Foraging Far from Home: Gps-Tracking of Mediterranean Storm-Petrels Hydrobates pelagicus melitensis Reveals Long-Distance Foraging Movements

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Research Papers

FORAGING FAR FROM HOME: GPS-TRACKING OF MEDITERRANEAN STORM-PETRELS *HYDROBATES PELAGICUS MELITENSIS* REVEALS LONG-DISTANCE FORAGING MOVEMENTS

ALIMENTÁNDOSE LEJOS DE CASA: EL SEGUIMIENTO POR GPS DEL PAÍÑO MEDITERRÁNEO *HYDROBATES PELAGICUS MELITENSIS* REVELA MOVIMIENTOS A GRANDES DISTANCIAS

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Summary.—Identifying important foraging areas is fundamental to detecting the demographic drivers of a species and ultimately to plan conservation measures. For some species, such as small pelagic seabirds, foraging grounds are difficult to locate and remain largely unknown. We used miniaturised GPS devices (~0.95g) to study foraging movements of Mediterranean Storm-petrels *Hydrobates pelagicus melitensis* during the incubation period. A total of 43 individuals at Benidorm colony (south-western Mediterranean Sea) were tracked during a single foraging trip. We first assessed potential negative effects of the tracking devices. We recorded 22 complete foraging trips and measured home-range, foraging areas and the degree of overlap among individuals. We used first passage time analyses (FPT) to differentiate foraging/resting from flying/travelling activities and to infer potential foraging areas. All tracked birds returned to the colony. On average, individual body weight slightly decreased after foraging trips, suggesting a small immediate negative effect of the device. Tracked birds had high breeding success (0.71). Foraging trips lasted between 1 and 4.5 days with the total distance travelled ranging between 303.14 and 1,726.53km. The visited areas covered the whole south-western part of the Mediterranean Sea. Tracked individuals shared more than 50% of their home-range areas. Foraging areas were located further from the colony than previously thought (from 240 to 469km away) on deep

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sea areas of the Alboran Sea and Cartagena Canyons. Further studies are needed to locate foraging grounds during other life-cycle periods and to evaluate repeatability yearly, in order to determine the important marine areas for the species.—Rotger, A., Sola, A., Tavecchia, G. & Sanz-Aguilar, A. (2021). Foraging far from home: GPS-tracking of Mediterranean Storm-petrels *Hydrobates pelagicus melitensis* reveals long-distance foraging movements. *Ardeola*, 68: 3-16.

Key words: ARS behaviour, foraging areas, home range, mediterranean, procellariiform, seabird, utilisation distribution.

RESUMEN.—Identificar las principales áreas de alimentación es fundamental para detectar los factores demográficos de una especie y, en última instancia, para planificar medidas de conservación. Para algunas especies, como las aves marinas pelágicas de pequeño tamaño, las zonas de alimentación son difíciles de localizar y siguen siendo en gran medida aún desconocidas. En este trabajo utilizamos dispositivos GPS miniaturizados (~0,95 g) para estudiar los movimientos de búsqueda de alimento del paíño europeo mediterráneo *Hydrobates pelagicus melitensis* durante el período de incubación. Se marcó un total de 43 individuos de la colonia de la isla de Benidorm (suroeste del mar Mediterráneo) durante un único viaje de alimentación. En primer lugar, evaluamos los posibles efectos negativos que podían tener los dispositivos de seguimiento. Registramos un total de 22 viajes completos de alimentación y medimos el área de distribución, las áreas de alimentación y el grado de superposición entre los viajes de cada individuo. Utilizamos análisis del primer tiempo de paso (FPT) para diferenciar las actividades de alimentación/descanso de las actividades de vuelo/viaje y así poder inferir en las posibles áreas de alimentación. Todos los pájaros que fueron equipados con GPS regresaron a la colonia. En promedio, el peso corporal individual disminuyó ligeramente después de los viajes de alimentación, lo que sugiere un pequeño efecto negativo inmediato del dispositivo. Las aves estudiadas tuvieron un alto éxito reproductor (0,71). Los viajes de forrajeo duraron entre 1 y 4,5 días con una distancia total recorrida entre 303,14 y 1.726,53 km. Las áreas visitadas cubrieron toda la parte suroeste del mar Mediterráneo. Los individuos estudiados compartieron más del 50% de sus áreas de distribución. Las áreas de alimentación se ubicaron lejos de la colonia, mucho más de lo que se pensaba anteriormente (de 240 a 469 km de distancia), todas en áreas de aguas profundas del mar de Alborán y en los cañones marinos cerca de Cartagena. Es necesario realizar más estudios para localizar áreas de alimentación durante otros períodos del ciclo de vida y evaluar si existe una repetibilidad anual, a fin de determinar las áreas marinas más importantes para la especie.—Rotger, A., Sola, A., Tavecchia, G. y Sanz-Aguilar, A. (2021). Alimentándose lejos de casa: el seguimiento por GPS del paíño mediterráneo *Hydrobates pelagicus melitensis* revela movimientos a grandes distancias. *Ardeola*, 68: 3-16.

Palabras clave: áreas de alimentación, ave marina, conducta ARS, distribución de utilización, Mediterráneo, Procelariforme, rango de hogar.

INTRODUCTION

Identifying seabird foraging areas is essential to designing protected areas (Camphuysen *et al*., 2012). For many seabird species, which forage far from their breeding sites or in inaccessible places, this task may be especially challenging (Lascelles *et al*., 2012, 2016; Ronconi *et al*., 2012; Soanes *et al*., 2016; Schreiber & Burger, 2001; Oppel *et al*., 2018). Nowadays, technological advances in GPS devices have provided new insights into the spatial distribution and movement patterns of seabirds (BirdLife, 2017; Yoda, 2019), helping to identify important marine areas for many species (Camphuysen *et al*., 2012; Lascelles *et al*., 2012; Ronconi *et al*., 2012; Lascelles *et al*., 2016; Soanes *et al*., 2016). The main limitations of GPS devices are their cost and relative

weight. Although progress in miniaturisation of tracking devices has allowed the direct tracking of small-sized species (Krüger *et al*., 2017; Critchley *et al*., 2018; Oppel *et al*., 2018), foraging areas for the smallest seabirds remain unknown (Oro, 2014; Rodríguez *et al*., 2019).

This is the case for the European Storm-petrel *Hydrobates pelagicus,* the smallest European seabird. Direct observations of this species are limited due to its strictly pelagic habit (Martínez *et al*., 2019) and only the Atlantic subspecies, *H. p. pelagicus* has been tracked with GPS devices (Oppel *et al*., 2018; *Critchley et al*., 2020). Evidence from light level geolocators (GLS; deployed in *H. p. melitensis*) and GPS devices (deployed in *H. p. pelagicus*) indicated that storm-petrels moved over longer distances than previously expected (Critchley *et al.,* 2018; Oppel *et al.,* 2018; Lago *et al*., 2019). Their foraging grounds were often assumed to be within 10-100km of breeding colonies (e.g. Soldatini *et al*., 2014; Soldatini *et al*., 2016; Ramírez *et al*., 2016). So far only GLS devices have been used to study the Mediterranean subspecies (Lago *et al*., 2019), but these data loggers are less accurate than GPS devices for identifying foraging areas (Phillips *et al*., 2004). Foraging movements in other small procellariiforms, such as Leach's Storm-petrel *Oceanodroma leucorhoa*, are already well known through the use of GLS devices (Hedd *et al*., 2018). For example, Hedd *et al*. (2018) found that individuals travelled long distances during the incubation period to highly pelagic waters. However, for the Mediterranean Storm-petrel the scarce information available could result in poor overlap between important foraging grounds and the established Marine Protected Areas and Important Bird Areas (MPAs and IBAs; Arcos, 2009; Critchley *et al*., 2018).

In this study we present for the first time the foraging movements of Mediterranean Storm-petrels breeding at Benidorm Island (western Mediterranean) using GPS devices (~1g). Although the IUCN lists the entire population of the European Storm-petrel as Least Concern (BirdLife International, 2020), the Mediterranean subspecies has a more restricted distribution and much lower breeding numbers than its Atlantic relative, resulting in a higher conservation concern (Massa and Borg, 2018). Identifying their foraging areas could help to protect the species from current and future potential threats at sea: overexploitation of marine resources, oil pollution, artificial lights or offshore wind-farms (Wiese *et al*., 2001; Azkona *et al*., 2006; Arcos, 2009). Here, we first assessed the potential effects of GPS devices on return rates and breeding performance (see recommendations in Murray and Fuller, 2000). We subsequently, with the spatial data obtained, i) provided detailed information on trip characteristics, and ii) identified the main foraging areas of the Mediterranean Storm-petrel during the incubation period.

Material and methods

Study area and GPS deployment

The study was conducted at Benidorm Island (38º 30' N, 0º 08' E, Spain), one of the most important colonies of the Mediterranean Storm-petrel in the western Mediterranean (Sanz-Aguilar *et al.,* 2019). Since 1993, breeding Storm-petrels there are captured annually at their nests and marked with stainless steel rings with a unique alphanumeric code (Sanz-Aguilar *et al*., 2009; Sanz-Aguilar *et al*., 2008). The breeding success of each marked individual and accessible nest is recorded every year (see details in Sanz-Aguilar *et al*., 2009; Hernández *et al*., 2017). To minimise disturbance, prevent nest desertion and avoid GPS loss, we equipped only experienced birds (i.e. those known to have bred at least once in previous years) with

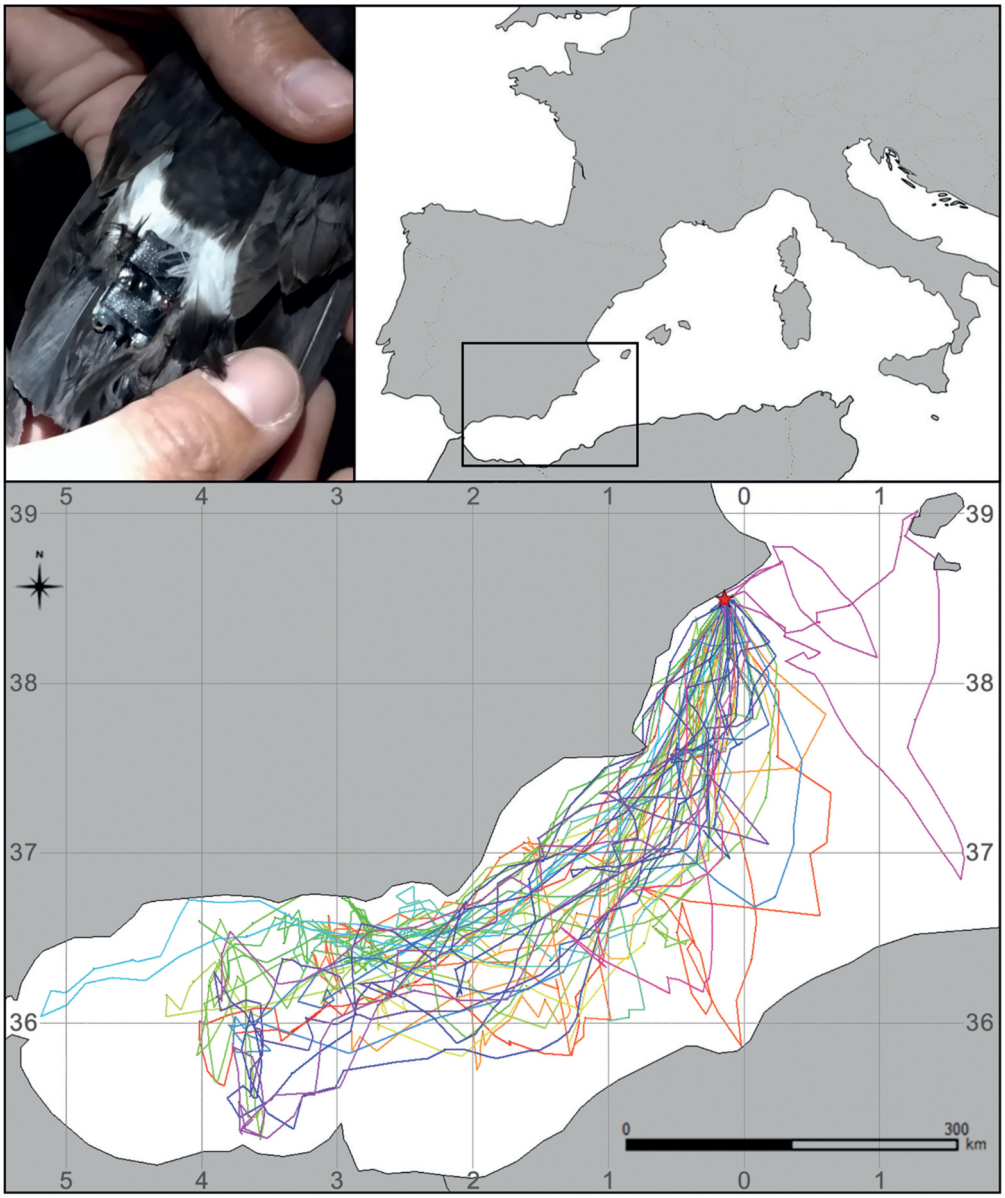

FIG. 1.—Top left: Nanofix GPS tag (Pathtrack Ltd) attached to a Mediterranean Storm-petrel using TESA tape. Top right: the south-western Mediterranean Sea showing the main foraging areas (black square). Below: tracks of single foraging trips during the incubation period of 37 Mediterranean Storm-petrels breeding at Benidorm Island (red star). Each colour corresponds to a single individual.
[Panel superior izquierdo: GPS Nanofix (Pathtrack Ltd) sobre un individuo de paíño europeo mediterráneo pegado con cinta TESA. Panel superior derecho: sudoeste del mar Mediterráneo mostrando el área principal de alimentación (cuadrado negro). Panel inferior: viajes de forrajeo individuales durante el período de incubación de 37 paíños europeos mediterráneos reproductores en la isla de Benidorm (estrella roja). Cada color corresponde a un solo individuo.]

body mass ≥ 28g and having incubated for at least ten days. From mid-May to the end of June 2019, 43 birds meeting the above criteria were equipped with Nanofix GPS loggers (nanoFix® GEO-MINI; size: 20 × 12 × 4mm, weight: 0.95g) from Pathtrack Ltd. (Otley, UK). The loggers were attached to the central four tail feathers with three narrow strips of TESA 4651 tape (Figure 1), resulting in a total load of 1.1g (< 4% of 28g, the mean body mass; see Sanz-Aguilar *et al*., 2019). We monitored only one foraging trip per bird. Storm-petrels were weighed twice, during the equipment and soon after recovering the device. Sex determination with certitude in storm-petrels is only possible through molecular analyses (Sanz-Aguilar *et al*., 2012). Here, the sex was known for 26 birds (13 males and 13 females) following analyses in 2005 and 2006 (Sanz-Aguilar *et al*., 2012).

Foraging trip characteristics

At first deployment (n = 10), GPS loggers were set to record a location every two hours. Using this setting, the battery level on recovery was still high. Consequently, we increased the frequency of locations to one per hour (n = 33). Sixty-three per cent (17/27) of the tracks recorded between May 15th and June 4th were incomplete. This temporal failure of loggers was due to humidity affecting the devices (Pathtrack pers. com.). To minimise this problem from June 5th onwards metal terminals of the devices were sealed using silicone grease (MARES S.p.A.) and the proportion of incomplete records dropped to 10% (1/10).

We considered only complete tracks and measured foraging trip duration (h), total distance travelled (km), maximum distance from the colony (km), mean travel speed (km/h), and proportion of record speed ≤ 10km/h, this last being a potential indication of 'resting on the water' behaviour (see Weimerskirch *et al*., 2002). Analyses were conducted in R 3.6.0, using Trip and AdehabitatLT packages (Calenge *et al.,* 2009; Sumner *et al.,* 2019).

Home-range and foraging areas

Home-ranges were calculated by means of fixed kernel density estimation (KDE; Worton, 1989) using 95% of locations (noted 95% Utilisation Distribution (UD) area; Downs and Horner, 2012). First, in order to evaluate site fidelity or space-use sharing among individuals we calculated the 95% UD overlap among individuals using the Utilisation Distribution Overlap Index (UDOI; function *kerneloverlaphr* in the AdehabitatHR package; Calenge, 2011). This index assumes that individuals use space independently and ranges from 0 (no overlap) to 1 (100% overlap; Fieberg & Kochanny, 2005).

We then pooled data from all the individuals in order to estimate a combined home-range for all tracked birds using the kernelUD function (Calenge, 2011). This analysis requires the definition of a smoothing parameter *h*, which was defined by the scale of the area of estricted search (ARS) of the species, which was calculated as the mean value of ARS extent exhibited across the tracked individuals (see Pinaud & Weimerskirch, 2005). First Passage Time (FPT) analyses (Lascelles *et al.,* 2016) were performed in order to estimate the ARS area of each trip. FPT is defined as the time required by an individual to cross a circle of given radius (Fauchald & Tveraa, 2003). According to Fauchald & Tveraa (2003), peaks in log-transformed variance of the FPT reveal the ARS scale at which the individual increased its searching effort, since this radius size is considered the optimal scale of FPT. The values of the FPT scale identify the periods featuring the ARS of each trip and its average represents the smoothing parameter, *h*.

Finally, for the identification of foraging areas we used data from complete tracks (n = 9) and nearly complete tracks (n = 12, mean time gap ± standard deviation (SD): 8.17 ± 6.25 hours, range = 4-23 hours) filling the temporal gaps by linear interpolation. Individual ARS values were calculated using FPT analyses (Kareiva & Odell, 1987; Lascelles *et al*., 2016). The detection of the periods in which birds increase their foraging effort or rest (stationary ARS segments) or the periods in which birds travel (no ARS segments) was carried out using Lavielle's segmentation method (Barraquand & Benhamou, 2008) from the AdehabitatLT package (Calenge *et al*., 2009). Stationary ARS segments also included periods resting on the water because in the absence of accelerometers we cannot distinguish resting from foraging behaviour (Sommerfield *et al*., 2013; Bennison *et al*., 2018). This method assigns a segment to stationary ARS behaviour when the mean FPT value of the segment is higher than the mean FPT value of the track (Mendez *et al*., 2016). Using the locations corresponding to ARS behaviour we established the foraging areas of intense use (50% UD and at 20% UD) through kernel density analyses.

Results

Addressing the potential effects of tagging

All 43 GPS-equipped birds returned to their nests after the monitored foraging trip (immediate return rate = 100%). Forty-two continued incubating while one lost its egg to Yellow-legged Gull *Larus michahellis* predation. Equipped birds lost on average 0.91g when recaptured, but this difference was not statistically significant (mean weight before tagging ± SD: 31.12 ± 2.15g and mean weight at recapture ± SD: 30.22 ± 2.24g; t = 1.857, df = 42, p = 0.07, n = 41). The breeding success of equipped birds was higher than the mean breeding success recorded for the whole colony (0.71 ± 0.43 SD, n = 38 and 0.61 ± 0.49 SD, n = 272, respectively).

Tracking data

We recovered the GPS device from 41 of the 43 equipped birds (95%); two individuals lost the device. Four trips did not deliver data due to device failure. All birds moved southwards, except the bird that lost its egg due to predation (Figure 1). This bird was omitted from ARS analyses. Unlike the other birds, this individual moved eastwards to the Balearic Archipelago and some of the nocturnal points recorded in its trip were near two other known Storm-petrel colonies, in Ibiza and Formentera (Figure 2).

A total of 1,487 positions were gathered from 15 incomplete journeys and 22 round trips. These involved five males, seven females, and ten individuals of unknown sex. All birds left and returned to the colony at night. Foraging trips were characterised by direct flights predominantly to the Gulf of Almeria (South of Spain), the Alboran Sea and the Oran coast (North of Africa; Figure 1), typically far offshore. Considering complete trips only, the mean duration was 3.03 days (range = 23 hours to 4.79 days). The mean trip distance travelled was 992.47km (range = 303.14-1,726.53km) and the mean maximum straight-line distance from the colony was 358.80km (range = 239.6-468.7km). About a third part of the flights (35%, range = 19-54%) between consecutive locations was at a speed ≤ 10km/h, which potentially corresponded to time spent on the water. The mean travel speed was 15.03km/h (range: 12.46-17.34km/h; Table 1 and Supplementary Material, Appendix 1, Table A1). Nineteen birds (86%) undertook foraging trips of over 600km and 11 individuals (52%)

FIG. 2.—Trajectory of individual T091756. This individual was the only one that lost its egg due to predation by a Yellow-legged Gull. It moved east to Balearic waters unlike all other tracked petrels. Left panel: the whole trajectory. Right panel: movements near to Ibiza and Formentera islands. Red stars indicate the position of all known Storm-petrel breeding colonies in the area.
[Trayectoria del individuo T091756. Este individuo fue el único que perdió su huevo por la depredación de una gaviota patiamarilla. Al contrario de todos los demás individuos estudiados, este se movió hacia aguas baleares. Panel superior izquierdo: se muestra la trayectoria completa. Panel derecho: movimientos cerca de las islas de Ibiza y Formentera. Las estrellas rojas indican la posición de todas las colonias conocidas de paíño europeo en la zona.]

of over 1,000km (Supplementary Material, Appendix 1, Table A1). Males and females showed very similar travel characteristics (see Supplementary Material, Appendix 1, Figure B1).

Home-range and foraging areas

UD analysis for all individuals (n = 37) identified a very large combined home-range (95% UD = 135,332.31km^2) covering all the south-western Mediterranean. The overlap index among individual home-ranges was 0.56 (i.e., 56% overlap). The FTP analysis estimated a mean ARS scale value of 37km (range = 20-80km). Lavielle's method detected ARS behaviour in 452 out of the 1,408 positions (interpolated points considered) of the complete trips (n = 21). ARS behaviour was assigned to 1.38 segments by trip (range: 1-3; Table 1 and Supplementary Material, Appendix 1, Figure C1). As expected, 'stationary' ARS segments were briefer (ANOVA, $F_{1, 1406} = 489.00$, $p < 0.001$) and at slower speeds than travelling segments (ANOVA, $F_{1, 1406} = 1791.00$, $p < 0.001$; Supplementary Material, Appendix 1, Table D1). Kernel analysis identified three areas where the ARS points concentrated (50% UD). The identified foraging areas corresponded to the submarine canyons near the Cartagena coast, the Oran Sea and the Alboran Sea (Figure 3). The potential foraging area in the Alboran Sea, covered 8,256.28km^2 and this was the main foraging area (20% UD).

TABLE 1

Mean values (± Standard Deviation) of foraging track statistics of Mediterranean Storm-petrels breeding at Benidorm Island from complete trajectories. The trajectory of one bird whose egg was lost to a predator was excluded from ARS analyses.
[Valores promedio (± desviación estándar) de las trayectorias completas de las rutas de alimentación de los paíños europeos mediterráneos que se reproducen en la isla de Benidorm. Se excluyó la trayectoria de un ave que perdió su huevo por depredación para los análisis de ARS.]

Parameter	mean ± SD	Range
Round trip characteristics (n = 22)		
Trip duration (days)	3.03 ± 0.91	0.96 – 4.79
Total distance travelled (km)	992.47 ± 305.55	303.14 – 1,726.56
Maximum straight-line distance from colony (km)	358.80 ± 104.81	239.60 – 468.70
Mean speed (km/h)	15.03 ± 2.43	12.46 – 17.34
Maximum travel speed km/h)	36.6 ± 11.99	23.06 – 80.86
% time on water	35.23 ± 9.77	19.00 – 54.00
Area-restricted search (ARS) behaviour (n = 21)		
Number of total segments per trip	3.76 ± 1.22	3.00 – 7.00
Number of ARS segments per trip	1.38 ± 0.70	1.00 – 3.00
Duration (h)	19.23 ± 13.60	6.00 – 56.00
Total distance covered (km)	144.64 ± 120.67	14.74 – 437.29
Speed (km/h)	7.30 ± 3.09	2.27 – 14.22

DISCUSSION

To our knowledge, we provide here the first GPS data on foraging movements of the Mediterranean Storm-petrel. No negative effects of carrying a GPS device on immediate return rates or breeding success were found (Costantini and Møller, 2013). All tracked birds came back to the colony after their foraging trips and they showed a very good breeding performance compared with the usual values recorded for the species (Hernández *et al*., 2017; Sanz-Aguilar *et al*., 2019). However, it is important to note that we equipped experienced birds during a single foraging trip to minimise nest desertion and maximise device recovery (Sanz-Aguilar *et al*., 2008). Caution should be taken when tagging naïve birds or birds at an early stage of incubation because disturbance can induce nest desertion (Blackmer *et al*., 2004). Equipped birds did not gain weight during foraging trips. Although we did not have control measurements, this may be an indication that the extra weight of the GPS device affected their foraging efficiency (Geen *et al*., 2019). Precise body mass gains are difficult to measure without subjecting the individuals to extra disturbance (i.e. multiple captures until the bird leaves the colony), which can increase nest desertion (Blackmer *et al*., 2004).

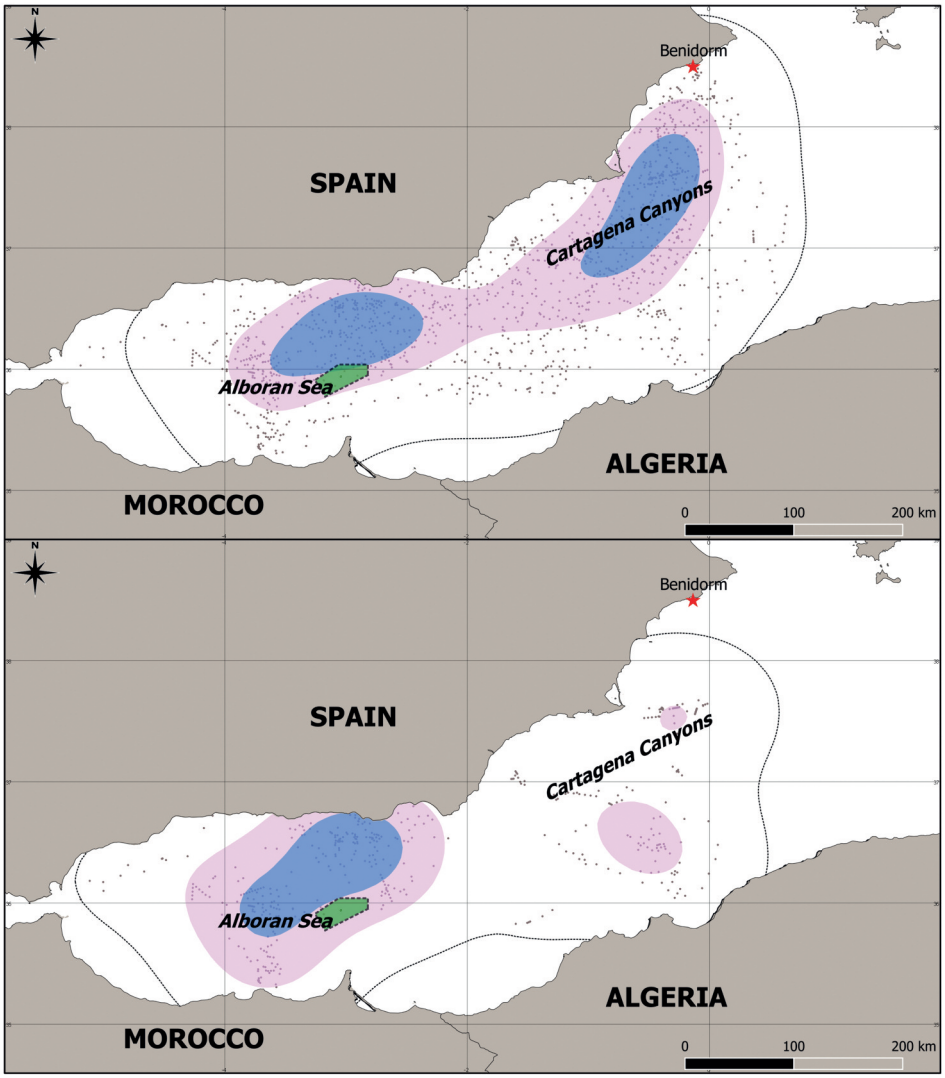

FIG. 3.—Top panel: Utilisation Distribution area of the Mediterranean Storm-petrel. Dashed line indicates the 95% UD or home-range area for all the individuals tracked from the colony. 50% and 20% UD are coloured in pink and blue, respectively. Black dots indicate locations and the red star the breeding colony. Bottom panel: foraging areas (ARS behaviour, dashed line = UD 95%ARS; light pink = UD 50%ARS, light blue = UD 20%ARS). Black dots correspond to ARS locations. Green = protected area of Alboran Island.

[Panel superior: Área de utilización (UD) del paíño europeo mediterráneo. La línea discontinua indica el 95% UD o área de campeo para todos los individuos equipados con GPS en la colonia. 50% y 20% UD están coloreados en rosa y azul respectivamente. Los puntos negros indican las ubicaciones detectadas por el GPS y la estrella roja la colonia de cría. Panel inferior: áreas de forrajeo (comportamiento ARS, línea discontinua = UD 95% ARS; rosa claro = UD 50% ARS, azul claro = UD 20% ARS). Los puntos negros corresponden a ubicaciones de ARS. En verde el área protegida de la isla de Alborán.]

Spatial data showed that incubating storm-petrels move further than previously thought (Arcos, 2009; Ramírez *et al*., 2016). The maximum straight-line distance reached from the colony (240-469km) was similar to those reported for the Atlantic sub-species of the European Storm-petrel (max. distance: 336km, Critchley *et al*., 2018; Oppel *et al*., 2018). In contrast, the total distance travelled per trip (mean: 992km, range: 303-1,727km) was greater than reported for the Atlantic subspecies (mean: 514km, range: 18-942km; Oppel *et al*., 2018). Moreover, our data indicated that Mediterranean Storm-petrels from the Benidorm colony have larger foraging ranges than Atlantic European Storm-petrels at High Island (Ireland; Critchley *et al*., 2020). In agreement with the results obtained for the Atlantic subspecies, the location of the main UD areas far from the continental shelf confirms the highly pelagic behaviour of the species (Oppel *et al*., 2018).

To date, the only available data on *H. p. melitensis* distribution at sea were collected by occasional sightings (Martínez *et al*., 2019) during oceanographic campaigns (Arcos, 2009) or by deploying geolocators with insufficient accuracy to detect foraging areas (Lago *et al*., 2019). Models based on observations during oceanographic campaigns predicted aggregations of *H. p. melitensis* on the Ebro-Columbretes platform and near Cape Nao (Arcos, 2009). This latter area and its surroundings were erroneously considered the main foraging area for Mediterranean Storm-petrels breeding at Benidorm Island (Ramírez *et al*., 2016; Keogan *et al*., 2018). The evidence provided in the stated studies should be reviewed since, at least in 2019, the Alboran Sea was the main foraging area of this colony. Moreover, it is important to remark that ARS segments include both searching behaviour and resting periods. To identify active searching using path segmentation techniques additional information provided by accelerometers (not available as ~1g GPS devices as used here) and more complex modelling procedures would be necessary (Jonsen *et al*., 2006; Sato *et al*., 2007; Bennison *et al*., 2018). In addition, storm-petrel species feed by pattering on water and can be active both day and night (Sanz-Aguilar *et al*., 2019). Consequently, we cannot attribute stationary segments at night to resting behaviour (Pinaud & Weimerskirch, 2007). New advances in tracking technologies are still necessary to identify possible specific resting areas within foraging areas in this species.

The Alboran Sea, the westermost arm of the Mediterranean, has never been considered an important foraging area for the species during the breeding season (Arcos, 2009; BirdLife International 2020). However, previous results, based on indirect evidence, hypothesised that the Alboran Sea might be an important wintering site for Mediterranean Storm-petrels breeding at Marittimo (Sicily, Central Mediterranean; Soldatini *et al*., 2014). In fact, the Alboran Sea is one of the most productive Mediterranean areas (Oguz *et al*., 2014; Salgado-Hernanz *et al*., 2019).

Within the Alboran Sea, Alboran islet and its surroundings was identified as an important area for cetaceans, Audouin's Gulls *Larus audouinii* and Cory's Shearwaters *Calonectris diomedea* and listed as a marine Important Bird Area and a marine protected area (Arcos, 2009). Our results clearly indicate that this mIBA also includes an important foraging area for the Mediterranean Storm-petrel. The Benidorm colony (459-630 breeding pairs; Sanz-Aguilar *et al*., 2019) represents 3-7% of the total Mediterranean breeding population (8,500-15,200 breeding pairs; Massa & Borg, 2018). Thus, the main foraging areas of this population could be considered mIBAS based on numerical criteria (Arcos, 2009). In this respect, the current Alborán islet mIBA (Figure 3) could be modified and enlarged. Such protection may help the conservation of the species, by for

example limiting the development of such activities as the establishment of offshore gas and oil platforms or wind-farms (Wiese *et al.,* 2001).

Our results show particularly interesting behaviour by the only bird that lost its egg by predation. This bird moved east, and probably visited other important breeding colonies at Ibiza and Formentera Islands (Sanz-Aguilar *et al*., 2019). As one hour elapsed between consecutive locations we cannot prove that the individual visited the breeding colonies, but it was very close and during night time (Figure 2). Prospection behaviour after breeding failure has been described for other seabirds (Ponchon *et al*., 2017) and our anecdotal data suggest that this behaviour could also exist in storm-petrels. However, we have never detected natal or breeding dispersal between Benidorm and the Ibiza colony, where birds have been marked since 2014 (own data).

In conclusion, we present here a first full description of foraging tracks of Mediterranean Storm-petrels during the incubation period, revealing flights to further distances than previously assumed. Our results clearly highlight the importance of the Alboran Sea as a foraging area for Mediterranean Storm-petrels. Further research should focus on assessing whether this area could also be important during other periods or for individuals nesting at other Mediterranean colonies. Such studies could provide important data for the definition of future Marine Protected Areas.

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AUTHOR CONTRIBUTIONS.—ASA and GT designed the study; AR, ASA and GT conducted the fieldwork; AR, AS and ASA did the analyses; AR wrote the first version of the manuscript and all authors contributed to the final version.

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Supplementary Electronic Material

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Appendix 1. Table A1: Trip characteristics.
Appendix 2. Figure B1: Locations and trip characteristics of five males and seven females.
Appendix 3. Figure C1: Examples of trip segmentation following Lavielle's method.
Appendix 4. Table D1: Area-restricted search (ARS) segment characteristics.

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