*Diversity and Distributions*

**SUPPORTING INFORMATION**

**It is the time for oceanic seabirds: tracking year-round distribution of gadfly petrels across the Atlantic Ocean**

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**Tracking data, filtering and its associated modelling.** Tracking data were gathered from diverse tracking devices (Table S1). PHAS breeding individuals were equipped with solar-powered Platform Terminal Transmitters (PTT; Table S1 for device details). Solar PTTs were attached to the back of birds using 4 subcutaneous sutures and a small amount of glue, and weighed 9.5 g, which corresponded to 2.2–2.5% of bird body mass (<4% of adult mass; Passos *et al.*, 2010). PTTs collected locations on a duty cycle of 8 h on followed by 24 h off, registered 1,642 locations during 488 bird-tracking days, and 45% of locations were accurate to < 1,500 m. For all other petrels in this data set, Global Location Sensor (GLS) tags (referred simply as geolocators) with a variety of characteristics (Table S1) were leg-mounted on breeding adults incubating an egg or rearing a chick. British Antarctic Survey (BAS) geolocators provide two positions per day (local midday and midnight), and are estimated from recorded light data using BASTrak software suite (British Antarctic Survey, 2008). We estimated dawn and dusk times by inspecting the integrity of each light curve; latitude was derived from daylength, and longitude from the time of local midday with respect to Greenwich Mean Time. For this analysis, we used a light threshold of 20 and sun angles (ranging from -4.7º to -3.5º) were selected for each species by visually inspecting bird positions during periods when breeding birds are presumed to be near the colony (Table 1). Lotek geolocators functioned on a similar principle to BAS geolocators, but incorporated on-board processing of the light data to compute latitude and longitude (one location per day). We excluded long periods spent in burrows during incubation, based on light data recorded by the logger. Accuracy of spatial data gathered from geolocators is rather low, with an average error of ~200 km (or ~ 2°; Phillips *et al.*, 2004).

First, in order to homogenise our dataset, raw spatial positions from PTTs of PHAS were simplified to two positions per day (computed as averaged coordinates of the 5% UDs of every 12-hour period of each track). Second, to filter unrealistic positions, we removed those that were (1) obtained from light curves showing interference at dawn or dusk (GLS); (2) within the 20 closest days to the equinoxes (GLS); and (3) that resulted in unrealistic flight speeds (>40 km h-1 sustained over 48 h; GLS and PTT) using user-defined routines written in R (R Development Core Team, 2010). Finally, filtered data were re-discretized twice by interpolating intermediate fixes between successive locations with fixed start and end points around any periods of missing data (Freitas et al., 2008).

Kernel Density Estimations (KDEs; “kernelUD” function in the adehabitat v.1.8.7 package in R; Calenge, 2006) were used with diverse datasets along the analyses. For such KDEs, we assumed a smoothing factor of *h* = 200, which corresponds to the average accuracy of geolocation in km (Phillips *et al.*, 2004). Different Utilization Distributions (UDs) from kernel analysis were used along the analysis: 5% UDs were used to estimate the centroids of the non-breeding ranges for each species, 50% UDs were used as proxies of core areas of the habitat used by individuals or species within a given period (Lascelles *et al.*, 2016), and 95% UDs were used when ascertaining the potential overlap among the species.

Timing of departure and arrival of individual birds at the different breeding areas were determined visually: departure date was considered to be the first day when the bird’s location was outside the cluster of positions of the previous days that corresponded to the breeding area, followed by directed movement away from this area; and arrival date was considered to be the first day of return to the breeding region after a directed movement towards that area (Table S3). We estimated five phenological and spatial parameters for every complete migration cycle (Table S3): (1) departure date, (2) arrival date, (3) duration of the non-breeding period (in days), (4) area exploited throughout the non-breeding period (as indicated by the 50% UDs; in 106 km2), and (5) non-breeding range (orthometric distance between the breeding colony and the centroid of the 5% non-breeding UDs; in km). We used Q-Q plots to check for normality of the distributions of these variables (by species). We evaluated the effect of species on values for these non-breeding parameters by fitting a set of candidate Linear Mixed Models (LMMs), where each of the five parameters described above was the response variable, species was the main (fixed) explanatory variable (Table 2). To account for annual heterogeneity in trip parameters, year of sampling was included in all LMMs as a random term. Gaussian distribution of error terms and an identity-link function were used in the modelling. LMMs were conducted in R version 2.8.1 (R Development Core Team 2010) with additional functions provided by the R packages ‘lme4’ (lmer; Bates *et al.*, 2008) and ‘MuMIn’ (dredge; Bartoń, 2009).

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**Table S1.** Manufacturer and deployment details of the tracking devices used on each of the eight gadfly petrel species we considered, and publication history.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Type | Models | Manufacturer | Attachment method | Weight\* (in g) | % of bird's body mass | Prior publication |
| PMAD | Geolocator | Mk14 | British Antarctic Survey | Metal ring | 1.5 | 0.7 | Ramos *et al.* (2016) # |
| PDES | Geolocator | Mk14 | British Antarctic Survey | Metal ring | 1.5 | 0.3 – 0.6 | Ramírez *et al.* (2015)  |
| PCAH | Geolocator | LAT2500 | Lotek Wireless | Plastic ring | 6.5 | 1.7 | New |
| PHAS | Satellite tag | PTT-9.5 GS | North Star | Sutures | 10 | 2.2 – 2.5 | Jodice *et al.* (2016) |
| PFEA | Geolocator | Mk9, Mk18-H, Mk19, Mk3005 | British Antarctic Survey, Biotrack | Plastic ring | 1.5 – 2.5 | 0.5 – 0.9 | Ramos *et al.* (2016) # |
| PARM | Geolocator | Mk3005 | Biotrack | Metal ring | 3.0 | 0.6 – 0.9 | New |
| PINC | Geolocator | Mk13, Mk14, Mk18-L | British Antarctic Survey | Plastic ring | 1.5 | 0.4 | New |
| PMOL | Geolocator | Mk13, Mk14 | British Antarctic Survey | Plastic ring | 1.5 | 0.8 | New |
| \* including the attachment method# partial prior publication with smaller sample size |  |  |  |  |  |  |

**Table S2.** Values obtained from the analysis of representativeness of the tracking datasets of gadfly petrels (*Pterodroma* spp.) split by species and period. As an example to illustrate its usefulness, a given representativeness index of 80% would mean that at least 50% of the population uses that area defined by the 50% UD from the kernel analysis (Lascelles et al., 2016). BirdLife International considers indices of a dataset below 80% (depicted in bold in the table) to be not representative of the spatial variability of the wider population, and therefore, not suitable for IBAs delineation (BirdLife International, 2010).

|  |  |  |
| --- | --- | --- |
| Species  | Period | Representativeness value (%) |
| PMAD | Breeding | 94.4 |
|  | Non-breeding | 80.3 |
| PDES | Breeding | 99.0 |
|  | Non-breeding | 92.0 |
| PCAH | Breeding | 88.0 |
|  | Non-breeding | **68.9** |
| PHAS | Breeding | n.a. |
|  | Non-breeding | n.a. |
| PFEA | Breeding | 96.9 |
|  | Non-breeding | 96.8 |
| PARM | Breeding | 93.7 |
|  | Non-breeding | 89.0 |
| PINC | Breeding | 95.8 |
|  | Non-breeding | 94.0 |
| PMOL | Breeding | n.a. |
|   | Non-breeding | n.a. |

**Table S3.** Migration characteristics (mean ± SD, and range in parentheses) of the eight gadfly petrels that breed in the Atlantic Ocean. For each species, “Total” refers to total number of migrations tracked.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Year | n | Colony departure date | Colony arrival date | Duration of the non-breeding period (days) |  Area of the non-breeding period (106 km2) | Distance from colony (km) |
| PMAD | 2007 | 2 | 12 Oct ± 0.7(12 Oct|13 Oct) | 29 Feb ± 0.0(29 Feb|29 Feb) | 137.5 ± 0.7(137|138) | 0.5 ± 0.0(0.5|0.5) | 2891 ± 1743(1659|4124) |
|  | 2008 | 3 | 21 Oct ± 9.7(13 Oct|01 Nov) | 25 Mar ± 24.8(26 Feb|09 Apr) | 155.3 ± 34.2(116|178) | 1.2 ± 1.3(0.4|2.7) | 2529 ± 1210(1791|3926) |
|  | 2009 | 3 | 17 Oct ± 4.4(12 Oct|20 Oct) | 16 Mar ± 28.9(29 Feb|19 Apr) | 149.7 ± 27.4(130|181) | 1.5 ± 1.7(0.2|3.4) | 3748 ± 1779(2027|5579) |
|  | 2014 | 4 | 16 Oct ± 5.4(11 Oct|24 Oct) | 12 Mar ± 26.2(28 Feb|21 Apr) | 146.2 ± 27.0(126|186) | 0.9 ± 1.2(0.2|2.6) | 2884 ± 1065(1909|3808) |
|  | 2015 | 3 | 21 Oct ± 7.0(14 Oct|28 Oct) | 17 Mar ± 28.6(29 Feb|19 Apr) | 146.0 ± 22.7(130|172) | 1.1 ± 1.4(0.2|2.7) | 3132 ± 1186(1764|3870) |
|  | **Total** | **15** | **18 Oct ± 6.3****(12 Oct|02 Nov)** | **15 Mar ± 23.0****(26 Feb|21 Apr)** | **147.5 ± 23.1****(116|186)** | **1.1 ± 1.1****(0.2|3.4)** | **3036 ± 1224****(1659|5579)** |
| PDES | 2008 | 5 | 02 Dec ± 11.2(16 Nov|12 Dec) | 08 Jun ± 9.7(27 May|18 Jun) | 188.2 ± 18.9(166|214) | 1.9 ± 1.1(0.4|3.3) | 4660 ± 1943(2000|7477) |
|  | 2009 | 10 | 29 Nov ± 14.4(11 Nov|29 Dec) | 30 May ± 7.1(23 May|11 Jun) | 181.0 ± 10.0(163|193) | 3.6 ± 3.8(0.5|13.6) | 5252 ± 2571(1073|7674) |
|  | 2010 | 15 | 04 Dec ± 17.7(30 Oct|09 Jan) | 31 May ± 10.0(18 May|30 Jun) | 177.4 ± 15.0(141|208) | 2.8 ± 1.7(0.4|5.9) | 5217 ± 1989(1969|7850) |
|  | 2011 | 19 | 05 Dec ± 25.1(22 Oct|27 Jan) | 07 Jun ± 14.7(20 May|04 Jul) | 182.7 ± 19.1(149|214) | 2.8 ± 2.1(0.4|8.5) | 5161 ± 2039(1352|7539) |
|  | 2012 | 8 | 20 Nov ± 16.7(25 Oct|12 Dec) | 26 May ± 11.3(02 May|09 Jun) | 187.0 ± 14.4(172|218) | 1.9 ± 1.5(0.4|4.6) | 5075 ± 2301(1794|7331) |
|  | **Total** | **57** | **25 Oct ± 100.5****(05 Jan|30 Dec)** | **02 Jun ± 12.1****(02 May|04 Jul)** | **182.1 ± 15.9****(141|218)** | **2.8 ± 2.3****(0.4|13.6)** | **5136 ± 2084****(1073|7850)** |
| PCAH | 2009 | 6 | 04 May ± 44.5(19 Apr|21 Jun) | 18 Oct ± 23.1(03 Sep|04 Nov) | 165.3 ± 44.9(134|254) | 1.0 ± 0.7(0.2|2.3) | 1881 ± 1232(545|3194) |
|  | 2010 | 1 | 27 May | 30 Oct | 155 | 0.6  | 642 |
|  | **Total** | **7** | **09 May ± 36.8****(23 Feb|07 Jun)** | **19 Oct ± 21.5****(03 Sep|04 Nov)** | **163.9 ± 41.2****(134|254)** | **0.9 ± 0.7****(0.2|2.3)** | **1704 ± 1218****(545|3194)** |
| PHAS | 2014 | 3 | 13 Jun ± 31.7(08 May|07 Jul) | 02 Nov\* | 95.7 ± 70.5(52|177) | 0.4 ± 0.2(0.2|0.6) | 1590 ± 231(1411|1851) |
|  | **Total** | **3** | **14 Jun ± 31.7****(09 May|08 Jul)** | **02 Nov** | **177** | **0.4 ± 0.2****(0.2|0.6)** | **1590 ± 231****(1411|1851)** |
| PFEA | 2007 | 3 | 07 May ± 18.4(17 Apr|23 May) | 02 Sep ± 0.6(02 Sep|03 Sep) | 117.0 ± 19.0(101|138) | 0.3 ± 0.2(0.2|0.6) | 478 ± 176(287|634) |
|  | 2008 | 2 | 09 May ± 30.4(18 Apr|31 May) | 02 Sep ± 0.0(02 Sep|02 Sep) | 114.5 ± 30.4(93|136) | 0.4 ± 0.2(0.2|0.5) | 804 ± 116(721|886) |
|  | 2009 | 2 | 29 May ± 26.9(10 May|17 Jun) | 31 Aug ± 2.8(29 Aug|02 Sep) | 93.0 ± 24.0(76|110) | 0.4 ± 0.2(0.3|0.6) | 660 ± 153(551|769) |
|  | 2011 | 1 | 12 Apr | 02 Sep | 142 | 0.3 | 866 |
|  | 2012 | 4 | 19 Apr ± 5.9(09 Apr|29 Apr) | 05 Sep ± 0.3(02 Sep|08 Sep) | 145 ± 0.5(135|155) | 0.3 ± 0.1(0.2|0.4) | 701 ± 224(469|1005) |
|  | 2013 | 1 | 30 May | 02 Sep | 94 | 0.2 | 789 |
|  | 2014 | 1 | 10 Apr | 11 Nov | 214 | 0.4 | 716 |
|  | **Total** | **14** | **01 May ± 24.4****(10 Apr|18 Jun)** | **06 Sep ± 18.8****(29 Aug|11 Nov)** | **128.3 ± 34.3****(76|214)** | **0.3 ± 0.1****(0.2|0.6)** | **681 ± 186****(287|1005)** |
| PARM | 2014 | 9 | 06 Aug ± 6.8(30 Jul|17 Aug) | 17 Feb ± 9.3(02 Feb|01 Mar) | 193.3 ± 12.2(178|210) | 6.1 ± 1.9(2.3|8.4) | 5336 ± 571(4536|6184) |
|  | 2015 | 2 | 09 Jul ± 15.6(29 Jun|20 Jul) | 06 Feb ± 4.9(03 Feb|10 Feb) | 210.5 ± 10.6(203|218) | 10.0 ± 1.7(8.8|11.2) | 4808 ± 176(4683|4933) |
|  | **Total** | **11** | **02 Aug ± 13.8****(29 Jun|18 Aug)** | **15 Feb ± 9.5****(02 Feb|29 Feb)** | **196.5 ± 13.4****(178|218)** | **6.8 ± 2.4****(2.3|11.2)** | **5240 ± 557****(4536|6184)** |
| PINC | 2010 | 6 | 01 Dec ± 30.2(12 Oct|23 Dec) | 27 Mar ± 21.6(29 Feb|13 Apr) | 115.3 ± 11.2(108|138) | 1.4 ± 0.8(0.5|2.5) | 3378 ± 453(2621|3746) |
|  | 2011 | 5 | 01 Dec ± 33.8(23 Oct|21 Dec) | 01 Apr ± 27.2(01 Mar|18 Apr) | 120.3 ± 6.7(116|128) | 1.4 ± 0.3(1.1|1.6) | 3501 ± 402(3049|3821) |
|  | 2012 | 4 | 15 Nov ± 39.9(12 Oct|23 Dec) | 23 Mar ± 26.6(29 Feb|17 Apr) | 127.5 ± 13.3(115|139) | 1.0 ± 0.5(0.4|1.6) | 3373 ± 332(3029|3708) |
|  | **Total** | **15** | **27 Nov ± 32.1****(13 Oct|24 Dec)** | **27 Mar ± 22.5****(29 Feb|18 Apr)** | **120.2 ± 11.6****(108|139)** | **1.3 ± 0.6****(0.4|2.5)** | **3405 ± 378****(2621|3821)** |
| PMOL | 2010 | 1 | 10 Apr | 17 Aug | 128 | 1.1 | 5127 |
|  | 2011 | 1 | 11 May | 13 Nov | 185 | 2.5 | 5061 |
|  | 2012 | 1 | 20 May | 03 Nov | 166 | 0.8 | 4900 |
|  | **Total** | **3** | **04 May ± 21.0****(11 Apr|21 May)** | **11 Oct ± 48.2****(17 Aug|13 Nov)** | **159.7 ± 29.0****(128|185)** | **1.5 ± 0.9****(0.8|2.5)** | **5029 ± 116****(4900|5127)** |

\* only one PHAS has a complete migration track. For the other two birds, signal was lost at the end of the non-breeding period.

**Figure S1**. Annual phenologies of the eight species of gadfly petrels that breed in the Atlantic Ocean (breeding in orange, migrating in grey and non-breeding in blue). PARM breeds year-round, but only sampled birds breeding from Feb–Aug are illustrated here.