calm with excellent visibility, clear sky and low sea state.

The observation transect was a total of 1145 km long and was divided into 27 sub-transects (Appendix 1, available on the Web site). On 12 September only, the survey covered shelf waters, and on all other dates, the survey covered deep sea areas (Fig. 1). The sub-transects surveyed on 12 and 13 September were within the Greenland Exclusive Economic Zone (EEZ). The transect surveyed on 17 September passed between two of the islands in the Azores archipelago (Canal de São Jorge).

Species account

The occurrence of all species recorded is described below and, in Appendix 1, densities and frequencies are given for some of the more numerous or remarkable species. Fig. 2 summarises the densities recorded for all seabird species combined.

Northern Fulmar *Fulmarus glacialis*. Numerous on the three first days (12–14 Sept). The southernmost bird was observed (off-transect) on 15 September at 48°26'N, 36°40'W. Many followed the ship when cruising or remained near the ship during stops.

Great Shearwater *Puffinus gravis*. Observed only on 14 September (n = 9 on-transect) and 15 September (n = 317 on-transect); as well, up to 120 were observed around the ship during stops.

Manx Shearwater *Puffinus puffinus*. 14 September four (one on-transect), 15 September one (on-transect) and 16 September one (on-transect).

Sooty Shearwater *Puffinus griseus*. Four were observed (on-transect) on 12 September on the Greenland shelf. A few were

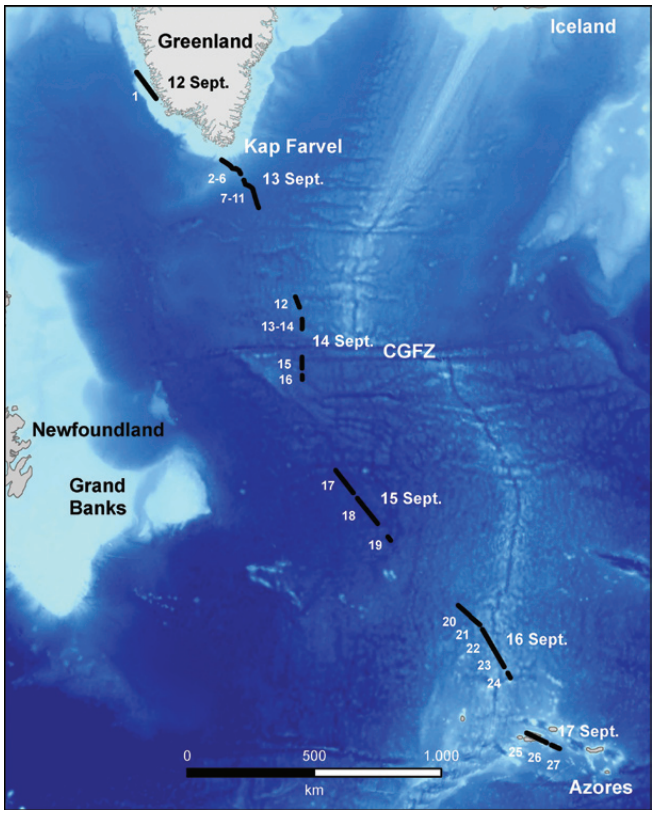

Fig. 1. The seabird-at-sea transect between Greenland and the Azores. Sub-transect numbers and dates are shown. Depth is indicated in shades of blue with pale indicating shallow (shelf) waters and dark indicating deep waters up to >4000 m. CGFZ is the Charlie–Gibbs fracture zone.

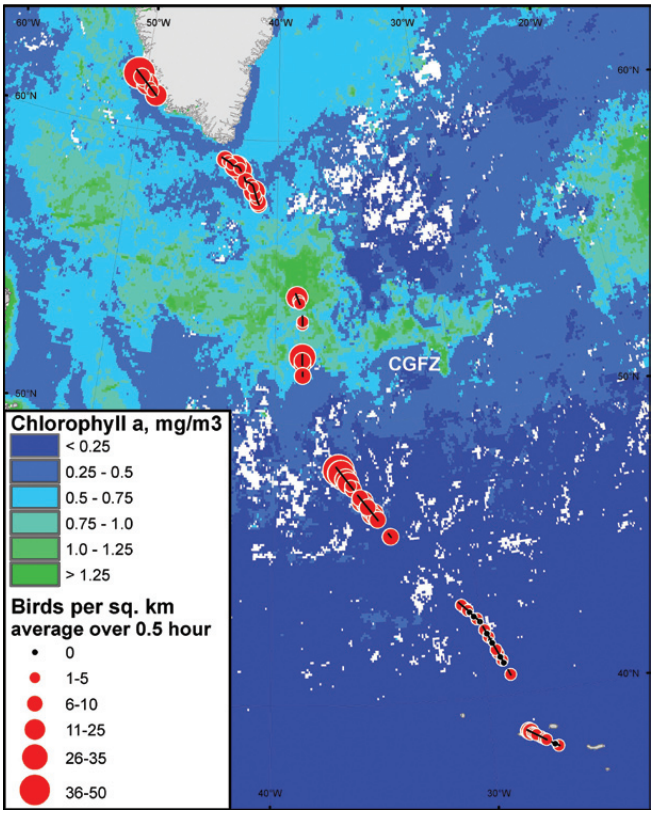

Fig. 2. Densities of seabirds (all species on-transect combined) along the transect in September 2006. Densities are aggregated over 30 min periods, to provide a better overview. Background is a synoptic Aqua Modis composite image of chlorophyll *a* in surface waters. CGFZ is the Charlie–Gibbs fracture zone.

later seen among Great Shearwaters on 14 September (sub-transects 12–14) and 15 September (sub-transect 17–18), for a total of ten (six on-transect).

Cory's Shearwater *Calonectris diomedea*. The first was observed on 15 September, almost simultaneously with the southernmost fulmar, and the Cory's Shearwaters were numerous during that afternoon on sub-transect 18 — in total 124 birds on-transect. The following day only five were observed. On 17 September, when the transect was close to the Azores, numbers increased slightly, with a total of 49 birds on-transect.

Leach's Storm-Petrel *Oceanodroma leucorhoa*. During the first sub-transect (17), on 15 September, 355 were recorded on-transect. Numbers decreased steadily throughout the day, with 187 on sub-transect 18 and 10 on sub-transect 19. The following day, only 22 were seen on-transect. Only one was seen on-transect on 17 September. More than 50% of 237 birds seen at < 100 m showed inner-primary hiatus in the remiges, indicating growing feathers.

Phalarope unsp. *Phalaropus* sp. Observed on 12 and 13 September (n = 45), usually in small flocks (4–24). A single phalarope was observed on 15 September. Previous observations in Greenland waters at this time of the year (pers. obs.) suggest that these birds were probably Grey Phalaropes (*Phalaropus fulicarius*).

Great Skua *Stercorarius skua*. One on transect on 14 September and seven on and two off-transect on 15 September.

Pomarine Skua *Stercorarius pomarinus*. Ten on-transect and four off-transect on 13 September. On 14 September one on-transect and five off-transect. All six adults were light morph.

Arctic Skua *Stercorarius parasiticus*. One adult off-transect on 13 September.

Long-tailed Skua *Stercorarius longicaudus*. Sixteen juveniles/immatures on-transect and one off-transect on 15 September. Fifteen were seen in 48 km between 48°26'28"N, 36°40'44"W and 48°06'49"N, 36°18'32"W; the last bird seen was 126 km to the southeast (see also Arctic Tern).

Glaucous Gull *Larus hyperboreus*. Two on-transect and a few seen during a stop for oceanographic studies on 12 September off southwest Greenland.

Herring Gull *Larus argentatus atlantis*. The first was seen on 16 September, an immature approximately 350 km north of Corvo in the Azores. Three were seen on 17 September in Canal de São Jorge.

Great Black-backed Gull *Larus marinus*. Five seen 12 September during the stop off southwest Greenland.

Lesser Black-backed Gull *Larus fuscus*. One seen on 14 September: an immature bird passed the ship during a stop.

Black-legged Kittiwake *Rissa tridactyla*. On 12 September 47 were seen, on 13 September 40, and on 14 September 152, all on-transect. Up to 60 followed the ship on the same dates.

Common Tern *Sterna hirundo*. Ten on 17 September, on-transect, in Canal de São Jorge.

Arctic Tern *Sterna paradisaea*. One (age not recorded) on 13 September 50 km south of Cape Farewell (Kap Farvel). On 15 September 17 on-transect (12 single birds, including three adults and six juveniles, a group of one adult and two juveniles, and two adults together) and three off-transect (age unknown). They were concentrated (65%) on sub-transect 17 between 48°26'28"N, 36°40'44"W and 48°06'49"N, 36°18'32"W in the same area as Long-tailed Skuas (see above). South of this concentration area, six birds (age unknown) were seen dispersed along the transect further on to 47°10'16"N, 35°19'26"W approximately 126 km to the southeast. The last Arctic Tern was seen two minutes after the last Long-tailed Skua.

Black Guillemot *Cepphus grylle*. One on 13 September, a bird in winter or juvenile plumage was seen on-transect, 90 km to the southeast of Cape Farewell (Kap Farvel).

Thick-billed Murre *Uria lomvia*. On the 12 September, 23 on-transect off southwest Greenland. The next day, a flock of three 63 km southeast of Cape Farewell (Kap Farvel).

Atlantic Puffin *Fratercula arctica*. On 12 September, 19 on-transect off the southwest Greenland. The following day (13 September), 62 on-transect and eight off, concentrated along sub-transects 7–11 (116 km) between 58°33'7"N, 42°11'28"W and 57°46'23"N, 41°15'25"W.

Other birds. A Turnstone (*Arenaria interpres*) passed the ship on 13 September, 163 km southeast of Cape Farewell (Kap Farvel); a Sanderling (*Calidris alba*) rounded the ship twice before proceeding southwards on 15 September, 1560 km from Greenland and 850 km from the nearest of the Azores islands; a Lapland Bunting (*Calcarius lapponicus*) circled the ship on 13 September, 230 km southeast of Cape Farewell (Kap Farvel).

Oceanographic data

The Ferry Box data showed a general increase in both temperature and salinity along the transect, with some abrupt shifts. The most significant shift occurred just north of 50°N, where salinity increased to more than 35 psu and temperature increased from 15.5 °C to 17.5 °C. This shift was interpreted as signalling the subpolar front, separating the cool, nutrient-rich and relatively less saline water of the subpolar gyre from the warmer, nutrient-poor and high-salinity water of the subtropical gyre (Rossby 1999, Søiland *et al.* 2008). South of this shift, and including the first sub-transect (17) on 15 September (230 km south of the shift), both salinity and SST varied strongly, indicating high eddy/meander variability with mixing of different waters. On the last two observations days, the SST ranged between 21.0 °C and 23.3 °C, indicating subtropical waters. This SST pattern was in general confirmed by the Aqua Modis data from September 2006 (Fig. 3). Chlorophyll *a* concentrations beyond the Greenland shelf were highest on 14 September (0.75–1.5 mg/m^3) and relatively low (<0.5 mg/m^3) on 15 September (Fig. 2).

Densities and species composition

During the first three survey days, the species composition was dominated by Northern Fulmars, Black-legged Kittiwakes and, during the first two days, alcids — mainly Atlantic Puffins. These species all belong to Arctic and sub-Arctic waters. The observed average densities per sub-transect (all species combined) ranged

between 3 and 17 individuals/km^2, with peaks up to 321 individuals/km^2 in a single 2 min period.

During the night of 14–15 September, the species composition shifted markedly. Leach's Storm-Petrel became the dominant species, followed by Great and Cory's Shearwater. The average density of seabirds on the first sub-transect (17) was 21 individuals/km^2 with a peak per 2 min observation period of 396 individuals/km^2 (Appendix 1), and there were very few 2 min periods without observations on the subsequent sub-transects (Appendix 1, Fig. 2). Both Leach's Storm-Petrels and Great Shearwaters declined in density after sunrise, while Cory's Shearwater increased, to the point that it was the most frequent bird on the last sub-transect (19) on 15 September. Very notable this day was the occurrence of Arctic Terns and Long-tailed Skuas. On the last two days, densities and the proportion of 2 min observation periods with observations were extremely low, with densities only exceeding 1 individual/km^2 when sailing through the Canal de São Jorge (Appendix 1).

DISCUSSION

Calculating densities based on strip-transect results assumes that all birds within the strip are observed. This assumption was met during days of relatively calm weather (i.e., on 12, 13, 16 and 17 September). However, on 14 September and to some degree on 15 September, the weather was rough and hampered observations, resulting in probable underestimates of bird densities. Despite this bias and the fact that my survey provides only a "snapshot" of the situation, there was a clear pattern in seabird density, with relatively high densities the first four days followed by extremely low densities the last two days in the warm subtropical waters. This pattern is well known (Jespersen 1924, 1930). The density peak observed south of the subpolar front on 15 September has apparently not been noted before, perhaps because all previous seabird-at-sea surveys in this part of the Atlantic sailed more or less parallel to the density gradients, while I sailed across. However, Wynne-Edwards (1935), who crossed my sub-transect 14 (at approximately 53°30'N and north of the subpolar front) twice in August and once in September 1933, found a peak in Great Shearwater densities between 35°W and 40°W, and also reported high numbers of Arctic Terns between 30°W and 50°W. Mayr (1938), who sailed westwards and crossed my sub-transect 17 (at approximately 47°45'N and south of the subpolar front) early in the morning on 2 August 1938, reported high numbers of Great Shearwaters on the afternoon of 1 August (approximately 350 km to the east of my transect) and almost no seabirds until noon on 2 August, when he was just south of the Grand Banks.

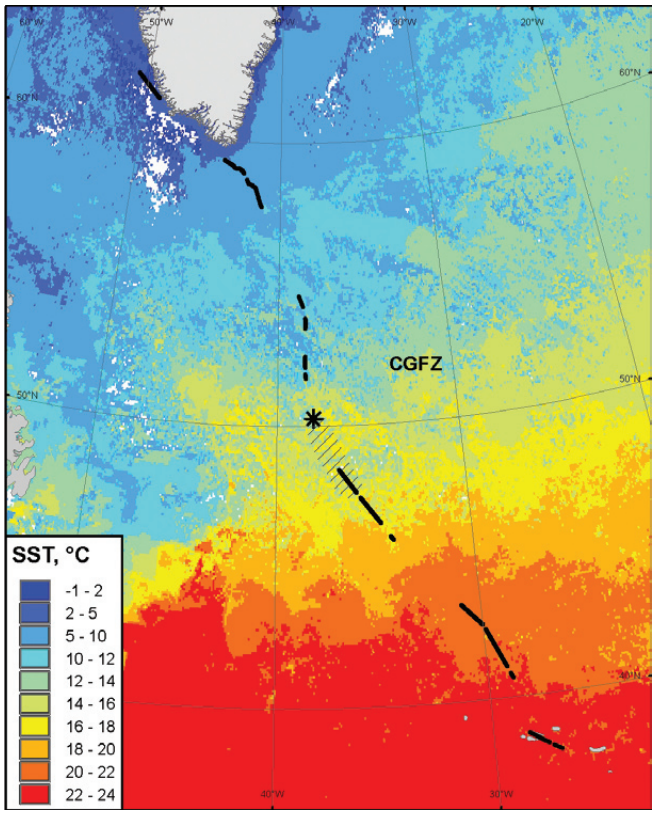

Fig. 3. The September 2006 transect laid over an Aqua Modis composite image of night-time sea surface temperatures (SST). The presumed location of the subpolar front is shown with an asterisk and the area with high variance in SST and salinity measurements is indicated with black hatching. CGFZ is the Charlie–Gibbs fracture zone.

My observations confirm the stopover site/foraging area located by several recent tracking studies including post-breeding Arctic Terns and Long-tailed Skuas and breeding Cory's Shearwaters (Magalhães *et al.* 2008, Egevang *et al.* 2010, Paiva *et al.* 2010, Sittler *et al*. 2010). However, the high densities observed were primarily made up of Leach's Storm-Petrels and Great Shearwaters. As all the species observed here are surface feeders (and partly klepto-parasites in the case of the skuas), food must be brought to the surface by eddies and other hydrographical discontinuities, as indicated by the mixed waters recorded. On 15 September, the highest densities of Leach's Storm-Petrels and Great Shearwaters were recorded early in the morning, and densities subsequently decreased, indicating that the northern limit of the high-density site was passed earlier during the night.

The presence of Atlantic Puffins north of the subpolar front was notable as little is known about the whereabouts of this species in the non-breeding season There are two other remarkable puffin observations in Greenland waters: one in October 1993 when thousands of puffins were counted on the banks off southwest Greenland (Mosbech *et al.* 1996), and one in September 2009 when puffins were recorded along the entire distance between south Greenland and Iceland (pers. obs.). The breeding population in Greenland is only a few thousand pairs (Boertmann & Mosbech 2001) and is unlikely to be the origin of all these birds. It is more likely that autumn migrants from Iceland and perhaps Norway and the British Isles move across the Atlantic to West Greenland and Newfoundland waters, as indicated by a few ring recoveries (Petersen 1998, Wernham *et al.* 2002, Bakken *et al.* 2003, Lyngs 2003).

The most remarkable observations south of the subpolar front were the Arctic Terns and Long-tailed Skuas on 15 September. Both species occurred in the peak density area and over exactly the same stretch of sub-transects 17 and 18. This location is in the centre of an autumn migration stopover site recently indentified for both species by tracking birds from Greenland breeding sites (Egevang *et al.* 2010, Sittler *et al*. 2010). Wynne-Edwards (1935) also noted the presence of these species in the mid-Atlantic in August and September, although his observations were 600–700 km north of mine.

Sooty Shearwaters were observed on both sides of the subpolar front, but in very low numbers. According to recent tracking results (Hedd *et al.* 2010), Sooty Shearwaters should utilise almost the same area as the Arctic Tern stopover site, but earlier, as they start

their migration towards the southern hemisphere breeding grounds in mid-September. Most had thus probably already left by the time of this study. However, some still lingered on much further north in the Greenland shelf waters, as recorded on 12 September. The Great Shearwaters, recorded on both sides of the subpolar front, were, like the Sooty Shearwaters, on migration away from their wintering grounds at this time of the year. Only the Cory's Shearwaters may have been breeding birds on long-range foraging trips away from the Azores (Magalhães *et al.* 2008, Paiva *et al.* 2010).

The many Leach's Storm-Petrels in active primary moult indicated that most, if not all, were immature birds. Jespersen (1930) also noticed many storm-petrels "in the Gulfstream region," although he identified them with "hardly any doubt" as Wilson's Storm-Petrels (*Oceanites oceanicus*). By far the majority I observed were Leach's Storm-Petrels, confirmed by two birds caught on board the ship during night-stops for oceanographic studies on 16 and 17 September. Only a few (n = 16) not identified to species could have been Wilson's Storm-Petrels. Wynne-Edwards reported very few Leach's Storm-Petrels in the mid-Atlantic (between 40°W and 45°W) in August and September 1933, but many more further west and to the north of the Grand Banks, indicating that in this season they are mainly found in the Gulf Stream waters south of the subpolar front.

Localised seabird feeding areas are often termed "hot-spots" (Bost *et al.* 2009), a term also adopted by Egevang *et al*. (2010) for the Arctic Tern stopover site. The high-density site I passed on 15 September extended perhaps 200 km from north to south. As Egevang *et al.*'s (2010) "stopover site" extended more than 1000 km east–west and Sittler *et al*.'s (2010) record of staging Long-tailed Skuas was between the Grand Banks and the Mid-Atlantic Ridge, the term "hot-spot" seems too restrictive, and I prefer "aggregation area" instead. This area covers an extensive oceanic region associated the subpolar front between the Grand Banks and the Charlie–Gibbs fracture zone.

Seabird data were not included among the ecological selection criteria when an area at the Charlie–Gibbs fracture zone was recently designated a Marine Protected Area (OSPAR Commission 2010). Large parts of this Marine Protected Area include the aggregation area described here. The lack of seabird data in the selection criteria underlines the need for data to describe and delimit the aggregation area and to identify conservation concerns, data which should be gathered by systematic and extensive seabird-at-sea surveys combined with synoptic oceanographic studies.

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REFERENCES

BAKER, R.H. 1947. Observations on the birds of the North Atlantic. *Auk* 64: 245-259.

BAKKEN, V., RUNDE, O. & TJØRVE, E. 2003. *Norsk ringmærkningsatlas.* Vol. 1. Stavanger Museum, Stavanger, Norway.

BAKKEN, V., BOERTMANN, D., MOSBECH, A., OLSEN, B., PETERSEN, A., STRØM, H. & GOODWIN, H. 2006. Nordic Seabird Colony Databases. *TemaNord* 2006: 512, Nordic Council of Ministers.

BOERTMANN, D. & MOSBECH, A. 2001. Offshore seabird distributions during summer and autumn at West Greenland. Ship based surveys 1977 and 1992-2000. National Environmental Research Institute, Denmark Technical Report 370.

BOERTMANN, D., MOSBECH, A., FALK, K. & KAMPP, K. 1996. Seabird colonies in western Greenland. National Environmental Research Institute, Technical Report 170. (http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR170.pdf).

BOST, C.A., COTTÉ, C., BAILLEUL, F., CHEREL, Y., CHARRASSIN, J.B., GUINET, C., AINLEY, D.G. & WEIMERSKIRCH, H. 2009. The importance of oceanographic fronts to marine birds and mammals of the southern oceans. *Journal of Marine Systems* 78: 363-376.

BUCKLAND, S.T., ANDERSON, D.R., BURNHAM, K.P., LAAKE, J.L., BORCHERS, D.L. & THOMAS, L. 2001. *Introduction to Distance Sampling. Estimating abundance of biological populations*. Oxford: Oxford University Press.

DANIELSEN, F., SKOV, H., DURINCK, J. & BLOCH, D. 1990. Maine distribution of seabirds in the Northeast Atlantic between Iceland and Scotland, June-September 1987 and 1988. *Dansk Ornitologisk Forenings Tidsskrift* 84: 45-63.

EGEVANG, C., STENHOUSE, I.J., PHILLIPS, R.A., PETERSEN, A., FOX, J.W. & SILK, J.R.D. 2010. Tracking of Arctic terns *Sterna paradisaea* reveals longest animal migration. *Proceedings of the National Academy of Sciences of the United States of America* 107: 2078-2081.

GARÐARSSON, A. 1999. The density of seabirds west of Iceland. *Rit Fiskideildar* 16: 155-169.

GJERDRUM, C., HEAD, E.J.H. & FIFIELD, D.A. 2008. Monitoring seabirds at sea in eastern Canada. *AZMP Bulletin PMZA* 2008 No. 7: 52-58.

HEDD, A., MONTEVECCHI, B., OTLEY, H., & PHILLIPS, R. 2010. Year-round tracking of Sooty Shearwaters from the Falkland Islands identifies important marine bird areas in the North and South Atlantic. Oral Presentation at the 1st World Seabird Conference, Victoria, BC, Canada, 7–11 September 2010.

JESPERSEN, P. 1924. The frequency of birds over the High Atlantic Ocean. *Nature* 114: 281-283.

JESPERSEN, P. 1930. Ornithological observations in the North Atlantic Ocean. *The Danish "Dana" expeditions 1920-22* No. 7.

LYNGS, P. 2003. Migration and winter ranges of birds in Greenland; an analysis of ringing recoveries. *Dansk Ornitologisk Forenings Tidsskrift* 97: 92-100.

MAGALHÃES, M.C., SANTOS, R.S. & HAMER, K.C. 2008. Dual-foraging of Cory's shearwaters in the Azores: feeding locations, behavior at sea and implications for food provisioning of chicks. *Marine Ecology Progress Series* 359: 283-293.

MAYR, E. 1938. Birds on an Atlantic crossing. *Proceedings of the Linnaean Society, New York* 49: 54-58.

OSPAR COMMISSION. 2010. Press release 24 September 2010. (http://www.ospar.org).

PAIVA, V.H., GERALDES, P., RAMÍREZ, I., MEIRINHO, A., GARTHE, S. & RAMOS, J.A. 2010. Oceanic characteristics of areas used by Cory's shearwaters during short and long foraging trips in the North Atlantic. *Marine Biology* 2010: 1385-1399.

PETERSEN, A. 1998. *Islenskir fuglar.* Vaka-Helgafell, Reykjavík.

REID, J.B., POLLOCK, C.M. & MAVOR, R. 2001. Seabirds of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research* 21: 1029-1045.

RONCONI, R.A. & BURGER, A.E. 2009. Estimating seabird densities from vessel transects: distance sampling and implications for strip transects. *Aquatic Biology* 4: 297-309.

ROSSBY, T. 1999. On gyre interactions. *Deep-Sea Research Part II: Topic Studies in Oceanography* 46: 139-164.

SKOV, H., DURINCK, J., DANIELSEN, F., & BLOCH, D. 1995. Co-occurrence of cetaceans and seabirds in the Northeast Atlantic. *Journal of Biogeography* 22: 71-88.

SITTLER, B., AEBISCHER, A. & GILG, O. 2010. Post-breeding migration of four Long-tailed Skuas (*Stercorarius longicaudus*) from North and East Greenland to West Africa. *Journal of Ornithology* doi:10.1007/s10336-010-0597-6.

SØILAND, H., BUDGELL, W.P. & KNUTSEN, Ø. 2008: The physical oceanographic conditions along the Mid-Atlantic Ridge north of the Azores in June–July 2004. *Deep-Sea Research Part II: Topical Studies in Oceanography* 55: 29-44.

TASKER, M.L., JONES, P.H., DIXON, T.J. & BLAKE, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk* 101: 567-577.

WEBB, A. & DURINCK, J. 1992. Counting birds from ship. In: Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds). Manual for aeroplane and ship surveys of waterfowl and seabirds. International Waterfowl and Wetlands Research Bureau (IWRB) Special Publication No. 19. pp. 24-37.

WYNNE-EDWARDS, V.C. 1935. On the habits and distribution of birds on the north Atlantic. *Proceedings of the Boston Society of Natural History* 40: 233-346.

WERNHAM, C., TOMS, M., MARCHANT, J., CLARK, J., SIRIWARDENA, G. & BAILLIE, S. (Eds). 2002. *Migration Atlas: movements of the birds of Britain and Ireland.* London: T.& A.D. Poyser.

WILEY, R.H. JR. 1959. Birds observed during two Atlantic crossings. *Wilson Bulletin* 71: 364-370.