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Identification of an assembly site for migratory and tropical seabirds in the South Atlantic Ocean

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ABSTRACT

Seabirds are good indicators of wider biodiversity and where they assemble in large numbers signifies sites important to many marine faunal species. Few such large assemblage sites have been identified and none in pelagic waters has been identified in the tropical Atlantic Ocean despite their importance for resident seabirds and those 'on passage' during migration. Here, we identify the likely location of just such an assembly site and provide preliminary information about the distribution of pelagic seabirds around Ascension Island in the tropical South Atlantic Ocean using a combination of trans-equatorial seabird migrant tracking data, records of at-sea surveys and land counts of seabirds returning from foraging trips. We found that waters north–north-west of Ascension Island are used more often by seabirds than those south and east of the island. Three-fifths of the species recorded in the assembly site breed at mid- or high-latitudes and some of these migratory seabirds stopover possibly to wait for favourable winds that facilitate onward flight. Our findings are important because to the best of our knowledge no seabird assembly sites have previously been identified in tropical Atlantic Ocean pelagic waters. We provide evidence to support the aspirations of the Marine Reserves Coalition that waters in the vicinity of Ascension Island should be recognised as a sanctuary for marine wildlife and we highlight an area that is worthy of further targeted investigation.

1. Introduction

Assembly sites are locations in which there is a co-occurrence of individuals of several species in time and space (Allaby, 1998). Assembly sites at sea are widely acknowledged as potential indicators of locations of marine biodiversity (Schreiber and Burger, 2002; Louzao et al., 2009) and important assembly sites provide a significant rationale for conservation action (Croxall et al., 2012). Ascension Island waters have been identified as a 'Hope Spot'; a place that is critical to the health of the ocean (Marine Reserves Coalition, 2015) and there are initiatives by some members of the United Kingdom (UK) Government (e.g. Goldsmith, 2014) and conservation bodies (e.g. the Royal Society for the Protection of Birds (RSPB); Hall, 2014) to designate waters around Ascension Island (part of the UK Overseas Territory (UKOT) of St Helena, Ascension and

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Tristan da Cunha) in the South Atlantic as a Marine Protection Area (MPA) (BirdLife International, 2014a). However, the failure to detect areas where several species regularly assemble beyond Ascension Island in-shore waters (Hall, 2014) may have hampered these initiatives to date.

The 'World Database of Protected Areas' (IUCN & UNEP-WCMC, 2013) contains records of more than 10 000 protected areas on land and at coastal sites. However, while open oceans comprise most (i.e. >70%) of the Earth's surface area, only 15 fully protected pelagic MPAs have been identified and described; they cover only 1% by area of the world's oceans (House of Commons EAC, 2014). None exists in pelagic waters of the tropical or subtropical Atlantic Ocean (IUCN & UNEP-WCMC, 2013). In these waters primary productivity is generally low compared with waters closer to the continental shelf (Marañón et al., 2003), and assembly sites may be rare and challenging to locate.

When compared with other taxa in marine ecosystems, assembly sites of seabirds are exceptionally well-studied (Croxall et al., 2012). Breeding sites, e.g. on seabird islands (Mulder et al., 2011) and sites where seabirds assemble during the non-breeding season, e.g. at coastal upwellings (Schreiber and Burger, 2002) are well-described (Wiens, 1997), compared to those in the open ocean that are harder to locate. However, one has been identified in the North Atlantic, e.g. Atlantic Northeast 1 – Marine IBA (BirdLife International, 2014b). In the middle of the tropical Atlantic Ocean important assemblages may only have the potential to occur at sites where seabirds (i.e. some Procellariiformes and Charadriiformes) that breed at high- or mid-latitudes, but are trans-equatorial migrants, mix with foraging tropical seabirds that breed on remote islands as year-round residents (Mulder et al., 2011). However, knowledge is limited because of scarcity of information about the movements of migrants that breed at higher latitudes (Newton, 2008).

During the last decade there has been an accumulation of evidence suggesting that pelagic seabird migratory flyways exist. These have been identified from tracking devices deployed on individual birds (Burger and Shaffer, 2008). Some seabirds migrate many thousands of miles and are trans-equatorial migrants, e.g. Sooty Shearwaters *Puffinus griseus* (Shaffer et al., 2006) and Arctic Terns *Sterna paradisaea* (Egevang et al., 2010). Procellariiformes and Charadriiformes that breed in the North Atlantic in populations numbering many thousands migrate annually from their breeding grounds to the South Atlantic, e.g. Manx Shearwaters *Puffinus puffinus* (Guilford et al., 2009). Some pelagic seabirds that breed in the South Atlantic migrate to the North Atlantic for the northern summer, e.g. Sooty Shearwaters (Hedd et al., 2012). Many migrants do not follow the shortest 'great circle' route connecting the breeding and non-breeding areas (Newton, 2008) but use flyways that closely match prevailing wind patterns (Felicísimo et al., 2008). To facilitate fast and energy-efficient migration, many seabirds in the Atlantic Ocean follow routes that are basically sigmoid resulting in an annual 'figure of eight' path around the ocean, following the trade-winds and ocean currents, clockwise around the North Atlantic gyre and counter-clockwise around the South Atlantic gyre. These trans-equatorial migrants follow distinctly different outbound and inbound migration routes that are probably genetically determined (Gwinner, 2003) from and to their breeding grounds. The intersection of their north- and southbound migratory flyway forms a spatio-temporal migratory focal point referred to as a 'centroid' by Sommer and Wade (2006).

Assembly sites for pelagic seabirds have been identified from at-sea surveys. However, efforts to establish seabird abundance and distribution at-sea can require years of ship time. While there are many methods employed to monitor species' distributions from ships (Tasker et al., 1984), most data have been collected opportunistically because observers have not been able to direct a ship's course. Seabirds are thinly scattered over a huge area of pelagic waters in the tropical South Atlantic Ocean. For example, Kampp (2001) reported a frequency of occurrence of approx. 0.48 birds per hour in April 2000 from a ship travelling at a speed of 8–10 knots with no fixed transect width and in good visibility between 16°S and 12°S latitudes. This contrasts markedly with records from more productive coastal waters, albeit at a different time of the year, where, for example, >5000 birds per hour were encountered in July 2005 from a ship travelling at 5 knots offshore from Mauritania (Wynn and Krastel, 2012). In less productive waters small changes in encounter rates make the margins of assembly sites especially difficult to locate and coarse-scale surveys (i.e. >1:5 000 000) have been used to provide evidence of oceanic assemblages of seabirds (e.g. Boertmann, 2011). Since 1946 the Royal Naval Birdwatching Society (RNBWS) has been collecting seabird observations from ships. Annual reports in *Sea Swallow* (RNBWS, 2012) show that observation effort in the South Atlantic increased during the Falklands conflict in the 1980s and data are sufficient to produce a coarse-scale plot of pelagic seabird distribution in the tropical South Atlantic.

In contrast to at-sea surveys, relatively easily collected data can be gathered from land-based sea watching and used to estimate the abundance and direction of movement of some pelagic species (British Trust for Ornithology, 2012; Grecian et al., 2012; Elmberg et al., 2013).

In this study we use a combination of data sources following techniques described by Croxall et al. (2012) to identify an assembly site for pelagic seabird species in the region of the Ascension Island Hope Spot (Marine Reserves Coalition, 2015). We have used migratory tracks of seabirds published in the literature, at-sea records collected by the RNBWS and on-land direction-timed counts of seabirds returning from foraging trips to identify an assembly site for seabirds in the tropical South Atlantic.

2. Materials and methods

We have employed nautical miles (M) and kilometres (km) as the units of distance (1 M = 1.852 km). Nautical miles were used because close to the equator one minute of latitude or longitude ≈1 M. The study area was centred on Ascension Island (07°57′S, 14°24′W, 97 km^2) and waters within 500 M of it. Ascension Island was used for land-based sea watches

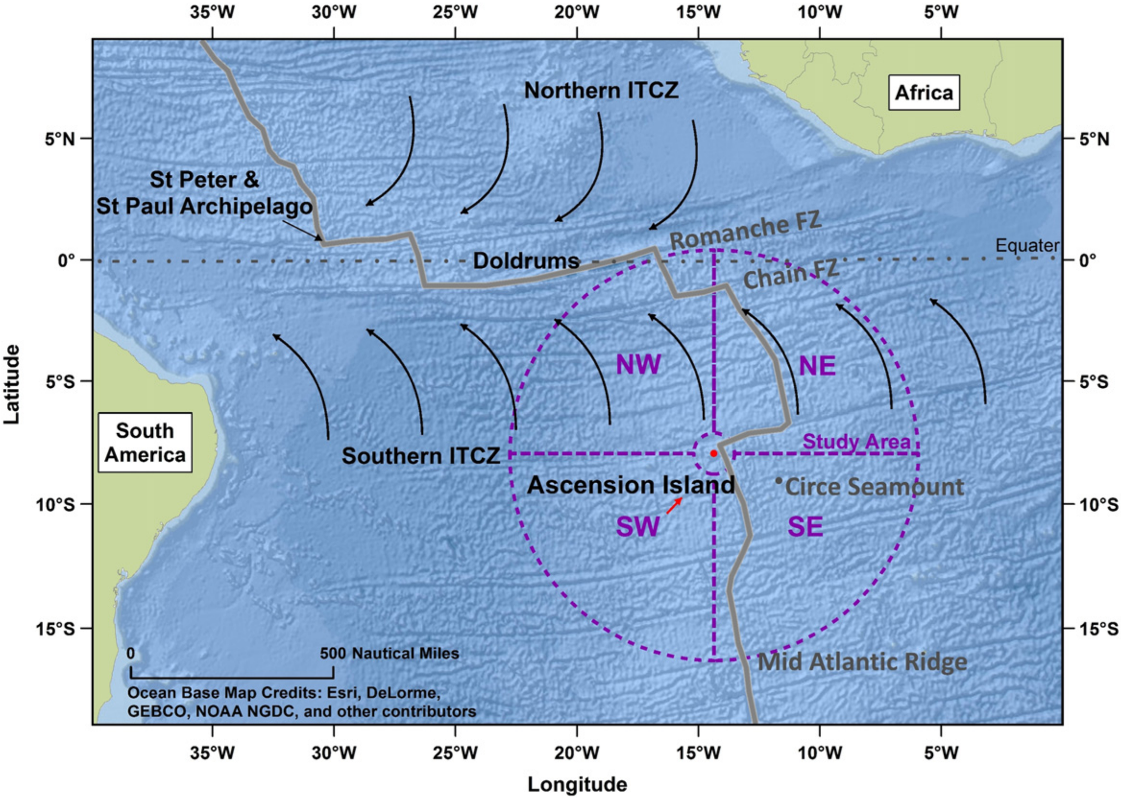

Fig. 1. Location of the study area in the tropical Atlantic Ocean which was split into four segments (NW, NE, SE and SW) centred on Ascension Island. Waters >50 M and <500 M from the island are shown. The jagged brown line indicates the Mid-Atlantic Ridge and curved black arrows the direction of prevailing winds. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

but assembly sites in waters that could be classed as in-shore (i.e. <50 M from Ascension Island) and within daily foraging range (Bolton and Oppell, 2014) of most Ascension seabirds were excluded from the study. The study area encompassed ≈2 700 000 km^2 of ocean south of the equator and some of the shortest routes for seabirds to cross between in-shore waters of African and South American continental land masses (Fig. 1). The only other land close to the study site is a few rocky outcrops and islets (e.g. Saint Peter and Saint Paul Archipelago; 00°55′1″N, 29°20′4″W). Ascension Island is volcanic and one of the high points on the Mid-Atlantic Ridge (MAR). This underwater mountain range runs north–south through the study area. The MAR is approx. 3 km in height above the ocean floor and 1000 km wide. Two narrow (mean width <20 km, running east to west—Mercier and Morin, 1997) submarine trenches (namely the Romanche Fracture Zone (FZ) and the Chain FZ) cross the MAR and facilitate circulation of bottom water (Mercier and Morin, 1997). The prevailing wind across most of the study area is from the south-east. The Intertropical Convergence Zone (ITCZ) or 'the doldrums' borders the northern edge of the study area (Fig. 1). The northern ITCZ is situated close to the equator between March and May and between 10°N and 15°N in August (Grodsky and Carton, 2003), and separates the North Atlantic gyre from the South Atlantic gyre. The study area was split into four segments each of ≈700 000 km^2 in area and referred to as 'North West' (NW), 'North East' (NE), 'South East' (SE) and 'South West' (SW) (Fig. 1). In each segment the area of 'high seas' (i.e. international waters) was approx. 570 000 km^2 and the area inside the Ascension Island Exclusive Economic Zone (EEZ) approx. 108 000 km^2. The area of the EEZ has been the subject of international debate (Cleverly and Parson, 2010) but currently extends 200 M from the island. A 2° × 2° grid was superimposed over the study area between 6°W and 22°W, and between the equator and 16°S. Grid squares with more than 75% of their area falling outside the study site were excluded from the analysis.

2.1. Trans-equatorial migrations

A literature search was carried out in Scopus and seaturtle.org using the keywords 'Tracking', 'Seabirds' and 'Migration' for reports of Atlantic Ocean trans-equatorial migratory bird species. We found reports and tracks of eight such trans-equatorial migrants that did not migrate along the African and South American continental shelf but crossed the equator mid-Atlantic (i.e. 22°W ± 7°). They breed in the three geographically distinct regions of the Arctic and Antarctic and at mid-latitudes (Table 1).

We located the centroid for species that visit the study area at least twice per year (e.g. Cory's Shearwater) when undertaking their migrations (González-Solís et al., 2007). We used the flyway intersections of north- and southbound

Table 1
Details of the breeding location and the number (n) of birds of pelagic seabird species tracked crossing the equator at the mid-Atlantic location of 22°W ± 7°.

Species' name	Breeding location	n	Reference
Cory's Shearwater *Calonectris diomedea*	Northwest Africa Islands	22	González-Solís et al., 2007
Great Shearwater *Puffinus gravis*	Tristan da Cunha South Atlantic	55	Martin and Ronconi, 2010
Sooty Shearwater *Puffinus griseus*	Kidney Island, Falkland Islands	26	Hedd et al., 2012
Manx Shearwater *Puffinus puffinus*	Skomer Island, UK	12	Guilford et al., 2009
Leach's Storm Petrel *Oceanadroma leucorhoa*	Bon Portage Island, Newfoundland	1	Pollet et al., 2014
South Polar Skua *Catharacta maccormicki*	South Shetland Islands Antarctica	27	Kopp et al., 2011
Long-tailed Jaeger *Stercorarius longicaudus*	High Arctic	8	Gilg et al., 2013
Arctic Tern *Sterna paradisaea*	High Arctic	11	Egevang et al., 2010

migrations of each species to estimate the latitude and longitude of the centroid. We located the position where trans-equatorial migrants (e.g. Manx Shearwaters—Kampp, 2001, Guilford et al., 2009) that visited the study area once per year (i.e. when migrating to the southern hemisphere) transit the equator (hereafter called the 'equator/longitude position'). Our study site encompasses some of these equator/longitude positions. As the flyways are hundreds of km wide and the average resolution of tracking devices (i.e. geolocators) attached to individual birds is 186 ± 116 km (Phillips et al., 2004), the accuracy of the flyway positions could be determined at best to approx. 2°. From tracking reports, we identified species that stopover for approx. 7 days. Dias et al. (2012) estimated the mean stopover time (±1 se) of 38 Cory Shearwaters during migration to their non-breeding site to be 7.2 ± 7.5 days.

2.2. At-sea surveys

We searched the Royal Navy's world database (RNBWS, 2012) for seabirds sighted (defined as one or more birds of the same species) in the study area between 1957 and 2011 (inclusive). The open access database contained approx. 35 000 at-sea records. Dates of sightings were used to identify temporal peaks in abundance. To estimate relative square abundance of species, we examined the relative occurrence of sightings in 2° × 2° grid squares. High-use squares were defined as those where the number of sightings was greater than the 90th percentile and the square with the largest number of sightings was identified as a potential assembly site. Some of the sightings were of species that are resident on Ascension Island e.g. Sooty Terns Onychoprion fuscatus (Hughes, 2014). To calculate foraging range (i.e. the distance from Ascension Island to where these seabirds were seen), we used the coordinates of each location and a geodetic distance calculator.

2.3. Land-based observations

To identify the direction of flight used most frequently by foraging seabirds that breed on Ascension Island, diurnal sea watches were conducted during field seasons between 1988 and 2012 (inclusive) (Hughes, 1994, 2014). Between 1990 and 1994 (inclusive) 12 headlands or prominent points with good seawards' views at regular intervals of approx. 5 km around the island were monitored at dawn (0700–0800 h GMT) and at dusk (1830–1930 h GMT). To ensure seabird movements were monitored at first and last light when many tropical seabird species are known to depart from, and return to, the colony (Lewis et al., 2004), teams of two or three people equipped with one or more 20–75× spotting scopes camped overnight at the sites. When congregations of birds generally moving in the same direction were observed, the observation sites were noted and later re-visited. In April 1994 three sites were re-visited and seabird movements were studied more closely by a larger team of four sea watchers (RCD unpubl. data) using standardised counts of seabirds in alternate 5-min periods throughout the hours of daylight (0700–1925 h GMT).

An analysis of the data revealed peak times of passage. Sea-watch effort then focused on the peak period from 1700 h GMT until last light (1910 ± 0015 h GMT). Between 1988 and 2012 (inclusive) more than 600 5-min timed counts and details of flight directions of seabirds returning to the island were recorded. The rate of passage was calculated as the number of birds flying past the sea-watch site per hour. First appearance directions at two sites were measured with a service pattern

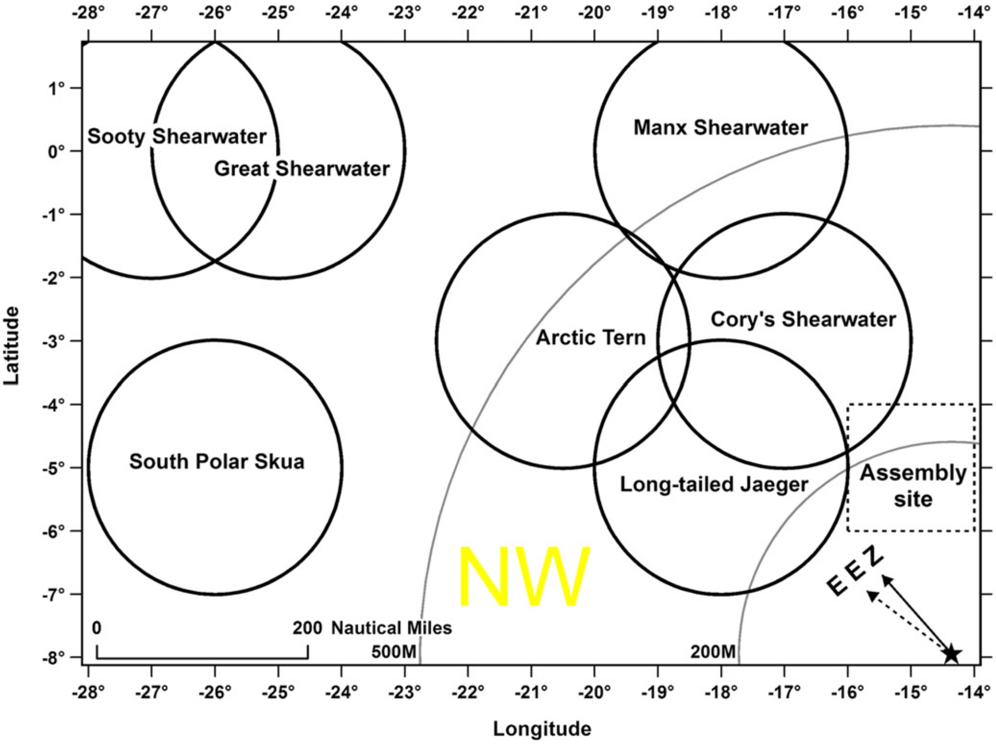

Fig. 2. Summary of distributions of seabird species in waters north-west (NW) of Ascension Island (star) in the South Atlantic. Shown is the distribution of centroids (i.e. the intersection of north- and southbound migratory flyways) of trans-equatorial migrant species and of equator/longitude (i.e. the longitude position when crossing the equator) of migrants that only use the centre of the tropical Atlantic when migrating in a southerly direction. Also shown is the $2^\circ \times 2^\circ$ grid square of the likely assembly site, study area boundary (i.e. 500 M), the Ascension Island Exclusive Economic Zone (EEZ, i.e. 200 M) and the first appearance directions of Sooty Terns (solid arrowed line), and Black Noddies and Masked Boobies (dashed arrowed line) returning to the island.

prismatic compass (Lawrence and Mayo, London, UK). To enable the direction to be plotted the bearing was converted by subtracting the magnetic variation (i.e. 17°, annual change 7′E—DGMS, 1992).

3. Results

3.1. Distributions of species from published tracking data

We found that centroids of the trans-equatorial migrant Long-tailed Jaegers *Stercorarius longicaudus* (Gilg et al., 2013), Arctic Terns (Egevang et al., 2010) and Cory's Shearwaters (González-Solís et al., 2007) were located in the NW segment of the study site (Fig. 2). Centroids of the Sooty Shearwater, as shown in Fig. 2 of Hedd et al. (2012), were situated 200 M north-west of the NW segment but northern migratory tracks of two birds (or 11%) passed through the segment. Centroids of South Polar Skuas *Catharacta maccormicki* (Kopp et al., 2011) were situated 200 M west of the NW segment.

Equator/longitude positions of Great Shearwaters *Puffinus gravis* (Martin and Ronconi, 2010) and Manx Shearwaters (as shown in Fig. 4 of Guilford et al., 2009) on their southbound migration are also shown in Fig. 2. We had insufficient data to identify the equator/longitude position of Leach's Storm Petrels. No equator/longitudes or centroids were identified in other segments of the study area. Two trans-equatorial shearwater species stopover in the northern half of our study area: 5–10 days in the case of Manx Shearwaters (as shown in Fig. 4 of Guilford et al., 2009) and one of five Cory's Shearwaters as a seasonal resident (as shown in Fig. 4(c) of González-Solís et al., 2007).

3.2. Distributions of species from at-sea watches

Between 1957 and 2011 (inclusive), 156 sightings of 37 pelagic seabird species were recorded by the Royal Navy between 50 and 500 M from Ascension Island. They occurred predominantly in either April or November (Fig. 3). Sightings were clumped with 74 or 48% of them recorded in just four high-use squares (Fig. 4). One third (i.e. 53 or 34%) of sightings were of tropical seabirds that are known to breed on Ascension Island and species that were seen on at least two occasions were Sooty Terns ($n = 10$), Band-rumped Storm-petrels *Oceanodroma castro* ($n = 7$), Masked Boobies *Sula dactylatra* ($n = 5$), Brown Noddies *Anous stolidus,* Ascension Frigatebirds *Fregata aquila* and Red-billed Tropicbirds *Phaethon aethereus* ($n = 3$ for each). Two thirds of the sightings were of long-distance migrants (102 or 65% of the total number of sightings). The most

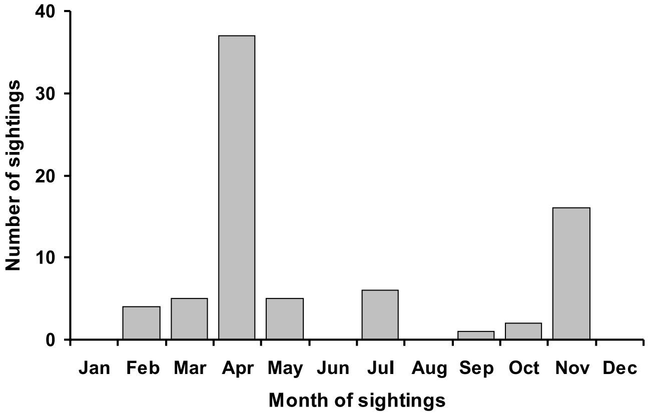

Fig. 3. Distribution of monthly sightings of one or more individuals of the same seabird species using the high seas north-west of Ascension Island in the tropical South Atlantic. Sightings are derived from the RNBWS' at-sea sightings database collated between 1957 and 2011 (inclusive).

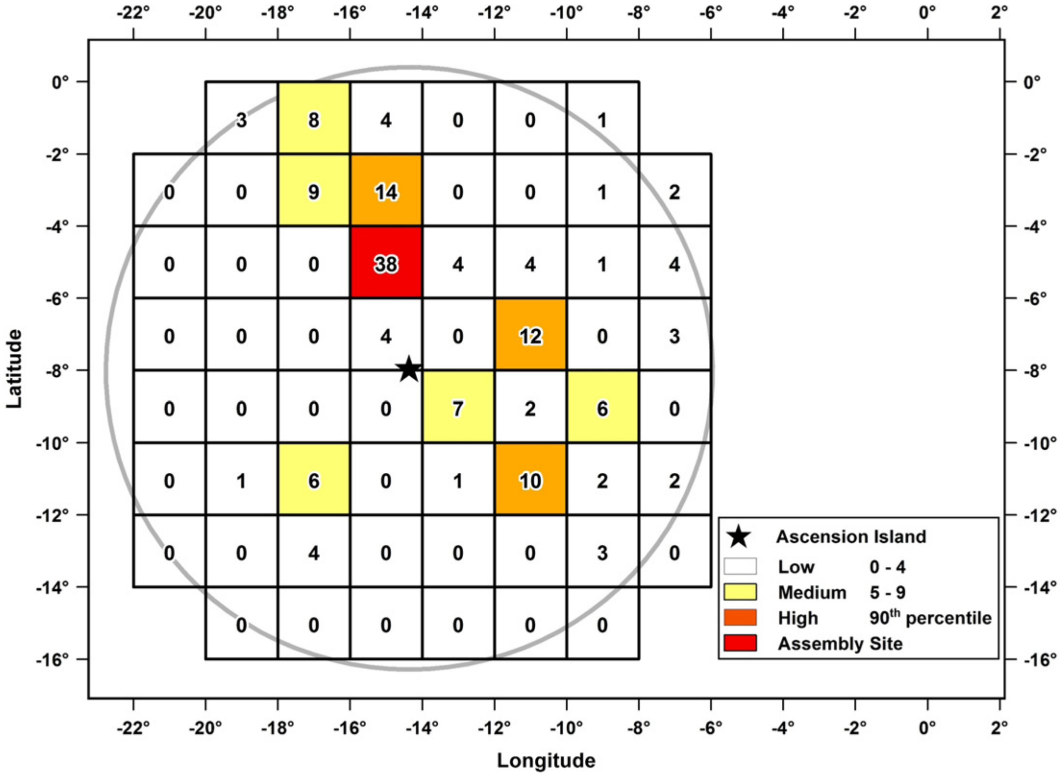

Fig. 4. At-sea sightings by the RNBWS of one or more seabirds of the same species in the middle of the tropical Atlantic Ocean between 1957 and 2011 (inclusive) throughout the study area. The four sighting classes were defined as 'low' (0–4 sightings), 'medium' (5–9 sightings), 'high' (>90th percentile) and 'potential assembly sites' (highest number of sightings).

highly-used square (i.e. the potential assembly site of $n = 38$ sightings; Fig. 4) was partly within Ascension EEZ waters and was 14–16°W and 4–6°S north–north-west (N–NW) of Ascension Island. The mean distance between Ascension Island and a sample of seabirds known to roost on Ascension Island (Bourne and Simmons, 2001) but seen in the potential assembly site was 453 ± 90 (±95% CL) km (range: 217–697 km, $n = 12$).

3.3. Flight direction of species from observations on land

In 1994 two distinct flyways used by seabirds breeding on Ascension Island were identified heading away from the island towards the NW segment. No flyways were identified in the NE, SE or SW segments of the study area. Flyways were observed from the west side and north-west corner of the island (Fig. 5). Of the 10 954 seabirds that were identified using the flyway

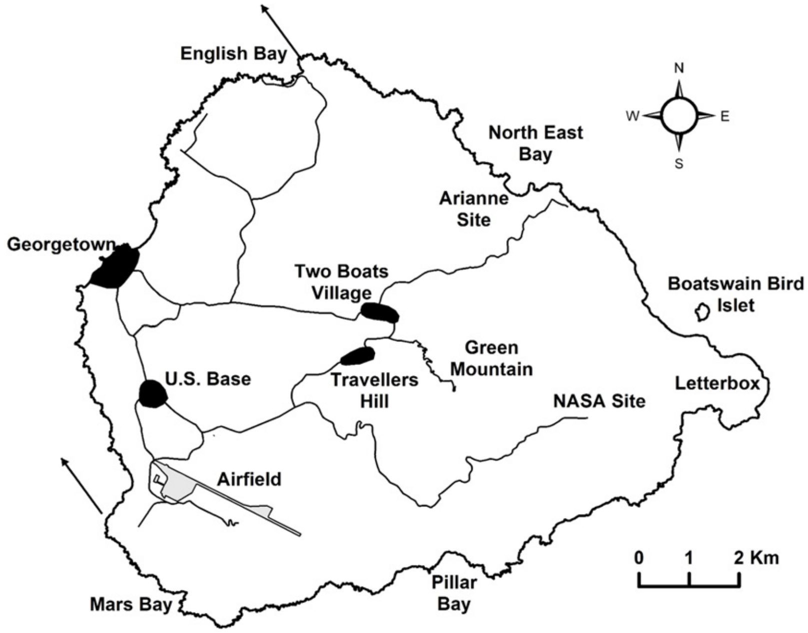

Fig. 5. Mean direction of flight (arrows) used by nesting seabirds on Ascension Island in the South Atlantic. Direction of flight is for Sooty Terns nesting at Mars and Pillar Bays, and for Masked Boobies and Black Noddies nesting on Boatswain Bird Islet and Letterbox.

on the west side of the island, 9254 (or 84%) were Sooty Terns. In contrast, of the 8822 that were identified from the north-west corner of the island, 4286 (or 49%) were Black Noddies *Anous minutus*, 3634 (or 41%) were Masked Boobies and 902 (or 10%) were other resident seabirds (predominantly Brown Noddies). The mean first appearance bearings of Sooty Terns, and of Black Noddies and Masked Boobies returning to the island were 312 ± 4° ($n = 7$) and 304 ± 7° ($n = 9$) from true north, respectively (Fig. 2). The highest rate of passage by seabirds along the flyways was represented by birds returning to the island towards dusk and continued after dark. From timed counts between 1988 and 2012 (inclusive), the mean rate of passage after 1800 h GMT was 1 650 ± 400 birds per hour for Sooty Terns ($n = 6$ timed observations), 800 ± 276 for Black Noddies ($n = 324$) and 950 ± 456 for Masked Boobies ($n = 273$). The mean rate of passage of these three species along the flyways between 1800 and 1900 h GMT was >3400 birds per hour. We detected no tail off in the rate of passage at last light.

3.4. *Assembly site*

Three independent datasets (i.e. migratory tracks of seabirds, at-sea records and on-land counts of seabirds) provided evidence of an assembly site in the NW sector, potentially at 14–16°W and 4–6°S (Fig. 2). Indicators that this location is likely to be an assembly site are that (1) two or more individuals of 20 species co-occurred in the site on two or more occasions (Croxall et al., 2012), (2) multiple seabird species were recorded in the site between 1957 and 2012 (inclusive) with peak aggregations occurring in two months of the year (i.e. April and November, Fig. 3) (Lascelles et al., 2012), (3) more than 3 400 tropical seabirds from Ascension returned from the direction of the site daily (BirdLife International, 2010), and (4) the species recorded in the assembly site breed in the four distinct geographical regions represented by the Arctic, the Antarctic, at mid-latitudes and on tropical Islands (Harrison, 1983, Table 2).

4. Discussion

Our results suggest that a non-breeding assembly site (i.e. a location in which there is a co-occurrence of individuals of several species in time and space) for pelagic seabirds is located in waters North–North West (N–NW) of Ascension Island in the South Atlantic Ocean. The focal point of the likely assembly site is a 2° × 2° grid square at 14–16°W and 4–6°S some 200 M from Ascension Island. Migratory tracks of seabirds, and at-sea and on-land counts of seabirds all indicate that the NW segment of our study area is used more intensely by trans-equatorial migrants and by resident species from Ascension Island than waters to the south or to the east of Ascension Island (Fig. 2). Of the 20 species recorded on at least two occasions at the assembly site, eight (40%) were tropical seabird species known to breed on Ascension Island. The breeding locations of trans-equatorial migrants recorded at the assembly site were split equally between the Arctic, Antarctic and mid-latitude regions with four species (20%) breeding in each region (Table 2). At-sea records suggest that the assembly site is used most months of the year but with peaks during migration in April and November. Our findings are important because to the best of our knowledge no seabird assembly sites have previously been identified in pelagic waters around Ascension Island.

Table 2
Breeding locations of pelagic seabird species recorded on two or more occasions in the assembly site at 14–16°W and 4–6°S N–NW of Ascension Island, South Atlantic.

Arctic	Antarctic	Mid-latitude	Tropical Islands
Long-tailed Jaeger *Stercorarius longicaudus*	Great Shearwater *Puffinus gravis*	Cory's Shearwater *Calonectris diomedea*	Red-footed Booby *Sula sula*
Parasitic Jaeger *Sterocorarius parasiticus*	Sooty Shearwater *Puffinus griseus*	Leach's Storm Petrel *Oceanadroma leucorhoa*	Masked Booby *Sula dactylatra*
Pomarine Skua *Stercorarius pomarinus*	White-bellied Storm Petrel *Fregetta grallaria*	Bulwer's Petrel *Bulweria bulwerii*	Ascension Frigatebird *Fregata aquila*
Arctic Tern *Sterna paradisaea*	Wilson's Storm Petrel *Oceanites oceanicus*	Common Tern *Sterna hirundo*	Red-billed Tropicbird *Phaethon aethereus*
			Sooty Tern *Onychoprion fuscatus*
			Black Noddy *Anous minutus*
			Brown Noddy *Anous stolidus*
			Band-rumped Storm-petrel *Oceanodroma castro*

4.1. Food availability and wind direction

Seabird assembly sites can be explained by food availability and we predict that the waters in local areas along the South Equatorial Current in the NW segment and possibly in the vicinity of the Circe Seamount may be more productive for seabirds that forage at higher trophic levels than the waters elsewhere in the tropical Atlantic Ocean (Bourne and Simmons, 2001). Leatherback Turtles *Dermochelys coriacea* that also feed at high trophic levels regularly use this NW segment (e.g. Fossette et al., 2014) while other taxa at lower trophic levels (e.g. Whale Sharks *Rhincodon typus*—Hueter et al., 2014) also appear to migrate to these waters to give birth. Migrating skuas (e.g. dark phase Parasitic Jaeger—BJH unpubl. data from 1990, Great Skuas—Simmons unpubl. field notes from 1997 and Pomarine Skuas—Bourne and Simmons, 1998) also find food in waters close to Ascension Island and are recorded targeting terns for kleptoparasitism. Some upwelling occurs at approx. 01$^1/_2$°S, 16°W where a ridge crest (Fig. 1) intersects the Romanche and Chain FZs (Mercier and Morin, 1997) and this may result in a local area of higher productivity.

Shearwaters and other trans-equatorial migrants are highly dependent on strong winds to fly effectively and often rest on the water when there is no wind (Furness and Bryant, 1996). A belt of calms and light winds (the doldrums; Fig. 1) borders the northern edge of the study area (Grodsky and Carton, 2003). During periods of calm Dias et al. (2012) showed that Cory's Shearwaters have the ability to stopover and wait for the wind to strengthen. During the months of September and October monsoon near-surface westerlies in the northern sector of the ITCZ (Fig. 1) delayed Cory's Shearwaters in transiting the equator with some stopping over and waiting for a change in wind direction (Felicísimo et al., 2008). The assembly site at the intersection of north- and southbound migratory flyways may well be a stopover point where Cory's and Manx Shearwaters (Guilford et al., 2009), and other trans-equatorial migrants wait for stronger winds or a change in wind direction.

4.2. Evidence to support the identification and location of our assembly site

General support for our findings was provided by Bourne and Simmons (2001) and Kampp (2001) who reported that counts of seabirds in the vicinity of the equator were 100 and 17 times higher, respectively, than in a comparable area to the south of Ascension Island. A notable scarcity of seabirds south of Ascension Island was also noted by Rowlands (1992). Seabird tracking shows birds crossing the NW segment which are matched by at-sea observations of the same species in the same area, such as in the cases of Cory's Shearwaters and Long-tailed Jaegers (González-Solís et al., 2007; RNBWS, 2012; Gilg et al., 2013). Furthermore, Great Shearwaters were observed by Bourne (1995) and also tracked by Martin and Ronconi (2010) in the NW segment. The flight directions that we monitored on Ascension Island were first identified by Blair (1989) and confirmed by Bourne and Simmons (2001). They are the likely start of flyways that extend from Ascension Island some 200 M in the north-westerly direction towards the assembly site (Fig. 2).

Assembly sites have not been identified from tracking of seabirds breeding on Ascension Island (e.g. Sooty Terns—SJR unpubl. data, Masked Boobies—Eaton et al., 2013). Furthermore, there are biases in at-sea survey data as they are not standardised because there was no measure of search effort or records of ship movements in the four quadrants under study. Thus, they generate purely descriptive data that cannot be subjected to rigorous statistical analysis. Nevertheless, although data from migratory flyways, and at-sea and land-based sea watches when taken in isolation may poorly identify an assembly site, when combined the results are stronger than the sum of the parts (Louzao et al., 2009). Therefore, our findings should be considered as important observations that will inform more systematic censusing efforts in this area of the South Atlantic Ocean to estimate seabird and other marine species' abundance. However, it should be recognised that this is a major undertaking as Ascension Island is geographically remote and facilities on the island are limited.

The key findings of this study are: (1) waters to the north-west of Ascension Island are more highly used by pelagic seabirds than those to the south or the east of the island; (2) the assembly site that we have identified for seabirds is partly within the EEZ of Ascension Island; (3) three-fifths of seabird species recorded at the assembly site on two or more occasions breed at mid- or high-latitudes; and (4) some migratory seabirds are seasonal residents in the NW segment and others stopover for seven or more days possibly to wait for favourable winds to facilitate north- or southbound migrations. The likely assembly site that we have identified for seabirds provides evidence in support of the establishment of an ocean sanctuary at Ascension Island. Our results are likely to supplement ongoing research by the RSPB and the Ascension Island Government tracking Masked Boobies and Ascension Frigatebirds (Bolton and Oppell, 2014). Ours are initial findings but clearly indicate that at-sea surveys of seabirds (Boertmann, 2011) and other marine species in waters N–NW of Ascension Island are a vital step towards the establishment of the ocean sanctuary. Vessels involved in the new fishery at Ascension Island (House of Commons EAC, 2014) could provide an important platform for further research in this regard.

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