New insights into the migration and wintering areas of Scottish-breeding Arctic Skuas

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Abstract

The Arctic Skua *Stercorarius parasiticus* is one Britain's rarest breeding seabirds. The entire British population is restricted to Scotland and has declined by 79% between 1986 and 2021. Most research on the skua's decline has focused on the breeding grounds. However, the species is a long-distance migrant, spending most of the year away from its breeding colonies. To date, potential threats to the species during the non-breeding season have largely been overlooked owing to limited knowledge on its movements and therefore the obstacles birds may face during this time. Here, we detail the migratory routes, staging and wintering areas and migratory strategies of geolocator-tagged, Scottish-breeding Arctic Skuas.

Introduction

Arctic Skuas *Stercorarius parasiticus* are long-distance migrants breeding at high latitudes in the northern hemisphere, from Alaska through Greenland to Siberia, and which winter in more southerly latitudes. In Britain, Arctic Skuas are at the southern edge of their breeding range and are restricted to the west and north of Scotland (Burnell *et al.* 2023). They are also one of Britain's most severely declining seabirds; since 1986, the first year that the Seabird Monitoring Programme (SMP) took place, Arctic Skuas have declined from 3,388 Apparently Occupied Territories (AOT) to just 727 AOT in 2015–21, a decline of 79% (Burnell *et al.* 2023). Consequently, the species is Red-listed in the seabirds addendum to *Birds of Conservation Concern 5* (Stanbury *et al.* 2024). In fact, long-term declines in breeding populations have been noted across the northeast Atlantic, resulting in the species being classified as Endangered on the European Red List of Species (BirdLife International 2021).

Most research into understanding these dramatic losses has focused on

what is happening during the breeding season, when birds are committed to their nests and are therefore relatively easy to study. Declines have largely been attributed to food shortages, which negatively impact productivity (Perkins *et al.* 2018; van Bemmelen *et al.* 2021). In Scotland, a reduction in the availability of marine prey during the breeding season has resulted in declines in the seabirds that Arctic Skuas kleptoparisitise, such as Kittiwakes *Rissa tridactyla* and Arctic Terns *Sterna paradisaea*. This is exacerbated in some colonies by predation of Arctic Skua chicks by Great Skuas *Stercorarius skua*, which increases in years when alternative fish prey that the Great Skuas would otherwise feed on is limited (Perkins *et al.* 2018). Great Skuas may also out-compete Arctic Skuas for breeding territories (Dawson *et al.* 2011).

However, Arctic Skuas spend only around one-third of the year on their breeding grounds; the remaining two-thirds of the year is spent at sea, where a range of other potential threats may be negatively impacting survival. In order to identify these potential threats, migration route(s) and wintering area(s), as well as any staging areas, need to be known.

At-sea observations have shown that the winter range of Arctic Skuas includes the waters around South America, from Peru to southern Brazil, around southern Africa, from Angola to Mozambique, and the seas around Australia, New Zealand and Polynesia. However, little evidence exists to show which populations are wintering in which areas. For example, do British birds winter in the southwest Atlantic, off South America, or in the southeast Atlantic, off southwest Africa? Ringing recoveries suggest the answer could be ‘both’, with long-distance recoveries of Scottish-ringed birds coming from west and southwest Africa and Brazil (Wernham *et al.* 2002; Spina *et al.* 2022). Ringing recoveries from France and Spain hint at the migration routes

of these birds, but the numbers of individuals ringed and subsequently recovered is too small to sufficiently determine patterns of movement during the non-breeding season. Not surprisingly, it is extremely difficult to determine the at-sea movements from ringing recoveries alone.

Although data from ringing are valuable, advances in modern tracking technology has enabled researchers to obtain more detailed information on where and when individual birds are located across the annual cycle (Burger & Shaffer 2008). Consequently, in this study, we used small, light-weight geolocators to identify the year-round movements of Scottish-breeding Arctic Skuas. These geolocators require retrieval to download data but, since Arctic Skuas return to the same nesting areas year-on-year, it was possible to retrap the adult birds carrying geolocators once they had returned to their breeding grounds.

Methods

Arctic Skuas from two breeding colonies in north Scotland were tagged. During the 2017 breeding season, Migrate Technology C65 Geolocator light-immersion loggers were deployed onto nine breeding adult Arctic Skuas on Fair Isle (from 30 AOTs). A further ten of these geolocators were deployed on breeding adults (from 15 AOT in the study area) on Rousay, Orkney, during the 2018 breeding season. These geolocators weigh less than 1 g and were attached to a unique plastic engraved colour ring on the leg (plate 367). Tagged individuals were recaptured at the breeding colony in subsequent years (2018–21) to retrieve the geolocators, with six and four individuals recaptured from Fair Isle and Rousay, respectively.

Arctic Skua with geolocator

Sarah Harris

367. Adult Arctic Skua *Stercorarius parasiticus*, Fair Isle, June 2022. This breeding bird – ring number AAA – is carrying a geolocator (the small, part-transparent device attached to the colour ring).

The mean error of geographical locations estimated from geolocaters is ± 185 km (Phillips *et al.* 2004). Therefore, they offer a broad, day-by-day indication of migration routes and wintering areas. Data downloaded from the retrieved geolocators were processed to calculate sunrise and sunset times (twilight events). Based on twilight events, longitudes were calculated from the timing of local noon and midnight, and latitudes from day length. Geographic locations outside the breeding area were assigned to ‘autumn migration’, ‘at the wintering area’ or ‘spring migration’, based on the direction of movement of individuals. To smooth the error around the geolocator location estimates, we took the average latitude and longitude from the two daily locations (noon and midnight), and then calculated three-day running

means (Gilg *et al*. 2013).

During migration, locations were classified as either on stopovers or on transit flights using a 2-state hidden Markov model (HMM) based on saltwater immersion data, which the geolocators also recorded (whether the logger was wet or dry; see O'Hanlon *et al.* 2024). An HMM is a statistical tool which categorises data into hidden states (in this case two states: stopovers or transit flights) based on observations (whether the logger was wet or dry) and probabilities (whether the following datapoint would be wet or dry). Locations were considered as stopover sites when associated with days where a higher proportion of the day was recorded as wet (when individuals spent more time foraging or on the sea surface). Locations were considered as areas of transiting flight when associated with days where a greater proportion of the day was dry (when individuals were largely in flight). We then used concentrations of stopover locations to identify staging areas (with stopovers being locations where individuals typically stayed for short durations to rest or feed within the larger staging areas).

368. Adult Arctic Skua, Fair Isle, June 2024.

Results

All tagged Arctic Skuas from which data were retrieved started their autumn migration between early August and early September and arrived back on their breeding grounds the following year between late April and mid May (table 1). During autumn, most individuals from both colonies migrated south through the North Sea and the English Channel to coasts off northwest Spain and western Portugal, then onwards to the waters off West Africa (fig. 1a & b). Skua AAU, from Rousay, took a more westerly route, migrating along the west coast of Ireland before heading southeast to the coast of Portugal; this bird took this route in both of the years that it was tracked. This individual, along with two from Fair Isle, wintered in the Canary Current off West Africa, while the remaining individuals continued south and then southwest to the Patagonian Shelf in the southwest Atlantic or southeast to the Benguela Current off southwest Africa.

Table 1. Summary information on the migratory timings and main wintering areas of the ten Arctic Skuas *Stercorarius parasiticus* from which geolocator data were retrieved (Fair Isle = 6 birds; Rousay = 4 birds). Several individuals were tracked for two consecutive years.

bird ID	year deployed	year retrieved	year tracked	start date of autumn migration	wintering-area arrival date	winter area depart date
Fair Isle						
AAK	2017	2018	2017/18	08/08/2017	24/09/2017	23/02/

AAA	2017	2018	2017/18	29/08/2017	27/10/2017	24/03/
AAL	2017	2018	2017/18	07/08/2017	11/09/2017	24/04/
AAJ	2017	2018	2017/18	09/08/2017	11/08/2017	24/03/
AAN	2017	2019	2017/18	30/07/2017	05/10/2017	03/03/
AAN	2017	2019	2018/19	20/08/2018	27/09/2018	09/03/
AAH	2017	2019	2017/18	19/08/2017	26/09/2017	04/04/
AAH	2017	2019	2018/19	23/08/2018	28/09/2018	06/04/
Rousay						
AAV	2017	2019	2018/19	02/08/2018	09/09/2018	17/03/
ACL	2018	2019	2018/19	03/09/2018	27/10/2018	09/04/
AAU	2018	2021	2018/19	11/08/2018	21/08/2018	27/03/
AAU	2018	2021	2019/20	03/08/2019	11/08/2019	N/A
AHN	2018	2021	2018/19	19/08/2018	14/09/2018	20/03/
AHN	2018	2021	2019/20	25/08/2019	24/09/2019	N/A

In spring, individuals that had wintered around the Patagonian Shelf (South America) and Benguela Current (southwest Africa) all returned north via the West African coast (fig. 1c & d). However, unlike in autumn, all individuals, including those wintering in the Canary Current, headed out into the mid-

Atlantic before returning east, back to their Scottish breeding colonies. For individuals that had two years of data, the migration routes taken during both autumn and spring were extremely similar between consecutive years, indicating that the skuas show strong repeatability in their non-breeding-season movements (fig. 2).

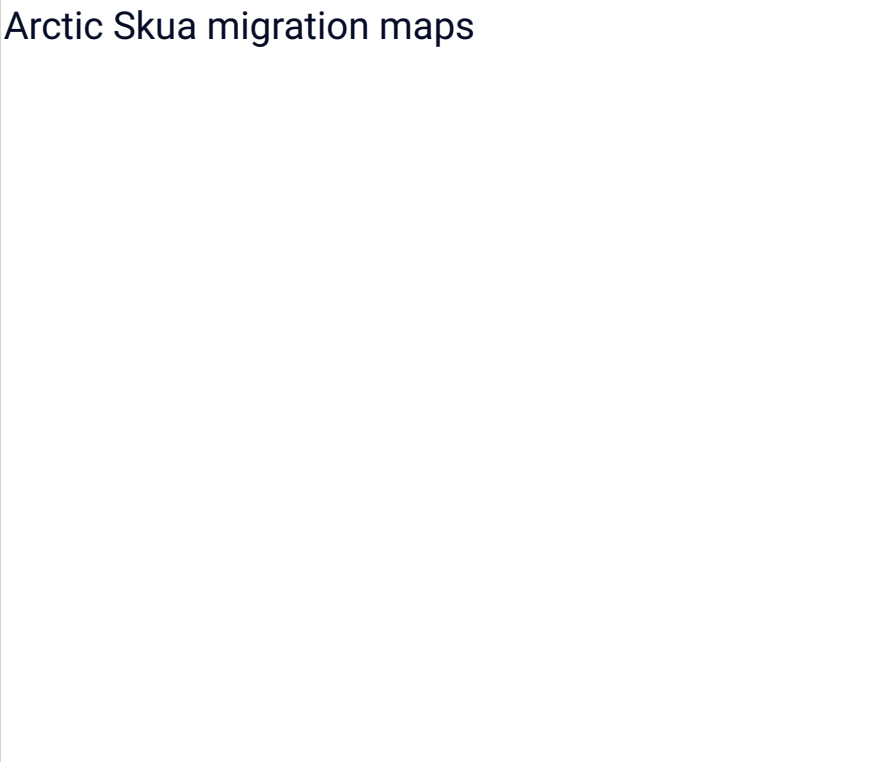


Fig. 1. Smoothed migration routes of tracked Arctic Skuas *Stercorarius parasiticus* from Fair Isle and Rousay, Orkney, during southbound (autumn) and northbound (spring) migration. The main staging areas of birds from each colony are shown for autumn (yellow) and spring (green) migration. The black circles show the location of Fair Isle and Rousay, while the triangles show the midwinter locations of each tracked Arctic

Skua. The colours and three-letter codes correspond to individual birds. Gaps in the migration routes are due to missing data around the autumn and spring equinoxes, when the errors around geolocator location estimates are high.

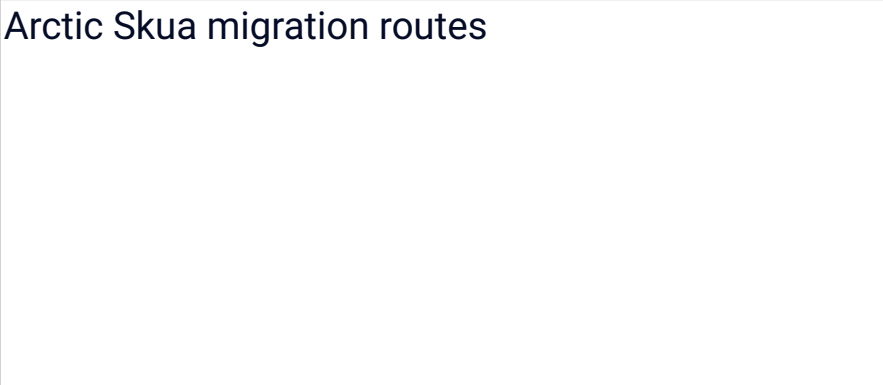


Fig. 2. Smoothed migration routes of tracked Arctic Skuas from Fair Isle and Rousay, showing individuals tracked over two years. The black circles show the location of Fair Isle and Rousay, while the triangles show the midwinter locations of each tracked Arctic Skua. Wintering areas of the individuals were virtually the same each year, while migration routes were also similar. During the second year of tracking for the Rousay individuals, data was available only for the autumn and part of the winter, therefore return spring migration routes are unknown.

Staging and wintering areas

Even within the small sample size in this study, and considering that birds bred no further than 92 km from each other in Scotland, wintering areas were separated by several thousand kilometres. Three individuals wintered in the Canary Current off West Africa, four in the Benguela Current off southwest Africa and three at the Patagonian Shelf off southeast South America (fig. 3). There was, amongst our sample, no indication that breeding location affected wintering areas, and individuals that were tracked for multiple years wintered in the same area in consecutive winters.

In autumn, individuals staged in British waters, in the southern North Sea and English Channel, and off the Iberian Peninsula. In spring, however, the skuas' main staging area was in the mid-North Atlantic (large green circle in fig. 3), far away from what would seem the most direct migration route back to the breeding grounds.

Data also showed a staging area off West Africa (small green circle in fig. 3), which was used during spring migration by individuals that wintered around the Patagonian Shelf and Benguela Current, before they headed northwest into the mid-North Atlantic.

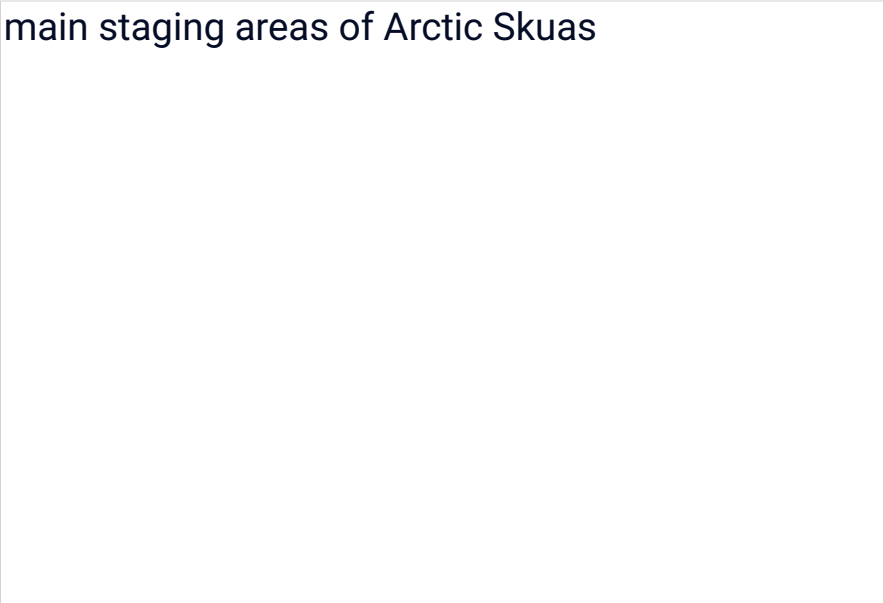


Fig. 3. The main staging areas of Arctic Skuas during autumn (yellow) migration and spring (green) migration and wintering areas (purple) for individuals tracked from Scotland (Fair Isle and Rousay). Letters refer to the three main wintering areas: CC = Canary Current; BC = Benguela Current; and PS = Patagonian Shelf.

Migratory strategies

During migration, long-distance migrants have to make trade-offs between fast flights, to cover the large distances needed to reach their wintering grounds, and stopovers in order to refuel. We calculated the number and duration of stopovers made by the tagged Arctic Skuas during each migration, and how far each bird travelled. For each individual, the total distance travelled from the breeding colony to the wintering area was calculated for the autumn migration, and from the wintering area back to the

breeding colony for spring migration. Distances were calculated between each smoothed daily location and included the direct-line distance between the last and first location during the ±17 days either side of the equinoxes, when equal day- and night-time-length meant that the loggers used on these birds were not able to give an accurate reading of location. Distances are likely under-estimated, especially for individuals that were actively migrating during the period around the equinoxes. Therefore, distances provide only a broad indication of the actual distances travelled by individuals given the error around raw geolocator positional fixes and the gaps around the equinoxes.

We found that the distance travelled by the Arctic Skuas was, as might be expected, related to where the birds wintered (tables 2 & 3), and this in turn influenced the number and duration of stopovers that birds made on migration. Only one individual that wintered in the Canary Current – i.e. the area involving the shortest migration distance from the breeding grounds – undertook a stopover during its autumn migration. Those Scottish birds with longer journeys, to the Benguela Current and Patagonian Shelf, made more stopovers for refuelling than those migrating shorter distances. Stopovers in spring were typically longer than in the autumn.

Arctic Skuas wintering in the Canary Current spent longer at their wintering areas, almost certainly since the birds had a shorter distance to reach the mid-North Atlantic stopover site before returning to breed.

Birds were not static on the wintering grounds and could range over considerable distances. Consequently, they did not start their spring migration at the same location where their autumn migration had finished, and therefore the distances flown during a bird’s autumn migration and its

spring migration typically differed.

Table 2. Summary information on the estimated mean (± SD) number, duration and total duration (days) of transit flights and stopovers, as well as distance travelled and total migration length, of individual Arctic Skuas tracked from Fair Isle and Rousay combined during autumn and spring migration.

migration	activity	transit flights	stopovers
autumn	number	2.50 ± 1.72	2.63 ± 1.6
	duration (days)	8.00 ± 8.45	8.36 ± 6.76
	total duration (days)	20.00 ± 13.58	22.00 ± 12.35
	distance (km)	9,911 ± 3,193	
	total migration length (days)	34.79 ± 18.95	
spring	number	2.00 ± 0.87	1.88 ± 0.83
	duration (days)	7.89 ± 7.04	9.27 ± 6.54
	total duration (days)	15.78 ± 8.73	17.38 ± 7.91
	distance (km)	14,269 ± 5,793	
	total migration length (days)	41.42 ± 13.25	

Table 3. Summary information on the estimated mean (± SD) number, duration and total duration (days) of transit flights and stopovers taken, as well as distance travelled and total migration length, by individual Arctic Skuas tracked from Rousay and Fair Isle, during southbound and northbound migration, split by wintering location, ordered from closest to furthest distance from the breeding populations. For individuals that were tracked over two years, only the first track was used. n = number of individuals/number of tracks.

[1] Only one of the Arctic Skuas migrating to the Canary Current made a stopover during the southbound migration, while two made stopovers during the northbound migration.

wintering area	**Canary Current (n=3)**[1]		**Benguela Current (n=4)**		**Patag**
activity	migrant flights	stopovers	migrant flights	stopovers	migra flights
southbound migration					
number	1.00	1.00	2.50 ± 1.29	2.25 ± 0.96	4.00 ± 2.00
duration (days)	4.68 ± 4.62	33.00	16.00 ± 16.47	7.13 ± 2.48	7.56 ± 3.03
total duration (days)	4.67 ± 4.62	33.00	26.00 ± 10.55	16.50 ± 10.97	27.33 11.68
distance (km)	4,232 ± 707		10,281 ± 608		1
total migration length (days)	14.00 ± 15.06		39.80 ± 13.61		46.40
total time in wintering area (days)	223.00 ± 3.46		169.50 ± 22.66		171.2
northbound migration					
number	2.00 ± 1.41	1.50 ± 0.71	2.25 ± 0.96	2.33 ± 1.16	1.67 ± 0.58
duration (days)	8.00 ± 5.66	17.25 ± 10.96	5.58 ± 3.36	8.33 ± 2.08	12.67 5.13
total duration (days)	12.00	22.00 ± 4.24	14.00 ± 8.76	19.00 ± 10.54	20.66 11.55
distance (km)	5,808 ± 159		15,577 ± 2474		1
total migration length (days)	29.33 ± 14.15		48.50 ± 11.73		

Arctic Skua

Roger Riddington

369. Adult Arctic Skua, Shetland, June 2023.

Discussion

Having gained substantial knowledge on the migration routes, staging areas and wintering grounds used by Arctic Skuas breeding in Scotland, the next step is to identify what threats may be encountered at these locations. For example, individuals migrating south through the North Sea in autumn might be vulnerable to increased collision risk with offshore windfarms. In spring, this risk may be reduced if individuals instead return to their breeding colonies via the mid-Atlantic, arriving in Britain from the west.

The mid-Atlantic staging areas used by the skuas during spring migration are in a region of high marine productivity and part of this region has recently been designated as a Marine Protected Area (MPA) owing to its importance for numerous seabirds and other marine fauna; this includes Kittiwakes, Arctic Terns and Long-tailed Skuas *S. longicaudus* (Davies *et al.* 2021). This

rich feeding area likely gives the Arctic Skuas a chance to refuel after making the long journey north from their wintering grounds, and to ensure they are in good condition for the forthcoming breeding season, since this stopover is a relatively short flight from the breeding grounds.

This study also identified an area off West Africa that was important for staging and wintering of Arctic Skuas from Scotland, and this area may also be worthy of designating as an MPA.

As part of this project, we collaborated with researchers who had deployed geolocators on Arctic Skuas at other breeding populations across northwest Europe. Combining this data showed how individuals from within these breeding populations also differed in where they overwintered, with birds spread from the Mediterranean Sea to the Patagonian Shelf; only in exceptional cases did an individual change where they wintered between years (van Bemmelen *et al.* 2024). In contrast to data from only birds breeding in Scotland, the larger sample of individuals showed that Arctic Skuas migrating to more distant wintering areas had on average *fewer* stopovers and spent a lower proportion of their migration at stopovers than skuas that wintered closer. This could be because some birds from other breeding areas employed a different migration strategy, such as migrating with flocks of other migrant species, such as terns or Sabine's Gulls *Xema sabini*, which the skuas could kleptoparasitise for food while on the move.

370. Adult Arctic Skua, Shetland, May 2020.

Our study also looked at the timings of the different stages within the annual cycle of each tagged Arctic Skua. The results showed that skuas from more northerly colonies bred later than birds farther south and started their autumn and spring migrations later. However, their spring migration was overall quicker. Furthermore, despite variation in how far individuals travelled to winter in different areas of the Atlantic, birds from the same breeding population arrived back at their breeding grounds at a similar time to each other when compared with birds from different breeding populations (van Bemmelen *et al.* 2024).

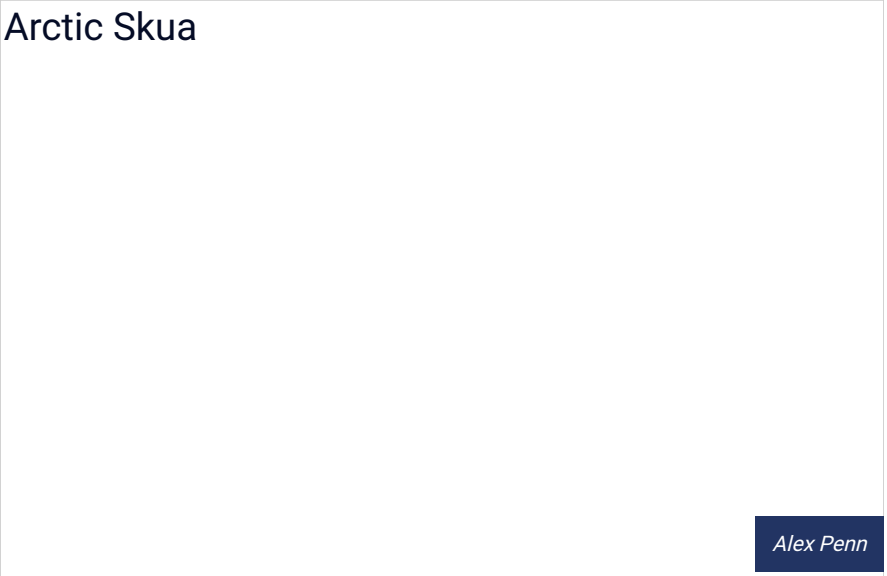
Data from tracked Arctic Skuas breeding in the Faroe Islands (23 birds), mainland Norway (57) and Svalbard (41) revealed that individuals from across these populations all staged in the mid-North Atlantic, particularly during spring migration, further highlighting the importance of this region for migrating Arctic Skuas from populations right across northern Europe (O'Hanlon *et al.* 2024). This low migratory connectivity, whereby individuals

from multiple colonies and breeding populations mix at staging and wintering areas, means that, if the skuas experience adverse foraging conditions or threats at these locations during the non-breeding season, there is a broad risk to birds from different populations across the species' breeding range. This is particularly true of the mid-North Atlantic staging area, given that individuals from all populations occurred there at some point along their migrations. Conversely, if a pressure occurs at just one wintering area, the impact on the species' breeding populations may be buffered if conditions are favourable at other wintering areas (Webster *et al.* 2002). The staging area off West Africa, used by individuals from Scotland during spring, was also used by individuals from the other breeding populations, emphasising the likely importance of this area to migrating Arctic Skuas.

By tracking birds from multiple populations, it is possible to determine whether differences – or similarities – exist in migratory routes, strategies and wintering areas and, if so, whether these are reflected in local population trends. As in Scotland, breeding populations of Arctic Skuas in the Faroe Islands and Norway are in steep decline (Santos 2018; van Bemmelen *et al.* 2021). In contrast, the Svalbard population is apparently declining but at a slower rate (Henriksen & Hilmo 2015). Although individual skuas from Svalbard wintered across a range of several locations, including those that overlapped with the wintering ranges of individuals from other populations, no birds were recorded wintering off southeast South America or southwest Africa; rather, many of the tracked birds from this population were found to be wintering close to the Caribbean Sea (van Bemmelen *et al.* 2024). Birds from Svalbard also tended to use stopover sites farther west in the mid-North Atlantic, especially during autumn migration, compared to other tagged birds in northern Europe. Therefore, it could be that at these northern hemisphere

locations, the skuas from Svalbard are experiencing more favourable conditions than those staging and wintering in other areas (O'Hanlon *et al.* 2024).

Understanding where Arctic Skuas are distributed during migration and the strategies they undertake is a vital first step in identifying threats individuals may encounter en route and how this may affect their survival and productivity, and therefore population trends. This in turn will help us to prioritise future research and conservation actions to benefit this declining, charismatic seabird.



371. Adult Arctic Skua, Fair Isle, June 2024.

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