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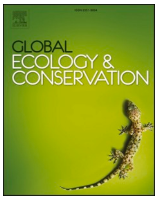

Original research article

Latitude, habitat and reproductive outcome shape breeding space use in common redshanks: First insights from GPS tracking across European landscapes

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ABSTRACT

The degradation and loss of breeding habitats due to agricultural intensification is driving severe declines in European bird populations. Understanding how breeding phenology and habitat use vary across a species' breeding distribution is essential for effective conservation. Here, we investigate how phenology and space use vary across latitude and habitat types of the common redshank (*Tringa totanus*) with breeding sites distributed across Europe, encompassing coastal, bog and agricultural landscapes. We used high-resolution GPS telemetry to track 85 adult redshanks throughout the breeding season. We quantified timing of reproductive stages, local movement behaviour, home-range size and habitat use during incubation and chick-rearing, and assessed how these parameters varied with latitude, habitat type and reproductive outcome. Spring arrival dates were strongly structured by latitude, whereas post-breeding departure was more closely linked to reproductive outcome. Later-arriving individuals exhibited flexible adjustment of breeding schedules across sites by shortening the pre-laying phase. Departure timing depended on reproductive outcome, with similar post-failure departure of both sexes but prolonged male residency following successful hatching, which is consistent with sex-specific parental roles. Space use varied markedly among sites and was strongly driven by dominant habitat type. In coastal systems, mudflats were heavily used throughout the breeding cycle,

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whereas bog-breeding redshanks increasingly used bog habitats during brooding, reflecting favourable conditions for chick development. Redshanks breeding in grassland make significant use of agricultural areas benefiting from conservation measures. Our results reveal behavioural flexibility in reproductive phenology and habitat use across the European breeding range of the redshank, allowing us to identify phases sensitive to disturbance in different populations. Agricultural habitats can be suitable, but birds seem to use mainly grasslands under protection measures, highlighting the importance of the implementation of AES (Agri-environment Schemes) and cooperation with farmers for the conservation of shorebirds.

1. Introduction

Over the last few decades, farmland bird populations have declined dramatically (Donald, 2001; Rigal et al., 2023). This decline is partly due to the intensification of agricultural practices, characterised by an increase in fertilisers and pesticides per hectare, overgrazing, drainage of wetlands and land artificialisation (Silva-Monteiro et al., 2021; Rigal et al., 2023). Predation pressure has increased in many European farmlands due to changes in predator communities and the simplification of vegetation structure, which reduces nest concealment and increases detectability (Roos et al., 2018; Teunissen et al., 2006). In parallel, early mowing and intensive grazing can cause direct nest destruction or create unfavourable microclimatic conditions for both eggs and chicks (Exo et al., 2017; Green et al., 1990; Norris et al., 1998). Moreover, declines in soil and aquatic invertebrates—driven by pesticides, fertilisers and altered hydrology—have reduced the food availability during the energetically demanding chick-rearing period (Silva-Monteiro et al., 2021; Rigal et al., 2023).

Among farmland birds, the common redshank (*Tringa totanus*; hereinafter: redshank) is a shorebird species widely distributed throughout Western Europe, particularly on the North Atlantic and Baltic coasts and, to a lesser extent, along the Mediterranean coast. Significant populations are also found inland like in Belarus and Ukraine (Birdlife DataZone, 2025). Three distinct subspecies are present: the nominate subspecies *T. t. totanus* on the western part of the European continent, *T. t. robusta* in Iceland and *T. t. britannica* in the UK (Ottvall et al., 2005). The global population of redshank in Europe (without Iceland) has declined by 56% over the period 1980–2024 (PECBMS, 2025), with a marked decline in certain European landscapes, such as in the Netherlands and United Kingdom (Booth Jones et al., 2022; Malpas et al., 2013; Roodbergen and Teunissen, 2014). In Iceland, which hosts 19% of the world's redshank population (Gunnarsson et al., 2006), the species has declined by 6% per year over the last decade (Pálsdóttir et al., 2025). Such declines are generally attributed to reduced reproductive success rather than adult survival (Grant et al., 1999; Kruk et al., 1997; Roodbergen et al., 2012). Redshanks are mainly associated with salt marshes and grasslands, but also breed, in lower densities, in natural habitats such as peat bogs (Järvinen and Sammalisto, 1976; Arvidsson et al., 1992). However, little is known about their ecology and population trend in this habitat type at European scale. Redshanks, like most shorebirds, breed mainly in base-enriched peatland systems in northern Europe (Aaapa mire), which are threatened by rapid and massive loss through drainage and climate change (Fox and Lehikoinen, 2025).

Although redshanks breed across diverse coastal–inland and natural–agricultural gradients, habitat-use research to date was largely focused on coastal habitats, particularly on salt marshes in the UK (Cervencl et al., 2011; Norris et al., 1998; Smart et al., 2006; Thompson and Hale, 1989). Coastal saltmarsh breeding territories are often associated with more natural hydrological dynamics compared to drained inland sites and natural or grazed vegetation mosaics (Smart et al., 2006; Verhulst et al., 2011), whereas inland populations frequently breed in managed grasslands embedded in agricultural landscapes (Sharps et al., 2016). However, the quality of these inland habitats has declined rapidly due to drainage, early mowing, and reduced invertebrate availability as a consequence of agricultural intensification (Exo et al., 2017; Silva-Monteiro et al., 2021; Rigal et al., 2023). Understanding how these contrasting factors shape habitat requirements and space use of birds is therefore essential to identify which types of landscapes conditions can still support viable breeding populations.

Recent developments in remote tracking now offer the ability for fine-scale quantification of spatial behaviour throughout the breeding phase, including incubation, chick rearing, and pre-migratory stages. These data provide new opportunities to link habitat structure with the functional space required by individuals to complete their reproductive cycle. While several telemetry studies have focused on site-specific populations (e.g., (Malpas et al., 2013; Laidlaw et al., 2017; Exo et al., 2017), few have compared breeding strategies across the broad range of habitats occupied by redshank in Europe. As a result, it is important to answer whether space use patterns reflect habitat condition and how this relates to breeding behaviour across contrasting landscapes. Quantifying the extent to which redshank breeding home ranges overlap with protected or managed areas is also a key step toward assessing how the current conservation networks cover the species' breeding distribution in Europe.

In this study, we use high-resolution GPS tracking data from multiple European breeding populations, obtained through two complementary deployment strategies: winter deployments generating a spatially dispersed sample of future breeders, and targeted spring deployments on breeding sites and habitat types of interest. Together, these datasets allow us to investigate how habitat type and breeding success shape spatial use and phenology throughout the breeding period. Specifically, we (i) examine the phenology and how it is related to latitude and breeding outcomes, (ii) quantify variation in home range size and habitat composition across major landscape types, and (iii) assess the proportion of breeding space located within protected areas. By integrating movement and habitat data, we aim to identify habitat conditions that effectively support redshank reproduction across Europe.

2. Material and methods

2.1. Tracking data

From 2024–2025, a total of 123 redshanks were either captured at roosts of different wintering or stopover sites using mist nets (n = 70), or at breeding sites during the incubation stage using clap nets or mist nets (n = 53). All birds were measured (i.e., flattened wing, tarsus, bill length), weighed, and ringed. All the birds were tagged with solar-powered Global Positioning System (GPS) transmitters with data transfer via the Global System for Mobile Communication (GSM) network (Ornitela, Lithuania; OT3–4G, 3 g; 2.48% of the bird body mass, mean body mass =120.6 g) using leg-loop silicone harnesses. Tags were set for a minimum interval of 5 min with a possible decrease depending on the battery percentage and recorded geographical position as well as date, time of day (UTC) and movement speed. For a subset of 29 birds, three body feathers were collected for molecular sexing (Tauros Diagnostics, Bielefeld). The incubation rhythm actograms for this subsample confirmed that females incubate mainly during the day (considered to be 6am−6pm) and males at night (considered to be 6pm−6am). This criterion was then used to determine the sex of others individuals when incubation data was available. Of the 33 birds captured on the nest with a clap net, one individual abandoned the clutch, while the other 32 resumed incubation after tagging.

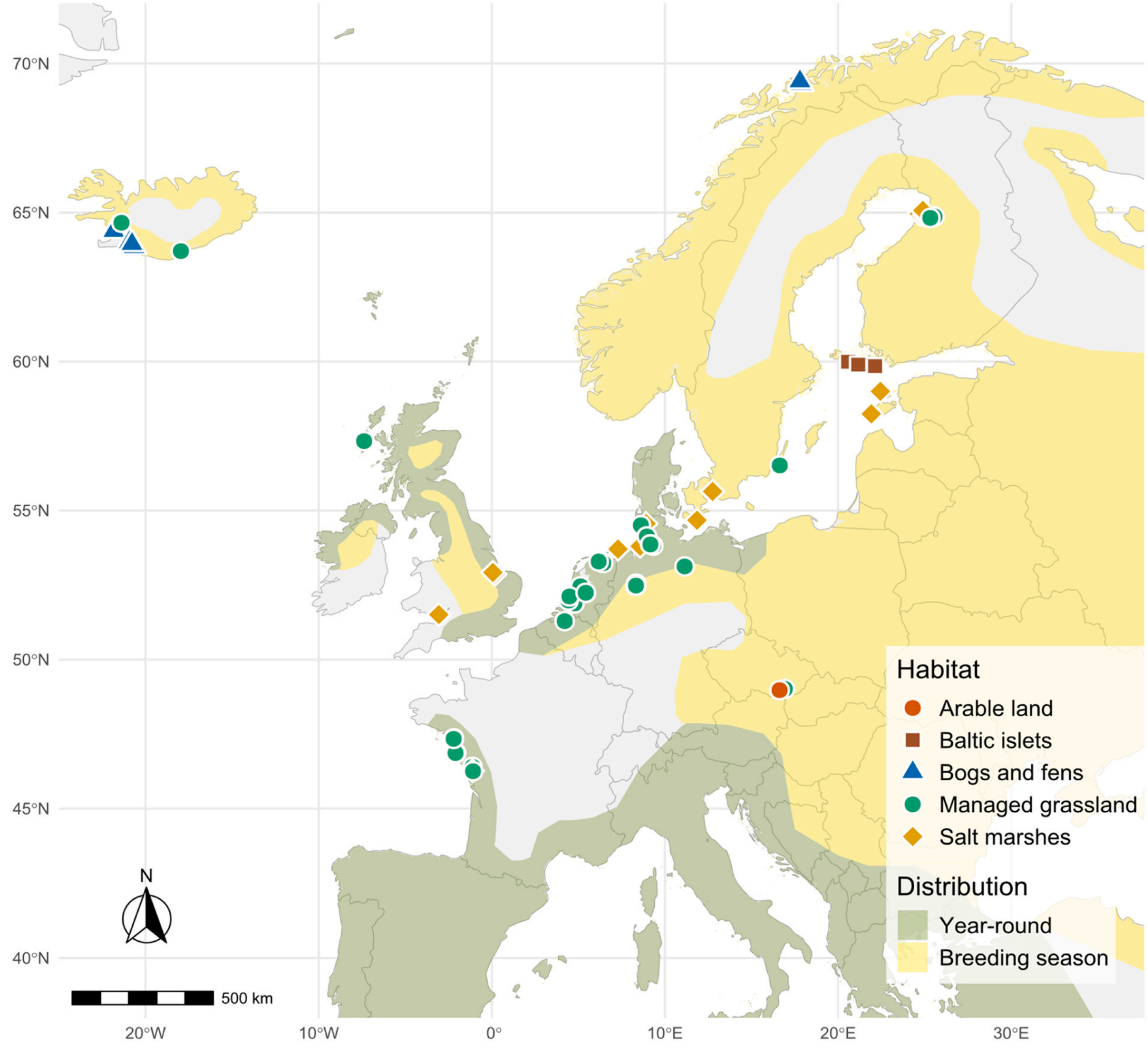

Fig. 1. Nest positions across Europe in relation to nest habitat type and breeding distribution range (BirdLife International, 2025).

2.2. Environmental data and conservation areas

Habitats were classified using the Copernicus Coastal Layer (https://land.copernicus.eu) which provides high spatial resolution (10 m) and detailed habitat nomenclature. For breeding territories located in the Czech Republic, which are not covered by this layer, a combination of the Copernicus High-Resolution Crops Layer and the CORINE Land Cover Backbone (https://land.copernicus.eu) dataset was used to delineate habitat types and distinguish between arable land and grassland.

Because grasslands are not differentiated by management type in these layers, we reclassified this habitat within incubation and rearing home ranges based on local information and following Silva-Monteiro et al. (2021): Low-intensity grassland (*Unimproved coastal meadows, floodplain meadows, wet meadows in nature reserve, no input*), medium-intensity grassland (*Traditionally/Extensively managed, low input grasslands, managed for breeding wader*) and high-intensity grassland (*Improved grassland, e.g. dominated by Lolium perenne*).

Spatial data on protected areas were obtained from the World Database on Protected Areas (WDPA; https://www.protectedplanet.net, Cambridge, UK: UNEP-WCMC and IUCN) and used to delineate legally designated conservation zones. To assess the degree of anthropogenic impact on areas used by birds, we used the Global 100 m Terrestrial Human Footprint (HFP, 2021) layer, which integrates land cover change, population density, night-time lights, roads, railways, and navigable rivers (Gassert et al., 2023).

For nesting sites that were located within agricultural landscapes outside protected areas, local farmers and coordinators of the organized farmer collectives for meadow bird protection, were contacted directly to determine whether agri-environmental schemes or other conservation measures had been implemented on the respective nesting parcels. This case only concerned birds in the Netherlands. Agri-environment schemes (AES) provide financial incentives to farmers to adopt management practices that support biodiversity conservation and the maintenance of ecosystem services. These schemes are designed in part to halt the decline of farmland species, including meadow-breeding birds, and are funded primarily through the Common Agricultural Policy (CAP) of the European Union (Barba-Escoto et al., 2024).

2.3. Breeding events

A total of 85 breeding territories with location of the nest were identified (Fig. 1, Table 1). Individuals excluded from the dataset showed incomplete information due to overwinter mortality, tag loss, death during the breeding season, or failure to detect the nest or breeding status. Of these 85 breeding events, 45 provided data on the complete breeding cycle i.e., from arrival to departure (individuals tagged in winter or when breeding the second year were used for analysis) and 40 provided data from parts of the incubation phase to departure (i.e., birds tagged at the breeding site without known arrival date). To verify that pooling complete and partial incubation datasets would not bias spatial metrics, we compared home range size during incubation between the two groups. No significant difference was detected (Wilcoxon rank-sum test: $p = 0.17$), probably reflecting the limited daily movements of incubating birds (Verhulst et al., 2007). Thus, the two groups were pooled.

Male and female redshank share egg incubation and are therefore alternately immobile at the nest during the 24-day incubation period (Cervencl et al., 2011). We extracted the nest positions from the GPS tracks by identifying the grid cell ($0.0001^\circ \times 0.0001^\circ$, corresponding to about 11.1 m × 11.1 m) containing the highest number of fixes (Fig. 1, Table 1). Once identified, the nest position was checked visually to confirm plausibility based on its location on a satellite image background (Bocher et al., 2024). For birds with replacement clutches, the last clutch was selected for analysis.

2.4. Assigning the breeding phases

To determine hatching success, we first identified incubation periods from actograms. For individuals monitored throughout the entire breeding phase (i.e., fitted with transmitters in winter or during stopover), incubation lasting ≥ 24 days (Cervencl et al., 2011) followed by frequent revisits within 400 m of the nest was classified as a hatching success, consistent with telemetry evidence that redshank chicks remain within ~0.4 ha after hatching (Thyen et al., 2008; Verhulst et al., 2007). Incubation shorter than 24 days and

Table 1
Overview of the breeding areas used by redshanks (n = 85) and according sample sizes. Birds not caught as breeders were tagged at wintering or stopover sites before breeding*.

Breeding area	**Caught as a breeder (n/total) ***	**Site characteristics**
Norway Fjords	0/**2**	Coastal bogs and grasslands with tidal influence
Southwest Iceland	0/**7**	Lowland bogs and grasslands in intensive agricultural landscape
Baltic Sea	9/**17**	Coastal meadows and managed grasslands in intensive agricultural landscape
Wadden Sea	0/**5**	Coastal grasslands and salt marshes with tidal influence
Lower Elbe	5/**6**	Extensively managed grasslands along estuarine margins
Upper Elbe	0/**1**	Managed grasslands within an agricultural landscape
British coast	0/**4**	Salt marshes and coastal grasslands
Dümmer Lake	6/**7**	Extensively managed inland grasslands
Inland Netherlands	0/**12**	Managed grasslands in an intensive agricultural landscape
South Moravia	2/**2**	Managed grasslands in an intensive agricultural landscape
Western France	22/**22**	Managed grasslands and salt marshes within an extensive agricultural landscape

no revisits indicated a failure. For birds monitored only during part of the breeding phase i.e., tagged on the nest or nearby), the end of incubation was determined from actograms, and post-incubation movements and revisits were examined to classify breeding outcomes. All classifications were visually verified using movement data and plots of distance to nest over time see methods in Bocher et al. (2024). As an additional validation, we compared the home range size one week before and one week after the end of incubation using paired *t*-tests. For birds classified as 'hatching successes', there was no evidence of an increase in home range size ($t = -1.4$, $df = 52$, $p = 0.173$). In contrast, birds classified as 'hatching failures', showed marked increase in home range size in the period following the end of incubation ($t = -3.7$, $df = 18$, $p = 0.001$). These results reflected the abandonment of territory and exploratory behaviour. Based on this contrast, post-incubation changes in home-range size were used as a supplementary criterion to support classification of hatching success or failure.

Both parents care for the chicks, which typically remain close to the nest (≤200 m; (Verhulst et al., 2007). When chicks disperse naturally, we would expect distances from the nest to increase gradually or to remain stable, whereas in case of brood failure (e.g., predation) we expected a sudden drop in nest revisits, reflecting a loss of territoriality. Consequently, post-hatching movement patterns allowed estimation of the duration of chick-rearing and assessment of habitat use during this phase. While this contrast provides supporting evidence for our classification approach, it does not constitute independent validation. Breeding outcome classifications and estimates of chick-rearing duration should therefore be interpreted with appropriate caution as an estimation.

2.5. Breeding home ranges

Kernel density estimates (KDE; Worton, 1989) were used to describe individual utilisation distributions (UD; (Laver and Kelly, 2008)) with the "kernelUD" function from the R package "adehabitatHR" (Calenge, n.d). The spatial distribution of bird locations and the point density in an area were considered by a KDE method to estimate the home ranges (at 95% isopleth) and core areas (at 50% isopleth) for each individual (Worton, 1989) with a smoothing factor of 30 (30 m) and an Albers Equal Area projection for all calculations. The accuracy of the kernel representation was determined by a single smoothing factor (h), allowing us to compare the HRs of all tracked individuals. To determine h, we visually compared the kernels of several individuals with more- or less-dispersed HRs (Schuler et al. 2014; Donnez et al., 2023) computed across a range of smoothing parameters (h = 20, 30, 50 and 70 m). An h of 30 m was visually determined to be the best compromise between under- and over smoothing and was therefore used in this study as it best captured fine-scale movement while remaining ecologically consistent with the landscape.

First, the home range size throughout the breeding phase (from incubation to departure) and the dominant habitat were determined (habitat type with the highest percentage inside home range). Second, the proportion of each habitat type used were estimated for the incubation phase, chick-rearing and post-breeding per bird and per site.

To assess the proportion of protected areas and anthropogenic impact (using HFP) in the areas used by the birds, we restricted our analysis to individuals tagged during wintering or migratory stopover periods (n = 28), in order to minimise sampling bias and ensure a spatially representative sample, because birds tagged during breeding were mostly caught in protected sites, and with several nests in the same country. To reflect functional breeding habitats while maximising sample size, we used the home range during incubation as the most sensitive area for nest survival and because not all birds provided rearing data.

We calculated the mean and range of HFP withing each home range and in the suitable habitat in the distribution range of the

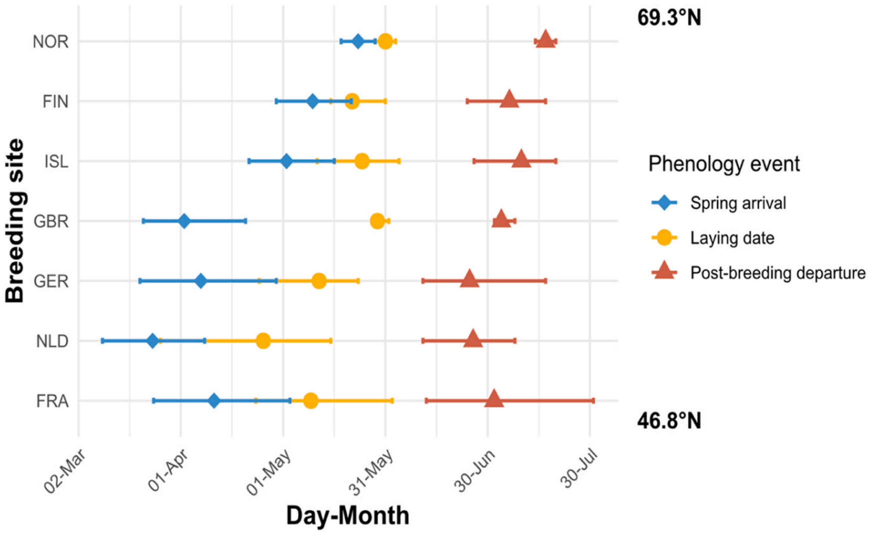

Fig. 2. Breeding phenology of different populations according to latitude. FRA = France, spring n = 4, laying n = 15, departure n = 20; NLD = Netherlands, spring, laying and departure n = 10; GER = Germany, spring n = 7, laying n = 11, departure n = 20; GBR = Great Britain, spring, laying and departure n = 3; ISL = Iceland, spring, laying and departure n = 8; FIN= Finland, spring n = 3, laying n = 8, departure n = 11; NOR = Norway, spring, laying and departure n = 2.

country (Fig. 1). Suitable habitat was defined as the habitat types selected in the analyses of habitat use.

2.6. *Statistical analysis*

All analyses were performed using R 4.3.3. We used a linear mixed-effects model (LMMs) to test the effect of arrival date on the time interval (days) between arrival and egg laying, using the lme4 package in R (Bates et al., 2015). Nest latitude was included as a fixed effect, and site was included as a random effect. To explain the variation in departure dates, we performed an ANOVA to test the effect of the interaction between sex and hatching success on the time interval (in days) between the end of incubation and post-breeding departure.

We assessed the effects of sex, hatching success, main habitat type, nesting habitat type, hatching to departure interval (days) and breeding year on breeding home range size using LMMs. Home range size was log-transformed prior to analysis to meet the assumption of normally distributed residuals. Model assumptions were evaluated visually using Q–Q plots and residuals versus fitted values.

An information-theoretic approach was used to compare a set of candidates LMMs to identify the main predictors of home range size ((Anderson and Burnham, 2002); see Appendix S1). Models were ranked according to the corrected Akaike Information Criterion (AICc).

3. Results

3.1. *Breeding phenology*

Breeding phenology varied markedly across sites. Birds breeding in the Netherlands exhibited the earliest timing, with a mean arrival date of 21 March (± 7.1 days, n = 10), a mean egg-laying date of 22 April (± 15.1 days, n = 10, Fig. 2), and a mean post-breeding departure date of 24 June (± 10.5 days, n = 10). In contrast, individuals breeding in northern Norway showed the latest phenology, arriving on average on 22 May (± 7.1 days, n = 2), laying eggs on 30 May (± 4.2 days, n = 2), and departing on 16 July (± 4.2 days, n = 2, Fig. 2).

Breeding latitude strongly influenced migration phenology. Birds breeding at higher latitudes arrived later in spring ($\beta = 2.13 \pm 0.43$, $p < 0.001$; $R^2 = 0.37$), with an average delay of approximately 2 days per degree of latitude. Redshanks spent an average duration of 79.1 ± 19.8 days (n = 45, from arrival to departure) at the breeding grounds. Later spring arrival was associated with a shorter interval between arrival and laying date ($\beta = -0.45 \pm 0.11$, $p = 0.001$, Fig. 3A). On average, across all birds, the interval between arrival and egg-laying was 26.2 days (±14.8).

Breeding latitude also affected the timing of post-breeding departure, although weaker than spring arrival. Individuals left the breeding sites about 0.6 days later per degree of latitude ($\beta = 0.64 \pm 0.19$, $p = 0.001$; $R^2 = 0.13$). The duration between the end of incubation and departure from breeding ground was influenced by sex and hatching success. Birds (males and females) with successful hatching remained longer than those with failed attempts ($F = 7.33$, $p = 0.008$, Fig. 3B), based on the last clutch in case of replacement (n = 11). Estimated marginal means indicated that following nest failure, females and males left breeding grounds after 19.4 ± 3.2 days and 20.7 ± 3.6 days respectively, showing no sex-effect. In contrast, following successful hatching, males remained significantly

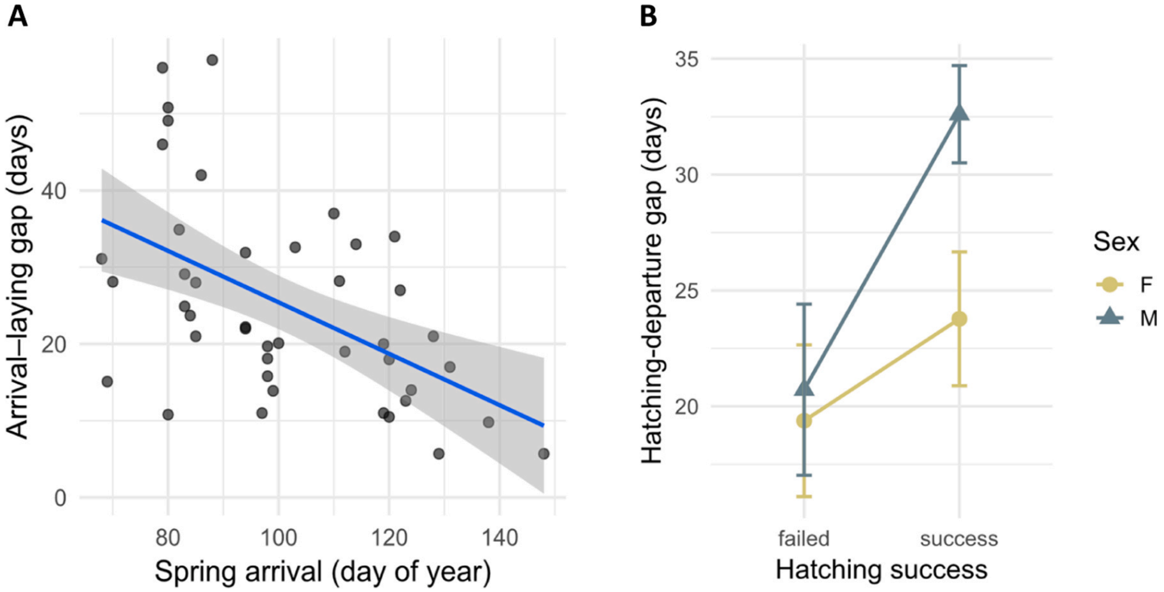

Fig. 3. Effect of arrival date in the breeding ground on the time gap before egg laying, shaded areas indicate 95% confidence intervals. (A) and time interval from hatching or incubation failure and departure (departure gap) between sex, values are shown as mean ± SE (B).

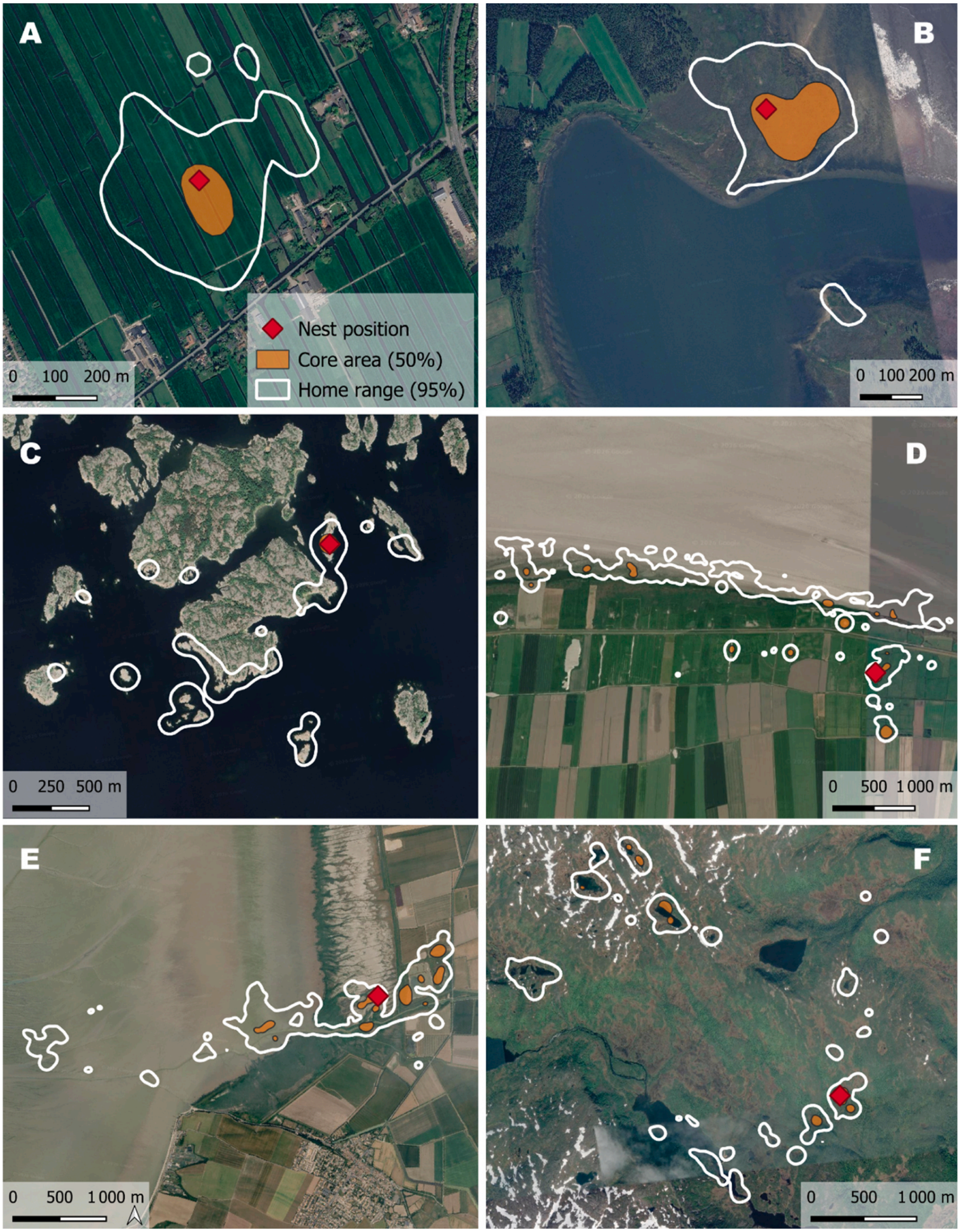

Fig. 4. Illustration of home ranges in different types of habitats during the breeding season. A) High-intensity grassland in Netherlands, B) Salt marshes (Baltic coastal meadow) in Finland, C) Baltic islets in Finland, D) Low-intensity grassland and intertidal mudflat in Elbe Estuary, Germany, E) Salt marshes and intertidal mudflat in western France and F) Bogs in Norway. (The 'Upper Elbe (DE)' site is not included here because n = 1).

longer than females, 32.6 ± 2.1 days and 23.8 ± 2.8 days, respectively.

3.2. *Home range size and habitat use*

This diversity of breeding sites extended from 46.9°N to 69.4°N (Fig. 1 and 4). The nesting habitats of all the birds consisted largely of managed grassland (70.2%) and salt marshes (20.3%), but also included bogs (5.4%), Baltic islets (2.7%) or arable fields (1.4%). Fig. 4.

The best-supported model (LMM, m3) included sex, hatching success, dominant habitat and breeding year as fixed effects with site as a random intercept and explained 46.9% of the variance. This model had the lowest AICc (167.0) and received 96.4% of the total model weight, indicating strong support relative to the other candidates. The second-best model (ΔAICc = 7.6. weight = 0.02) received substantially less support, suggesting that adding nest habitat did not improve model fit (Supplementary Table S1). More complex models including the interval (in days) between end of incubation and post-breeding departure ("incubation-departure gap") was poorly supported (ΔAICc > 10, Supplementary Table S1). Overall, the sex, hatching success, and dominant habitat emerged as the key predictors of home range size in this dataset. However, there was no evidence that sex or hatching success alone affected home range size, when considering the entire breeding season (Table 2). When comparing the post-incubation phase (in case of failure) and the rearing phase (in case of successful hatching), there was a marked increase in the home range for birds that failed compared with those that were rearing chicks (*t*-test; t = −3.74, df = 18, p = 0.001). Males (70.3 ± 10.2 ha) and females (75.6 ± 10.9 ha) exhibited similar values of home range surfaces (Table 2), and individuals with hatching success (72.3 ± 9.6 ha) did not differ from unsuccessful ones (73.5 ± 10.9 ha; Table 2) during the full breeding phase. Dominant habitat type within the home range influenced home range size (Fig. 5, Table 2). Birds using intertidal flats had the largest home ranges (112.6 ± 13.8 ha, n = 14), significantly larger than those than mainly use grassland [low management] (Table 2). Individuals using mostly coastal waters (83.9 ± 30.2 ha, n = 2), watercourses (114.5 ± 39.5 ha, n = 1), and bogs and fens (131.5 ± 30.0 ha, n = 2) also occupied significantly larger areas (Table 2). No evidence towards larger home ranges was found in highly and medium-intensity managed grasslands compared to low-intensity managed grassland (48.4 ± 14.0 ha, n = 10 [high], 38.2 ± 12.8, n = 19 [medium] and 31.6 ± 14.6, n = 13 [low]; Table 2). No significant differences were observed among other habitat categories (Table 2).

When birds nested in grasslands with access to mudflat, mudflat often became the dominant habitat, with up to half of the points occurring in this habitat at some sites (e.g., Lower Elbe; Fig. 6). This pattern was less pronounced for birds nesting in salt marshes with access to mudflats. Birds nesting in bogs consistently used additional habitats, such as grassland and marshes in Southwest Iceland, or mudflats and grassland in the Norwegian fjords (Fig. 6).

During the post-breeding phase, some individuals located close to the coast shifted almost entirely to intertidal mudflats (e.g., Western France, Lower Elbe or Wadden Sea), whereas others showed no marked change in habitat use (Fig. 6).

There was a strong overlap between incubation and brooding home ranges (59.1 ± 22.3%, n = 83). During incubation, birds remained at an average distance of 359 ±1179 m (n = 85) from the nest with 50% of the position being < 48 m. During brooding and post-breeding stages, distances to nest increased on average to 1483 ±3148 m (n = 55) with 50% of the position being < 409 m (n = 51).

3.3. *Nesting habitat and protected sites*

Among birds tagged on wintering or stopover sites, four geographically distinct breeding population were identified across Europe (Iceland, UK, Germany and Netherlands). The home ranges of redshanks were associated with similar mean values of Human Footprint (HFP) across three populations (Iceland, the UK, and Germany), despite heterogeneity in HFP between countries within the available areas (Fig. 7B). In contrast, the home range in the Netherlands had higher HFP values, but all were benefiting from protection measures (Fig. 7A). Interestingly, in Iceland birds do not utilise the lowest levels of HFP, even though it is available in their distribution area. (Fig. 7B).

Individuals breeding in Germany and the Netherlands settled in grasslands located either within nature reserves or under AES. In

Table 2
Results of the linear mixed model (LMM) testing the effects of sex, hatching success, and main habitat type on home range size. The model explained 46.9% of the total variance. Estimates are presented on the log scale; multiplicative effects are obtained by exponentiating coefficients.

Predictors	Estimate	Std. error	*t* value	*p* value
(Intercept)	3.38	0.27	12.36	**< 0.001**
Sex [male]	−0.19	0.18	−1.07	0.289
Hatching success [success]	−0.07	0.17	−0.44	0.658
Main habitat [Managed grassland (medium)]	0.29	0.27	1.09	0.311
Main habitat [Managed grassland (high)]	0.44	0.31	1.41	0.189
Main habitat [Intertidal flats]	1.41	0.31	4.57	**0.010**
Main habitat [Coastal water]	1.20	0.53	2.26	**0.043**
Main habitat [Inland marshes]	0.70	0.51	1.37	0.176
Main habitat [Salt marshes]	0.54	0.35	1.54	0.241
Main habitat [Water courses]	1.46	0.68	2.14	**0.037**
Main habitat [Bogs and fens]	1.43	0.51	2.79	**0.013**
Breeding year [2025]	−0.08	0.19	−0.40	0.69

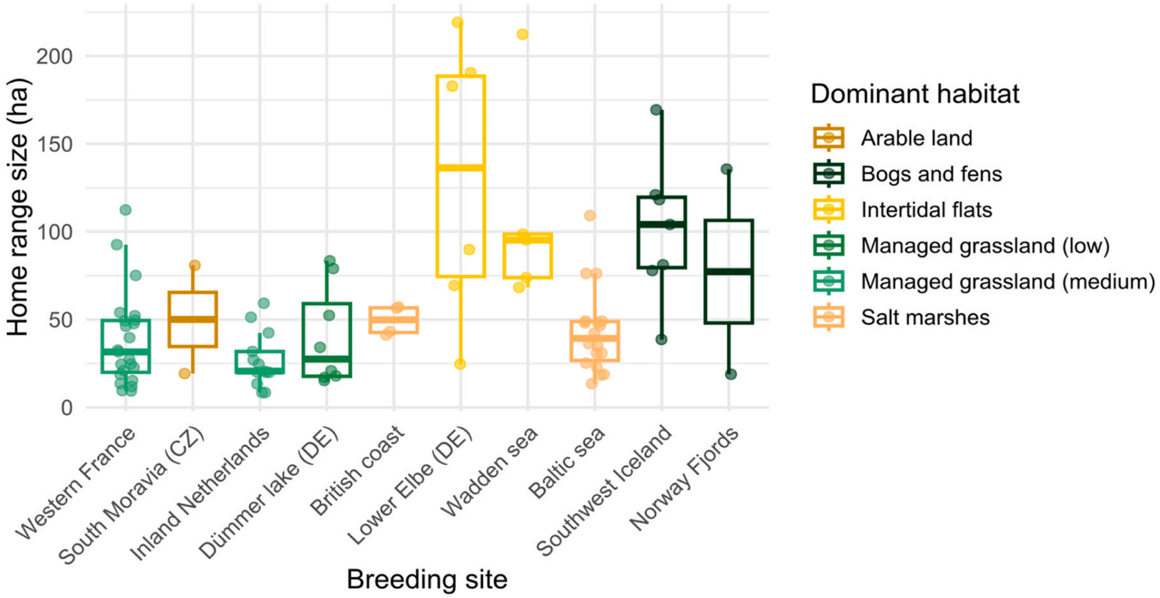

Fig. 5. Home range size during the full breeding phase. The boxplot colour represents the dominant habitat.

the Netherlands, seven birds nested in grasslands managed under AES by 'nature' farming collectives. Three in particularly wet grasslands (60% wet area) located in nature reserves managed by NGO-farmers collaboration plus combination with postponed mowing between 15th of June or 1th July. From the seven nests in AES grasslands, three had nest protection measures in combination with strips of postponed mowing in the parcel, and four in grassland parcels with postponed mowing until 15th of June and/or a water table management (60% surface water coverage on the field). All seven nests in parcels with AES had in the direct neighbourhood (within 100–250 m) other AES-schemes like 60% wet surface, postponed mowing until first, 8th or 15th of June. In contrast, in Iceland almost none of the nesting habitat was protected, with only 16.7% falling under any protection (Fig. 7A). In the UK, half of the home range was under strong protection measures.

4. Discussion

Using high-resolution GPS tracking across multiple European breeding populations, we provide the first continental-scale assessment of breeding phenology and habitat use in the common redshank (*Tringa totanus*). Our results revealed strong latitudinal structuring of breeding timing, flexible adjustment to reproductive outcomes, and pronounced differences in space use among habitat types, highlighting the importance of landscape context for breeding behaviour and conservation.

4.1. Breeding phenology

Our results show that latitude strongly shapes spring arrival timing and the interval between arrival and breeding (Conklin et al., 2010; Schamel and Tracy, 1987), but has a weaker effect on autumn departure. This suggests that stronger environmental constraints at higher latitudes impose tighter synchronization of spring arrival (Conklin et al., 2010; Nightingale, 2023). In contrast, the post-breeding period appears more flexible, with reproductive success more directly influencing departure timing, which may explain the limited latitudinal effect in autumn.

We also found a clear link between arrival and breeding schedules: later-arriving birds shortened the interval between arrival and egg laying, whereas early arrivals maintained longer pre-laying periods. This capacity to adjust breeding timing has also been reported in other waders, such as the Whimbrel *Numenius phaeopus islandicus* (Carneiro et al., 2023) and the Black-tailed Godwit *Limosa limosa islandica* (Nightingale, 2023). The persistence of this negative relationship across sites, after accounting for geographic variation, indicates that adjustment of the arrival–lay interval is a general mechanism rather than a latitude-specific response.

After nest failure, males and females left the breeding grounds within a similar timeframe (~20 days), indicating that reproductive failure prompts departure in both sexes (after the final clutch in cases of replacement). In contrast, following successful hatching, males remained on average eight days longer than females, suggesting sex-specific parental investment during chick rearing. Males likely continued territory defence or chick guidance, whereas females departed as chicks approached fledging. Although telemetry alone cannot fully confirm these roles, this pattern aligns with field observations of colour-ringed individuals (Tijsen, pers. obs.). Overall, both sexes contribute to chick rearing but differ in the duration of post-hatching residency.

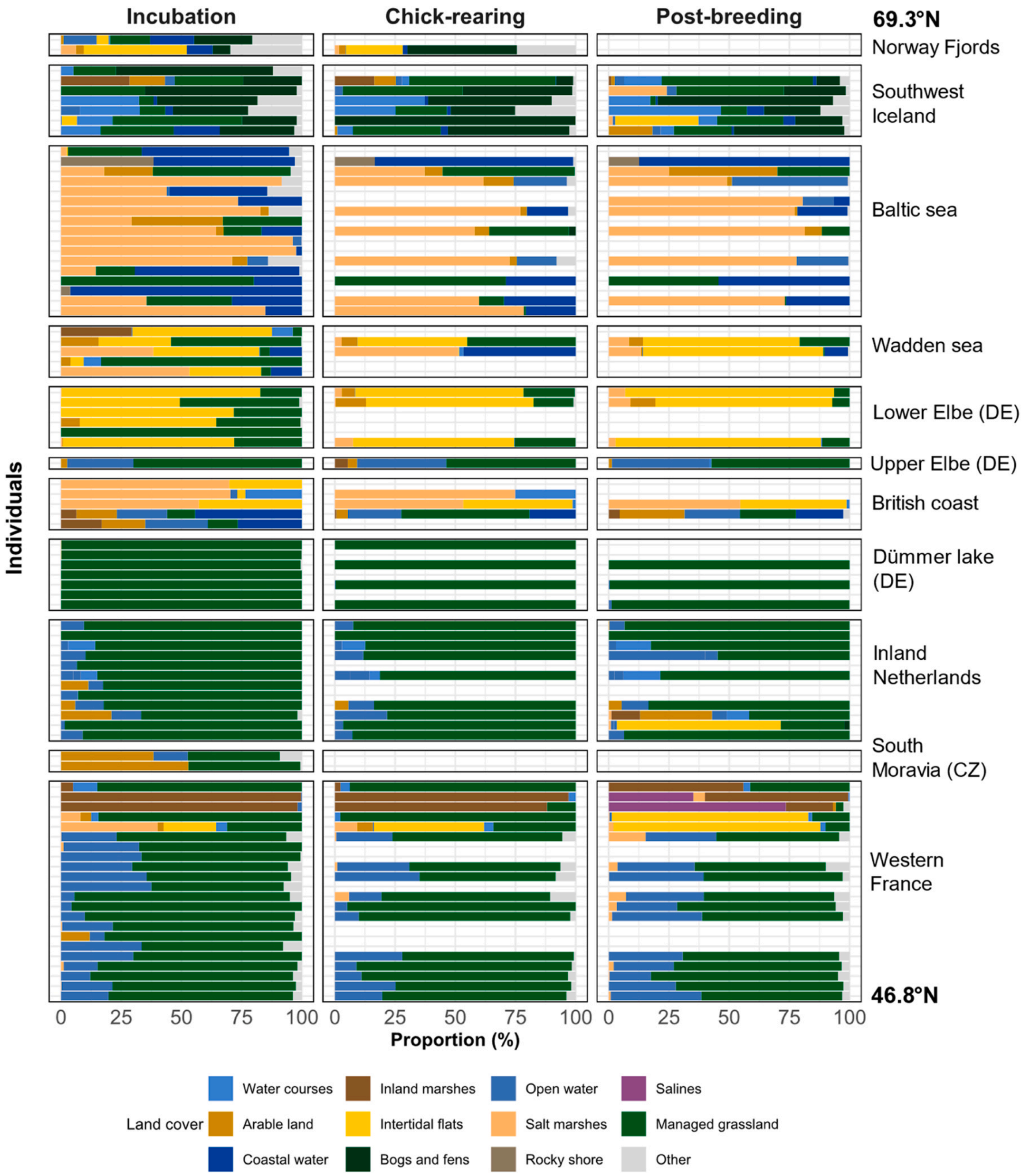

Fig. 6. Habitat use of Common Redshank according to the breeding site, from the southernmost to the northernmost.

4.2. Home range size and habitat use

During incubation, redshanks stayed very close to the nest, with half of all locations occurring within a short distance (about 50 m), which is consistent with field observations reporting incubation movements of 15–60 m (Verhulst et al., 2007). During chick rearing, space use expanded substantially, with half of the locations occurring within c. 400 m of the nest. This demonstrates the importance of local habitat quality and the availability of nearby resource-rich patches at fine spatial scales play a crucial role during rearing, likely by reducing foraging distances and energetic costs which may enhance breeding success (Smart et al., 2006; Verhulst et al., 2007).

Our results highlight spatial and habitat-use differences between sites and individuals, but also reveals a common reliance on agricultural habitat mosaics, even for those nesting in bogs. In managed grasslands, redshanks exhibited the smallest home ranges, particularly in the Netherlands (10.6 ± 3.71 ha during incubation), while in coastal landscapes they used much larger areas when the

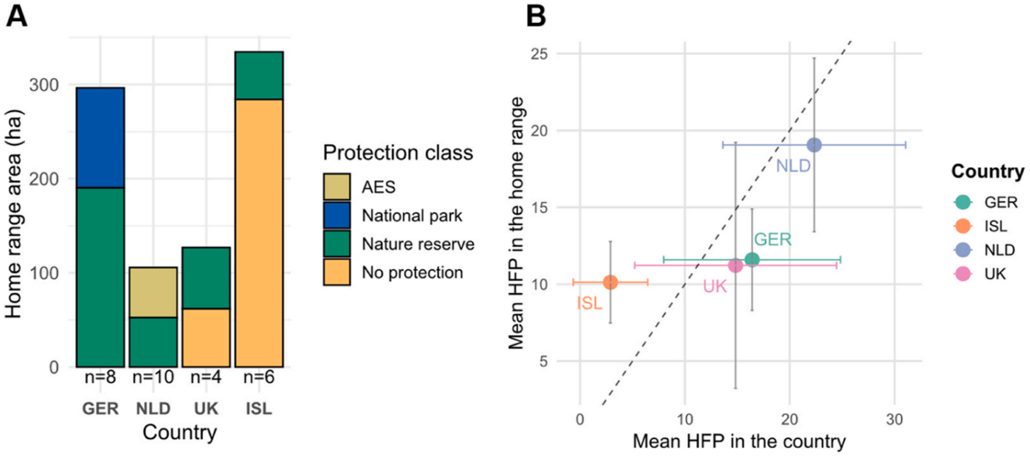

Fig. 7. Area (ha) of breeding home range area with or without protection during incubation period (AES =Agri-environmental Scheme implemented for waders' conservation) for birds tagged at wintering and stopover sites (A) and the relationship between the average (± SD) human footprint (HFP) in the home range and the corresponding national mean (B). The dashed line indicates proportional use (y = x).

intertidal mudflats were close to nests. Interestingly, the use of mudflats occurred during both incubation and the chick-rearing phases, meaning that birds routinely leave the breeding territory to forage in highest quality habitat (Ausden et al., 2003). At the Lower Elbe site, where birds exhibit this type of behaviour, the nests were nevertheless located in herb-rich wet grasslands managed for the conservation of shorebirds. These patterns likely reflect differences in resource distribution and availability. Habitats such as mudflats and coastal waters provide high-quality but spatially dispersed foraging opportunities (Piersma 1993; Jourdan et al., 2021), requiring birds to cover larger areas but offering better intake rates (Lourenço et al., 2005; Masero and Pérez-Hurtado, 2001), resulting in larger home ranges. From a conservation perspective, this indicates that protecting nesting sites alone is insufficient in coastal populations; functional connectivity must be maintained by also preserving access to adjacent mudflats to support the full range of breeding activities. Breeding at the interface of two habitat types such as mudflats and grassland seems to provides the opportunity to use both as foraging sites and by this to account for possible temporal resource limitations in either habitat type.

Redshanks breeding in bogs in Iceland and Norway, and for which bogs were the main habitat, exhibited larger home ranges than individuals in other habitat types and consistently used adjacent habitats such as grasslands, mudflats, and saltmarshes. Although they used these complementary habitats, redshanks increased the proportion of time spent in bogs during the brooding phase. This pattern suggests that bogs alone may not provide sufficient resources to meet adult energetic requirements. However, bogs appear to offer favourable conditions for chicks, likely due to their vegetation structure, wetness, and probably coinciding with the seasonal emergence of abundant arthropods at the time of chicks rearing, such as crane flies (Diptera: Tipuloidea) that are typical of bogs and fens (Salmela and Ilmonen, 2005; Olsen and Andersen, 2022). Nevertheless, our understanding of breeding habitat conditions for shorebirds in bogs ecosystems remain limited (Fraixedas et al., 2017), but our study provides now rational for future studies on the specific habitat requirements and how important it might be to tailor conservation measures to the different habitat mosaics.

Two individuals from western France (Brière), nesting in inland marshes, shifted to saltpans during the post-breeding period. These saltpans have been described as high-quality foraging habitats for their energy intake, providing abundant resources for pre-migratory refuelling (Masero and Pérez-Hurtado, 2001; Masero et al., 2000) and thus also appear to be important for post-nuptial migration fuelling.

4.3. *Implications of protected areas and conservation schemes*

All individuals from the Netherlands in our sample nested on fields managed either by a nature organization or under AES by so called 'nature-farming' collectives (Tijsen *Com. pers.*). Although based on a limited number of individuals, this pattern is consistent with broader evidence that redshanks in the Netherlands, like black-tailed godwits, increasingly concentrate in AES-managed or nature reserve parcels. Considering that 94% the Dutch grasslands is intensively managed for increasing the productivity, the surrounding parcels of extensively managed grasslands offer insufficient habitat quality (Barba-Escoto et al., 2024; Li et al., 2023). The existence of NGO-farmer collaborations in the Netherlands, a governance model relatively unique in Europe, appears to complement standard AES by enabling landscape-scale conservation actions (Runhaar and Polman, 2018). Comparable initiatives, such as the "*Paysans de Nature*" network in western France (Dulac and Richard, 2022), suggest that farmer-led conservation models may have broader relevance, though direct comparisons remain limited by the context-specific nature of these schemes.

Of the eight birds captured during wintering and then broadly dispersed in Germany, all nested in highly protected areas managed as nature reserves. In contrast, in Iceland, a small proportion of the nesting habitat is legally protected (16.7%), despite almost the entire Icelandic population breeds in lowland agricultural areas (97% below 200 m; (Gunnarsson et al., 2006). The currently low human footprint partially offsets this lack of formal protection, but ongoing agricultural intensification, with over 60% of lowland areas potentially convertible to farmland with gain in production benefiting from warming temperatures in a near-future (Björnsson et al., 2011; Jóhannesdóttir et al., 2017) and may represent a future threat. Given the small sample sizes on some sites underlying these observations, these findings should be interpreted cautiously, but they nonetheless point to the potential value of implementing targeted protection measures in currently unprotected breeding areas.

5. Conclusion

By integrating high-resolution GPS telemetry data across multiple breeding populations distributed across a wide range of environmental and agricultural contexts, we show that breeding phenology and space use in the common redshank vary markedly with latitude, habitat type and reproductive outcome. Redshanks exhibit behavioural plasticity in the arrival–lay interval, suggesting an ability to adjust phenology of reproduction under environmental constraints.

Home range size varied substantially across habitat types, reflecting differences in local resource distribution and management. In coastal systems, the use of mudflats during both incubation and chick-rearing highlights the importance of preserving functional connectivity between nesting sites and adjacent foraging habitats. In bog area, reliance on surrounding habitat types suggests that bogs alone may not meet adult energetic requirements, even if they offer favourable conditions for chick development. These findings reinforce the value of considering breeding habitat as a multi-component mosaic rather than a single land-cover type.

Overlap analyses between home ranges and protected or managed areas revealed geographic disparities across sites. In the Netherlands and Germany, individuals concentrated in AES-managed or nature reserve fields, consistent with the limited availability of suitable habitat in intensively farmed landscapes. In Iceland, most breeding areas fall outside formal protection, though the currently low human footprint may partially offset this gap. Finally, our results illustrate how telemetry can help identify spatially explicit conservation priorities for migratory shorebirds under ongoing land-use change, complementing and extending information obtained from more conventional methods such as ringing and population counts

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2026.e04291.

Data availability

Data will be made available on request.
3413053243 (Movebank)

References

Anderson, D.R., Burnham, K.P., 2002. Avoiding Pitfalls When Using Information-Theoretic Methods. J. Wildl. Manag. 66, 912–918. https://doi.org/10.2307/3803155.

Arvidsson, B.L., Boström, U., Dahlén, B., De Jong, A., Kolmodin, U., Nilsson, S.G., 1992. The importance of mires as breeding habitat for wetland birds in Sweden. Ornis Svec. 2 (2), 67–76. https://doi.org/10.34080/os.v2.23059.

Ausden, M., Rowlands, A., Sutherland, W.J., James, R., 2003. Diet of breeding Lapwing *Vanellus vanellus* and Redshank *Tringa totanus* on coastal grazing marsh and implications for habitat management. Bird. Study 50, 285–293. https://doi.org/10.1080/00063650309461321.

Barba-Escoto, L., Howison, R.A., Fokkema, R.W., Duriaux-Chavarría, J.-Y., Stessens, M., van der Velde, E., Hooijmeijer, J.C.E.W., Piersma, T., Tittonell, P.A., 2024. Are they even there? How agri-environment schemes investments reach their target species in Dutch dairy-farmland, the case of meadow birds. Glob. Ecol. Conserv. 56, e03286. https://doi.org/10.1016/j.gecco.2024.e03286.

Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting Linear Mixed-Effects Models Using lme4. J. Stat. Softw. 67 (1), 1–48. https://doi.org/10.18637/jss.v067.i01.

BirdLife International (2025). Species factsheet: Common Redshank Tringa totanus. Downloaded from⟨https://datazone.birdlife.org/species/factsheet/common-redshank-tringa-totanus⟩ on 16/12/2025.

Björnsson, H., Jóhannesson, T., Snorrason, Á., et al., 2011. Recent Climate Change, Projected Impacts, and Adaptation Capacity in Iceland. In: Linkov, I., Bridges, T.S., et al. (Eds.), Climate. Springer Netherlands, Dordrecht, pp. 465–475. https://doi.org/10.1007/978-94-007-1770-1_24.

Bocher, P., Donnez, M., Chenu, A., Sviridova, T., Fort, J., Garthe, S., Jiguet, F., Piha, M., Elts, J., Marja, R., Amélineau, F., Robin, F., Rousseau, P., Schwemmer, P., 2024. Home ranges and hatching success of threatened Eurasian curlew in north-eastern Europe relates to habitat type: Natural vs. agricultural landscapes. Glob. Ecol. Conserv. 50, e02851. https://doi.org/10.1016/j.gecco.2024.e02851.

Booth Jones, K., O'connell, P., Wolsey, S., Carrington-Cotton, A., Noble, D., Mcculloch, N., Calladine, J., 2022. Loss of breeding waders from key lowland grassland sites in Northern Ireland, 11–22.

Calenge, C., n.d. Home Range Estimation in R: the adehabitatHR Package.

Carneiro, C., Gunnarsson, T.G., Alves, J.A., 2023. Annual schedule adjustment by a long-distance migratory bird. Am. Nat. 201, 353–362. https://doi.org/10.1086/722566.

Cervencl, A., Esser, W., Maier, M., Oberdiek, N., Thyen, S., Wellbrock, A., Exo, K.-M., 2011. Can differences in incubation patterns of Common Redshanks Tringa totanus be explained by variations in predation risk? J. Ornithol. 152, 1033–1043. https://doi.org/10.1007/s10336-011-0696-z.

Conklin, J.R., Battley, P.F., Potter, M.A., Fox, J.W., 2010 Sep 7. Breeding latitude drives individual schedules in a trans-hemispheric migrant bird. Nat. Commun. 1, 67. https://doi.org/10.1038/ncomms1072.

Donald, P. et al., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations | Proceedings of the Royal Society of London. Series B: Biological Sciences [WWW Document]. URL ⟨https://royalsocietypublishing.org/doi/abs/10.1098/rspb.2000.1325⟩ (accessed 11.27.25).

Donnez, M., et al., 2023. Small space but high diversity: spatial and temporal habitat use by endangered eurasian curlew at wintering sites throughout Europe. Wetlands 43 (7), 80. https://doi.org/10.1007/s13157-023-01728-w.

Dulac, P., Richard, M., 2022. Ressorts agro-écologiques de l'expansion de la population de Barge à queue noire en Marais breton: bilan de 15 ans d'animation de territoire – LPO Vendée. juillet 2022. ⟨https://www.paysansdenature.fr/wp-content/uploads/2025/03/rapport_ressorts-agroecol-bqn.pdf⟩.

Exo, K.-M., Wellbrock, A.H.J., Sondermann, J., Maier, M., 2017. Assessing the impact of mowing on Common Redshanks Tringa totanus breeding on saltmarshes: lessons for conservation management. Bird. Conserv. Int. 27, 440–453. https://doi.org/10.1017/S0959270916000496.

Fox, A.D., Lehikoinen, A., 2025. Disappearing aapa mires and why we should care: unnoticed climate change exacerbates drainage effects on birds. Ibis 167, 591–598. https://doi.org/10.1111/ibi.13385.

Fraixedas, S., Lindén, A., Meller, K., Lindström, Å., Keišs, O., Kålås, J.A., Husby, M., Leivits, A., Leivits, M., Lehikoinen, A., 2017. Substantial decline of Northern European peatland bird populations: consequences of drainage. Biol. Conserv. 214, 223–232. https://doi.org/10.1016/j.biocon.2017.08.025.

Gassert, F., Venter, O., Watson, J.E.M., Brumby, S.P., Mazzariello, J.C., Atkinson, S.C. and Hyde, S. (2023). Global 100 m terrestrial Human Footprint (HFP-100) v1.2.

Grant, M.C., Orsman, C., Easton, Jon, Lodge, C., Smith, M., Thompson, G., Rodwell, S., Moore, N., 1999. Breeding success and causes of breeding failure of curlew Numenius arquata in Northern Ireland. J. Appl. Ecol. 36, 59–74. https://doi.org/10.1046/j.1365-2664.1999.00379.x.

Green, R.E., Hirons, G.J.M., Cresswell, B.H., 1990. Foraging Habitats of Female Common Snipe Gallinago gallinago During the Incubation Period. J. Appl. Ecol. 27, 325–335. https://doi.org/10.2307/2403589.

Gunnarsson, T.G., Gill, J.A., Appleton, G.F., Gíslason, H., Gardarsson, A., Watkinson, A.R., Sutherland, W.J., 2006. Large-scale habitat associations of birds in lowland Iceland: implications for conservation. Biol. Conserv. 128, 265–275. https://doi.org/10.1016/j.biocon.2005.09.034.

Järvinen, O., Sammalisto, L., 1976. Regional trends in the avifauna of Finnish peatland bogs. Ann. Zool. Fenn. 13 (1), 31–43. ⟨http://www.jstor.org/stable/23731782⟩.

Jóhannesdóttir, L. et al. (2017) « Reconciling biodiversity conservation and agricultural expansion in the subarctic environment of Iceland », Ecology and Society, 22. Disponible sur: https://doi.org/10.5751/ES-08956-220116.

Jourdan, C., Fort, J., Pinaud, D., Delaporte, P., Gernigon, J., Guenneteau, S., Jomat, L., Lelong, V., Lemesle, J.-C., Robin, F., Rousseau, P., Bocher, P., 2021. Highly diversified habitats and resources influence habitat selection in wintering shorebirds. J. Ornithol. 162, 823–838. https://doi.org/10.1007/s10336-021-01873-1.

Kruk, M., Noordervliet, M.A.W., ter Keurs, W.J., 1997. Survival of black-tailed godwit chicks *Limosa limosa* in intensively exploited grassland areas in The Netherlands. Biol. Conserv. 80, 127–133. https://doi.org/10.1016/S0006-3207(96)00131-0.

Laidlaw, R.A., Smart, J., Smart, M.A., Gill, J.A., 2017. Scenarios of habitat management options to reduce predator impacts on nesting waders. J. Appl. Ecol. 54, 1219–1229. https://doi.org/10.1111/1365-2664.12838.

Laver, P.N., Kelly, M.J., 2008. A critical review of home range studies. J. Wildl. Manag. 72, 290–298. https://doi.org/10.2193/2005-589.

Li, Y., Piersma, T., Hooijmeijer, J.C.E.W., Howison, R.A., 2023. Land-use intensity impacts habitat selection of ground-nesting farmland birds in The Netherlands. Ecol. Solut. Evid. 4, e12201. https://doi.org/10.1002/2688-8319.12201.

Lourenço, P.M., Granadeiro, J.P., Palmeirim, J.M., 2005. Importance of drainage channels for waders foraging on tidal flats: relevasnce for the management of estuarine wetlands. J. Appl. Ecol. 42, 477–486. https://doi.org/10.1111/j.1365-2664.2005.01045.x.

Malpas, L.R., Smart, J., Drewitt, A., Sharps, E., Garbutt, A., 2013. Continued declines of Redshank Tringa totanus breeding on saltmarsh in Great Britain: is there a solution to this conservation problem? Bird. Study 60, 370–383. https://doi.org/10.1080/00063657.2013.781112.

Masero, J.A., Pérez-Hurtado, A., 2001. Importance of the supratidal habitats for maintaining overwintering shorebird populations: how redshanks use tidal mudflats and adjacent saltworks in southern Europe. Condor Ornithol. Appl. 103, 21–30. https://doi.org/10.1093/condor/103.1.21.

Masero, J.A., Pérez-Hurtado, A., Castro, M., Arroyo, G.M., 2000. Complementary use of intertidal mudflats and adjacent salinas by foraging wader S.

Nightingale et al., 2023. Does early spring arrival lead to early nesting in a migratory shorebird? Insights from remote tracking - Nightingale - 2024 - Ibis - Wiley Online Library [WWW Document]. URL ⟨https://onlinelibrary.wiley.com/doi/full/10.1111/ibi.13268⟩ (accessed 8.22.25).

Norris, K., Brindley, E., Cook, T., Babbs, S., Brown, C.F., Yaxley, R., 1998. Is the density of redshank *Tringa totanus* nesting on saltmarshes in Great Britain declining due to changes in grazing management? J. Appl. Ecol. 35, 621–634. https://doi.org/10.1046/j.1365-2664.1998.355339.x.

Olsen, K.M., Andersen, T., 2022. Tipulidae (Tipuloidea). Diptera Rich. fens Other Habitats East. Part. Innlandet Southeast. Nor. VII.

Ottvall, R., Höglund, J., Bensch, S., Larsson, K., 2005. Population differentiation in the redshank (Tringa totanus) as revealed by mitochondrial DNA and amplified fragment length polymorphism markers. Conserv. Genet. 6, 321–331. https://doi.org/10.1007/s10592-005-4973-3.

Pálsdóttir, A.E., Þórisson, B., Gunnarsson, T.G., 2025. Recent population changes of common waders and passerines in Iceland's largest lowland region. Bird. Study 72, 204–216. https://doi.org/10.1080/00063657.2025.2450394.

PECBMS, 2025. The State of Europe's Wild Birds 2025. CSO, Prague, Czech Republic.

Piersma, T., Hoekstra, R., Dekinga, A., Koolhaas, A., Wolf, P., Battley, P., Wiersma, P., 1993. Scale and intensity of intertidal habitat use by knots *Calidris canutus* in the Western Wadden Sea in relation to food, friends and foes. Neth. J. Sea Res. 31, 331–357. https://doi.org/10.1016/0077-7579(93)90052-T.

Rigal, S., Dakos, V., Alonso, H., Auniņš, A., Benkő, Z., Brotons, L., Chodkiewicz, T., Chylarecki, P., de Carli, E., del Moral, J.C., Domşa, C., Escandell, V., Fontaine, B., Foppen, R., Gregory, R., Harris, S., Herrando, S., Husby, M., Ieronymidou, C., Jiguet, F., Kennedy, J., Klvaňová, A., Kmecl, P., Kuczyński, L., Kurlavičius, P., Kålås, J.A., Lehikoinen, A., Lindström, Å., Lorrillière, R., Moshøj, C., Nellis, R., Noble, D., Eskildsen, D.P., Paquet, J.-Y., Pélissié, M., Pladevall, C., Portolou, D., Reif, J., Schmid, H., Seaman, B., Szabo, Z.D., Szép, T., Florenzano, G.T., Teufelbauer, N., Trautmann, S., van Turnhout, C., Vermouzek, Z., Vikstrøm, T., Voříšek, P., Weiserbs, A., Devictor, V., 2023. Farmland practices are driving bird population decline across Europe. Proc. Natl. Acad. Sci. 120, e2216573120. https://doi.org/10.1073/pnas.2216573120.

Roodbergen, M., Teunissen, W., 2014. Meadow bird conservation in The Netherlands – lessons from the past and future developments. Vogelwelt 135, 29–34.

Roodbergen, M., van der Werf, B., Hötker, H., 2012. Revealing the contributions of reproduction and survival to the Europe-wide decline in meadow birds: review and meta-analysis. J. Ornithol. 153, 53–74. https://doi.org/10.1007/s10336-011-0733-y.

Roos, S., Smart, J., Gibbons, D.W., Wilson, J.D., 2018. A review of predation as a limiting factor for bird populations in mesopredator-rich landscapes: a case study of the UK. Biol. Rev. 93, 1915–1937. https://doi.org/10.1111/brv.12426.

Runhaar, H., Polman, N., 2018. Partnering for nature conservation: NGO-farmer collaboration for meadow bird protection in the Netherlands. Land. Use Policy 73, 11–19. https://doi.org/10.1016/j.landusepol.2018.01.033.

Salmela, J., Ilmonen, J., 2005. Cranefly (Diptera: Tipuloidea) fauna of a boreal mire system in relation to mire trophic status: implications for conservation and bioassessment. J. Insect Conserv. 9, 85–94. https://doi.org/10.1007/s10841-004-5275-7.

Schamel, D., Tracy, D.M., 1987. Latitudinal Trends in Breeding Red Phalaropes (Tendencias Latitudinales en la Reproducción de Phalaropus fulicaria). J. Field Ornithol. 58, 126–134.

Sharps, E., Garbutt, A., Hiddink, J.G., Smart, J., Skov, M.W., 2016. Light grazing of saltmarshes increases the availability of nest sites for Common Redshank *Tringa totanus*, but reduces their quality. Agric. Ecosyst. & Environ. 221, 71–78. https://doi.org/10.1016/j.agee.2016.01.030.

Silva-Monteiro, M., Pehlak, H., Fokker, C., Kingma, D., Kleijn, D., 2021. Habitats supporting wader communities in Europe and relations between agricultural land use and breeding densities: A review. Glob. Ecol. Conserv. 28, e01657. https://doi.org/10.1016/j.gecco.2021.e01657.

Smart, J., Gill, J.A., Sutherland, W.J., Watkinson, A.R., 2006. Grassland-breeding waders: identifying key habitat requirements for management. J. Appl. Ecol. 43, 454–463. https://doi.org/10.1111/j.1365-2664.2006.01166.x.

Teunissen, W., Schekkerman, H., Willems, F., 2006. Predation on meadowbirds in The Netherlands – results of a four-year study.

Thompson, P.S., Hale, W. g, 1989. Breeding site fidelity and natal philopatry in the Redshank Tringa totanus. Ibis 131, 214–224. https://doi.org/10.1111/j.1474-919X.1989.tb02764.x.

Thyen, S., Exo, K.-M., Esser, W., Cervencl, A., Oberdiek, N., 2008. Salzwiesen im niedersächsischen Wattenmeer als Brutgebiet für Rotschenkel Tringa totanus: wertvolle Rückzugsgebiete oder ökologische Fallen? Saltmarsh as habitat of Common Redshanks Tringa totanus breeding in the Wadden Sea of Lower Saxony, Germany: useful hideaway or ecological trap? Vogelwarte 46, 43–52.

Verhulst, J., Brock, S.D., Jongbloed, F., Bil, W., Tijsen, W., Kleijn, D., 2007. Spat. Distrib. Breed. Meadow birds Implic. Conserv. Res.

Verhulst, J., Kleijn, D., Loonen, W., Berendse, F., Smit, C., 2011. Seasonal distribution of meadow birds in relation to in-field heterogeneity and management. Agric. Ecosyst. Environ. 142 (3-4), 161–166.

Worton, B.J., 1989. Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies. Ecology 70, 164–168. https://doi.org/10.2307/1938423.