 DOI: 10.13157/arla.73.1.2026.ra1

Research Papers

STONE-CURLEWS *BURHINUS OEDICNEMUS* WINTERING IN GROSSETO PROVINCE (CENTRAL ITALY): STATUS, HABITAT USE AND POSSIBLE THREATS

ALCARAVÁN COMÚN *BURHINUS OEDICNEMUS* INVERNANTES EN LA PROVINCIA DE GROSSETO (ITALIA CENTRAL): ESTADO, USO DEL HÁBITAT Y POSIBLES AMENAZAS

Marco Dragonetti[1], Valentina Falchi[2],
Fabrizio Farsi[1], Dimitri Giunchi[2 *], Luca Passalacqua[1],
Angela Picciau[1] and Pietro Giovacchini[3]

Summary.—The Eurasian Stone-curlew *Burhinus oedicnemus* is a steppe bird distributed in Europe, Asia and North Africa. Although not globally threatened, it is considered a species of European conservation concern. The Grosseto province is one of the most important areas for Stone-curlews in Central Italy. Previous studies there have found that this population is largely resident and therefore suitable for assessing long term population trends. We carried out this study from December 2013 to January 2023, surveying all known winter roost sites annually. Our estimate shows that over the past ten years, the population has remained relatively stable, with no significant increasing or decreasing trend. However, both the raw survey data and the predicted values from a GAMM model, developed to estimate the global trend, reveal considerable fluctuation in the count data. For this reason, and given the elusive behaviour of the species, it is difficult to produce an accurate estimate of the minimum and maximum number of birds wintering in the Grosseto area. Nonetheless, maximum counts of 500-600 birds suggest that this may be approximately the size of the wintering Stone-curlew population. In addition, ten GPS-tagged birds were studied to outline their roosting behaviour. These data helped to explain the observed variability in the counts. Stone-curlews exhibited two contrasting behaviours: they showed remarkable fidelity to certain roosting areas that were regularly used over multiple years, but they also displayed notable mobility between different roosts, occasionally occupying new sites not previously used. Overall, the incidence of disturbance factors was low but warrants further investigation. Recent agricultural changes in Grosseto –particularly the expansion of vineyards and the decline of traditional

[1] Gruppo Ornitologico Maremmano, Studi Naturalistici “A. Ademollo”, c/o Museo di Storia Naturale della Maremma, Grosseto, Italy.

[2] Ethology Unit, Department of Biology, University of Pisa, Pisa, Italy.

[3] Department of Physical Science, Earth and Environment, University of Siena, Siena, Italy.

* Corresponding author: dimitri.giunchi@unipi.it

farming– appear to be partially exploited by Stone-curlews, which frequently used vineyards as winter roosts. However, the conservation value of these habitats remains uncertain, especially given their potential negative impacts during the breeding season.—Dragonetti, M., Falchi, V., Farsi, F., Giunchi, D., Passalacqua, L., Picciau, A. & Giovacchini, P. (2026). Stone-curlews *Burhinus oedicnemus* wintering in Grosseto province (Central Italy): status, habitat use and possible threats. *Ardeola,* 73: 3-21.
Keywords: agricultural landscape changes, disturbing factors, long term population trend, roosting behaviour, wintering Stone-curlew.

Resumen.—El Alcaraván común *Burhinus oedicnemus* es una especie esteparia distribuida en Europa, Asia y el norte de África. Aunque no está globalmente amenazada, se considera una especie de preocupación para la conservación en Europa. La provincia de Grosseto es una de las áreas más importantes para el alcaraván común en el centro de Italia, y estudios previos han demostrado que esta población es en gran parte residente, por lo que puede constituir un caso de estudio adecuado para evaluar tendencias poblacionales a largo plazo. Llevamos a cabo este estudio desde diciembre de 2013 hasta enero de 2023, censando anualmente todos los dormideros invernales conocidos. Nuestra estimación muestra que, en los últimos diez años, la población se ha mantenido relativamente estable, sin una tendencia significativa al aumento o a la disminución. Sin embargo, tanto los datos brutos del censo como los valores predichos por un modelo GAMM desarrollado para estimar la tendencia general revelan una fluctuación considerable en los recuentos. Por esta razón, y dado el comportamiento elusivo de la especie, resulta difícil producir una estimación estadística precisa del número mínimo y máximo de aves invernantes en la zona de Grosseto. No obstante, los conteos máximos de 500-600 individuos sugieren que este podría ser, aproximadamente, el tamaño de la población invernante de alcaravanes. Además, se estudiaron diez individuos marcados con GPS para describir su comportamiento en los dormideros. Estos datos ayudaron a explicar la variabilidad observada en los recuentos. Los alcaravanes mostraron dos comportamientos contrastantes: una notable fidelidad a ciertas zonas de descanso utilizadas regularmente durante varios años, y al mismo tiempo una marcada movilidad entre distintos dormideros, ocupando ocasionalmente sitios nuevos no utilizados previamente. En general, la incidencia de factores de perturbación fue baja, aunque merece ser investigada con mayor profundidad. Los recientes cambios agrícolas en la provincia de Grosseto –en particular la expansión de los viñedos y el abandono de la agricultura tradicional– parecen ser parcialmente aprovechados por los alcaravanes, que utilizaron con frecuencia los viñedos como dormideros invernales. Sin embargo, el valor de conservación de estos hábitats sigue siendo incierto, especialmente considerando los posibles efectos negativos durante la temporada de cría.—Dragonetti, M., Falchi, V., Farsi, F., Giunchi, D., Passalacqua, L., Picciau, A. y Giovacchini, P. (2026). Alcaraván común *Burhinus oedicnemus* invernantes en la provincia de Grosseto (Italia central): estado, uso del hábitat y posibles amenazas. *Ardeola,* 73: 3-21.
Palabras clave: Alcaraván común invernante, cambios en el paisaje agrario, comportamiento en los dormideros, factores perturbadores, tendencias poblacionales a largo plazo.

Introduction

The Eurasian Stone-curlew *Burhinus oedicnemus* is a cryptic species with nocturnal habits, living across temperate and tropical latitudes in steppe, mild temperate and arid zones of mainly continental climate (Cramp & Simmons, 1983). The species is distributed in Europe, Asia and North Africa, with either resident or migrant populations (Vaughan & Vaughan-Jennings, 2005; Giunchi *et al.,* 2015). Although it is not globally threatened (BirdLife International, 2024), the species is of European conservation concern and subject to special measures to promote its survival and reproduction within its European range (Directive 2009/147/EC). The European population, which is mainly concentrated in southern Europe and the Mediterranean area (Vaughan & Vaughan-Jennings, 2005; Hume & Kirwan, 2020), has experienced an overall decline and range contraction since the second half of the 19th century (Delany *et al.,* 2009), which still seems to be ongoing (Keller *et al.,* 2020). In Europe the species has been subjected to strong pressure from habitat loss and disturbance, particularly associated with forestry, agricultural intensification, decline in sheep rearing, climate change and human recreational activity on coasts and sometimes elsewhere (Hume & Kirwan, 2020; Dedeban *et al.,* 2025). In Italy the Stone-curlew distribution is discontinuous and fragmented in restricted areas, mainly in Sardinia, Sicily, in Central and Southern Italy and, patchily in Northern Italy, particularly along some river courses (Brichetti & Fracasso, 2004). Its conservation status was "Vulnerable" in 2012 but currently it is classified as "Least Concern" (Gustin *et al.,* 2021), as the estimated population is considered relatively large (BirdLife International, 2017). Nevertheless, a reliable estimate of the Italian breeding population trend is not yet available due to the absence of long-term studies (Nardelli *et al.,* 2015; Giunchi & Meschini, 2022). Thus the observed increase in recent years is likely attributable to enhanced survey efforts, even though the survey protocols were often not specifically designed for monitoring the Stone-curlew population (Baccetti *et al.,* 2002; Zenatello *et al.,* 2014).

One of the core areas for the Stone-curlew in Italy is the central Tyrrhenian region (Brichetti & Fracasso, 2004; Giunchi & Meschini, 2022), particularly northern Lazio and southern Tuscany. Within this area, the province of Grosseto stands out as one of the most favoured zones, offering a high availability of extensive agricultural habitats (e.g. pastures), which are important land-use/land-cover drivers of habitat suitability for the species (Tinarelli *et al.,* 2009). Recent studies have shown that the Stone-curlew population in Grosseto is mainly resident, with only a very small proportion of migrating birds (Falchi *et al.,* 2023). Therefore, it can serve as a good subject for assessing long-term population trends, both in the wintering and breeding seasons. Given the elusive and nocturnal behaviour of the species, the census of breeding birds is objectively very difficult, particularly in the Grosseto area, where nests are placed in many different habitat types over a very large geographical area (Giovacchini & Stefanini, 2008). As for other wader species (Sutherland, 2006), censusing wintering Stone-curlews is relatively easy, given that they become gregarious after the breeding season. Indeed, in autumn and winter they flock and roost communally (Rasmussen & Anderton, 2005; Vaughan & Vaughan-Jennings, 2005) and moreover most roost sites are occupied for many years (Dragonetti *et al.,* 2014). For these reasons long-term monitoring of the wintering population can be fruitful. In Grosseto province, the Stone-curlew predominantly uses extensive agricultural habitats (e.g. pastures), which have been identified as the most important land-use/land-cover factor influencing habitat suitability for the Stone-curlew (Simoncini *et al.,* 2025). Given both the abundance of the population and the characteristics of the landscape, our investigation could serve as an important case study for developing monitoring strategies applicable to other areas.

Since 2013 we have conducted a long-term study of the wintering population in Grosseto province by means of a monitoring protocol that involved surveying all known roosting sites. The counts were facilitated by the presence of substantial numbers of birds at some roosts, and the resulting data can provide an indirect quantitative estimate of this mainly resident population (including both breeding and non-breeding individuals) during spring and summer as well. It is important to emphasise that flocking and roosting behaviour at wintering sites plays a key role in delivering adaptive benefits to the species. These include enhanced protection from predators through improved threat detection and increased foraging efficiency (Spencer, 1982; Eiserer, 1984; Wang & Chu, 2021). However, such social behaviour may not protect the species from anthropogenic disturbances (sensu Salafsky *et al.,* 2008; Battisti *et al.,* 2016). A detailed understanding of these behaviours, which are critical for the survival of the wintering population, is important for informing effective conservation strategies for the species.

Our research aimed: (i) to analyse the long-term winter population trend in the Grosseto area; (ii) to estimate the number of wintering birds, considering that they are mainly resident and so likely to be present during the breeding season also; (iii) to study, using ten GPS-tagged stone-curlews, the behaviour of roosting birds, movements between different roosts, occupancy timing and potential use of previously undetected roosting sites; (iv) to describe the land types of the roosting areas; and (v) to identify the most significant threats and disturbances observed in these habitats, as incidental findings of our research.

Methods

Study area and survey protocol

The study was carried out from December 2013 to January 2023 in Grosseto province (Central Italy, see Figure 1). Roosting sites (hereafter roosts), where Stone-curlews habitually gather in flocks for diurnal rest during winter, were areas of 25-35 ha characterised according to the different types of adjacent fields (e.g., ploughed field, vineyard, pasture, sowed field). The minimum distance between different roosts was two kilometres. For conservation reasons, we provide only approximate geographic locations for each roost (Figure 1). Most roosts are located in areas where hunting is permitted, and during December hunters are allowed to access private properties. Although the Stone-curlew is a protected species, the risk of illegal shooting remains quite high (M. Dragonetti, pers. obs.). Ten roosts were already known before the beginning of this study (see Dragonetti *et al.,* 2014), while five additional roosts were progressively identified after 2013 (Figure 1). These were discovered through a combination of GPS tracking of tagged individuals, occasional observations and targeted surveys of habitat types considered suitable for roosting.

The study was carried out for ten winter seasons (December–January, with a few exceptions defined below). Each winter we conducted three surveys: the first (hereafter named Winter1) was between 13 and 17 December (the date varied slightly from year to year); the second (Winter2) was between 28 and 31 December and the third (Winter3) between 13 and 19 January, aligning with the timing established for the International Waterbird Census (Delany, 2005). According to the available data, the timing of our census does not significantly overlap with the main periods of migratory movements (Falchi *et al.,* 2023; Dedeban *et al.,* 2025). In Winter1 and Winter3, we monitored all known roosts on the same day from 09.00 am to 04.00 pm, while Winter2 surveys took place on two consecutive days (from 09.00 am to 04.00 pm), since it was more difficult to organise volunteer fieldwork during holiday periods. We visited each roost for at least one hour. We counted birds using a 20-60× spotting scope or binoculars. The count on the ground was always checked against a second count of flying birds, when these either left spontaneously or were flushed when we made a transect in the area. We used this second method as the roost sites were relatively wide and open; the birds alighted soon after a brief flight and did not leave the area. Out

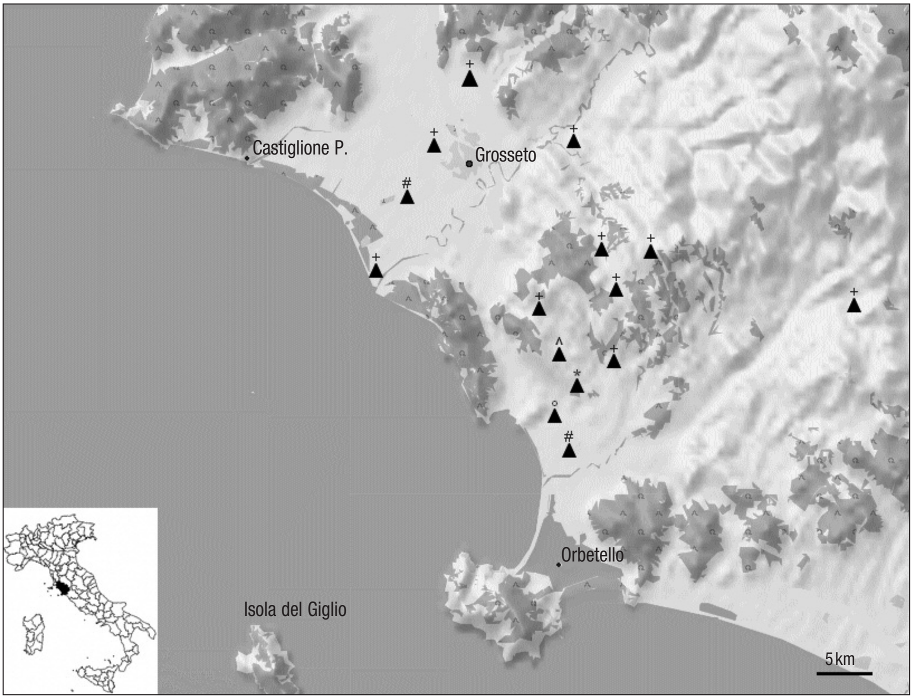

FIG. 1.—Locations of roosting areas (black triangles) already known before 2013/14 (+) or discovered in 2014/15 (#), 2015/16 (*), 2016/17 (°), 2017/18 (^). Map by open access Freizeitkarte ITA (https://www.freizeitkarte-osm.de/).

[Mapa de las áreas de descanso (triángulos negros) ya conocidas antes de 2013/14 (+) y descubiertas en 2014/15 (#), 2015/16 (*), 2016/17 (°), 2017/18 (^). Mapa basado en Freizeitkarte ITA de acceso abierto (https://www.freizeitkarte-osm.de/).]

of the possible 450 surveys (10 years × 3 periods × 15 roosts), we successfully conducted 388 effective surveys, due to the progressive discovery of previously unknown roosts at the beginning of the study and the restrictions imposed in 2020 by the Covid-19 pandemic. Our approach was shaped by two main needs: ensuring replicability and conducting bird counts during periods when migratory movements are almost completely halted. The ecological diversity of the area, partly due to ongoing farming activities, highlights the importance of repeated counts to obtain reliable data across such a wide region. Given the variability in migration timing –with some Stone-curlews departing as late as the second half of December (Falchi *et al.*, 2023)– it is essential to schedule counts well into the winter. The number and distribution of replicates were constrained by logistical challenges associated with organising large-scale surveys by volunteers, as well as by the need to minimise disturbance to roosting birds.

Statistical analysis of the survey data

The trend in the total number of birds counted each winter in the study area during 2013-2022 was analysed using a Generalized Additive Mixed Model with a Gaussian error structure, employing the mgcv 1.9-1 package (Wood, 2017) in the R 4.3.2 environment (R Core Team, 2023). The dependent variable of the model was the total number of birds counted across all monitored roosts in each survey. The predictors were: a) 'year', included as a smooth term using a thin plate regression spline with k = 9 as the basis dimension; b) the number of censused roost sites, included as an offset; and c) the replicate (a three-level factor corresponding to the three surveys conducted each year), included as a random intercept with a parametric term penalised by a ridge penalty (Wood, 2017) and k = 3 as the basis dimension. The actual degree of smoothing was estimated by generalized cross-validation (Wood, 2017). Model assumptions, including autocorrelation, distribution of residuals, homogeneity of variance, influential observations and overdispersion, were checked following Wood (2017) using the mgcv package. The plot of the predicted effect derived from the model was obtained using the tidygam package 0.2.0 (Coretta, 2023).

Recording behaviour of roosting birds, disturbance factors and roost type

For an analysis of the variation in bird counts within winter seasons, we compared the percentage changes of Winter2 and Winter3, with Winter1 set to 100. We used only data from roosts surveyed in all three winter periods; therefore roosts with fewer than 3 valid surveys were not included in this analysis. Winter 2020/21 was omitted as all data are incomplete due to Covid-19 restrictions (total surveys considered = 303). As minimum temperature is one of the variables known to affect the likelihood of migrant bird departure (Burnside *et al.,* 2021; Falchi *et al.,* 2023), we calculated the Winter3 variation in total bird numbers relative to the first annual count (Winter1 = 100) and tested the correlation between these variations and the number of days with minimum temperatures <1°C recorded in the fifteen days before the survey dates (weather data from the Grosseto Airport Historical Weather Archive). This threshold was chosen because it is reported that temperatures near 0°C or below dramatically increase the likelihood of migrant bird departure (Falchi *et al.,* 2023). A negative correlation would support the hypothesis that some birds migrate or stay, following adverse or favorable weather conditions.

To outline the land type use by roosting birds, we only analyzed surveys with non-zero counts (n = 228). We categorised the fields where birds were actually found as follows: 1) vineyard = a field with an intensively managed plantation of grapevines; 2) vineyard cult. = a vineyard with an adjacent cultivated field (sown, ploughed, or a permanent meadow). In such cases, most birds stay in the vineyard, but some are in the adjacent field; 3) uncultivated = a field not worked for more than one year; 4) worked soil = ploughed soil, land prepared for sowing with a disc cutter machine, freshly sown land without vegetation growth, and uncultivated land treated with a disc cutter machine to remove wild vegetation cover; 5) hazelnut grove = intensively managed hazelnut cultivation; 6) pasture = a permanent meadow or a hay sown field grazed by livestock (mainly sheep); 7) sown land = recently sown fields with a vegetation cover not taller than 15-20cm (cereals, legumes and hay).

We also kept track of all potential disturbance factors encountered during all 388 valid surveys: 1) hunting = the presence of multiple people hunting wild boar or one or a few hunters with dogs near the roost; 2) farming activity = landowner working with or without machines near the roost; 3) grazing livestock = a large herd of livestock grazing in the roost area; 4) other works = large earthmoving machines working near the roost. We assigned a '1' to any event observed at a given roost site during the survey time, regardless of its duration, frequency, intensity, or size (e.g., number of hunters/dogs, area of farming activities). We were unable to assess the direct effect of these events on roosting birds, as in most such cases, no birds were present at the roosting site.

Statistical analysis of behavioural data

Data on bird number variation within winter seasons, land type use for roosts, and disturbance factors are summarised with descriptive statistics. Correlation between the number of days with temperature <1°C and the percentage variation in bird number on Winter3 compared to the Winter1 period was tested using Spearman's rank correlation coefficient.

Tracking data

Fifteen birds were captured in Grosseto province during the breeding period (March-July) between 2013 and 2017 by different methods (i.e., mist nets, fall traps, dip nets). The birds were captured only during favorable weather days. Birds were sexed by molecular methods (Griffiths *et al.,* 1998) and were measured according to standard ringing procedures. GPS-UHF data loggers (model Harrier, Ecotone) were attached according to the Rappole technique (Rappole & Tipton, 1991). Tag weight averaged less than 4% of the birds' body weight (Kenward, 2001; Barron *et al.,* 2010; mean bird weight = 463.9g ± 29.1 SD, N = 15; mean tag weight = 16.9g ± 2.3 SD, N = 14). The tagging procedure lasted less than fifteen minutes and the birds were released near the capture site. We did not have the opportunity to adequately test the impact of tags and cannot rule out the possibility that they might have affected the behaviour of tagged animals (Geen *et al.,* 2019). However, all the tagged birds that we were able to observe post-tagging behaved normally and did not show any signs of distress. Ten out of the 15 were selected for analysis because their records were continuous during December and January, i.e., the monitoring period of winter roosts (see above). Four birds were tracked for one complete winter season, four for two winters and two for three winters. Data analysis was conducted only for daylight hours, using data from one hour after sunrise to one hour before sunset. Sunlit durations were calculated using the R package suncalc 0.5.1 (Thieurmel & Elmarhraoui, 2022).

The following parameters were calculated: 1) number of roost changes performed by each bird during each winter period; 2) number of different roost sites used by each bird each winter; 3) number of days spent by each bird in habitual roosts during each winter (a roost was defined as 'habitual' when occupied for at least seven consecutive or non-consecutive days during each winter period); 4) number of days spent by each bird in erratic roosts during each winter period (a roost was defined as 'erratic' when occupied for a maximum of six consecutive or non-consecutive days during each winter period). See also Supplementary material (Figures S1 and S2) for an example of movements in an habitual roost (eleven days) and in an erratic roost (two days); 5) Number of days spent by each bird in unsurveyed roost sites (e.g. unknown erratic roosts, roosts on private properties or cultivated land where entry was forbidden, where grazing animals and/or guard dogs were present, at sites lacking suitable habitat for the species but with roosting individuals unexpectedly present) during each winter period; 6) Number of roost changes made by each bird before the beginning of the daylight period (one hour after sunrise) in each winter, and 7) Number of roost changes made by each bird during the daylight period in each winter.

Given that GPS-tagged birds were studied in the same years and months as our field survey protocol, the GPS data can greatly help to better understand and clarify the data resulting from fieldwork. Parameters 1, 2, and 3 provide a measure of the birds' mobility and site fidelity in winter, while parameters 4 and 5 allow an estimation of the magnitude of the risk of missing roost sites during fieldwork. Since roosting during daylight is a resting period for the Stone-curlew (Biondi *et al.,* 2011), whose active life particularly in winter, takes place mainly at night (Vaughan & Vaughan-Jennings, 2005), birds normally do not abandon roosts during daylight unless greatly disturbed (M. Dragonetti, pers. obs.). Therefore, parameter 7 may provide a rough estimate of the degree of disturbance suffered by birds in winter. However, since not all disturbances drive birds from their roost, parameter 7 can only provide a rough estimate of major disturbances that force birds to move to a different roost. On the other hand, parameter 6 allows for the estimation of unforced roost choices made by birds at the end of their night-time activity.

TABLE 1

Results of surveys of wintering Stone-curlews in Grosseto province from 2013-2014 to 2022-2023. **N roosts** = number of roosting areas surveyed on the same day for each winter season period. **Period** = the three counts made per season (See Method). * Covid-19 restrictions prevented some planned surveys in December 2020.

*[Resultados de los censos de Alcaravanes comunes invernantes en la provincia de Grosseto entre 2013-2014 y 2022-2023. N dormideros = número de áreas de descanso censadas en el mismo día para cada periodo de la temporada invernal; * = en diciembre de 2020 no fue posible realizar todos los censos programados debido a las restricciones por la Covid-19.]*

Winter	Period	N roosts	N birds
2013-2014	Winter1	10	108
	Winter2	10	193
	Winter3	9	293
2014-2015	Winter1	11	275
	Winter2	12	342
	Winter3	11	285
2015-2016	Winter1	13	513
	Winter2	13	453
	Winter3	12	426
2016-2017	Winter1	14	377
	Winter2	14	446
	Winter3	14	251
2017-2018	Winter1	15	494
	Winter2	15	534
	Winter3	15	350

Winter	Period	N roosts	N birds
2018-2019	Winter1	15	368
	Winter2	15	385
	Winter3	14	469
2019-2020	Winter1	15	308
	Winter2	15	249
	Winter3	15	331
2020-2021	Winter1	8*	157
	Winter2	1*	8
	Winter3	15	344
2021-2022	Winter1	15	329
	Winter2	15	396
	Winter3	15	313
2022-2023	Winter1	15	427
	Winter2	15	415
	Winter3	15	449

Statistical analysis of tracking data

To address the non-independence of GPS data (as some birds were tracked for more than one winter season), we calculated the median and the bootstrap 95% confidence intervals for each parameter using the accelerated bias-corrected percentile method (BCa; Puth *et al.,* 2015) with 9,999 replicates, employing the R-package rcompanion v. 2.4.34 (Mangiafico, 2023).

RESULTS

Survey results

We monitored a maximum of fifteen roosts in Grosseto province up to January 2023. The number of known roosts increased from ten at the start of our fieldwork to twelve in 2014-2015, thirteen in 2015-2016, fourteen in 2016-2017 and fifteen in 2017-2018. The overall distribution of the known roosts is shown in Figure 1.

After winter 2017-2018, the number of roosts monitored each year remained stable at fifteen in at least one survey period per year. During this latter six-year period when the number of monitored roosts was relatively stable, we recorded a minimum of 249 birds and a maximum of 534, with a mean count of 385 and a relatively high coefficient of variation (19.8%, calculated as the ratio of the standard deviation to the mean, expressed as a percentage). These minimum data exclude the two incomplete surveys of 2020-2021. All counts from the surveyed roosts over the entire ten-year period, including the two incomplete surveys of 2020-2021, are summarised in Table 1.

We did not find any significant trend in the size of the wintering stone-curlew population over the ten-year period ($F_{3.7, 23.3} = 2.6$, $p = 0.05$; Figure 2). While there is no clear increase or decrease, the results are close to

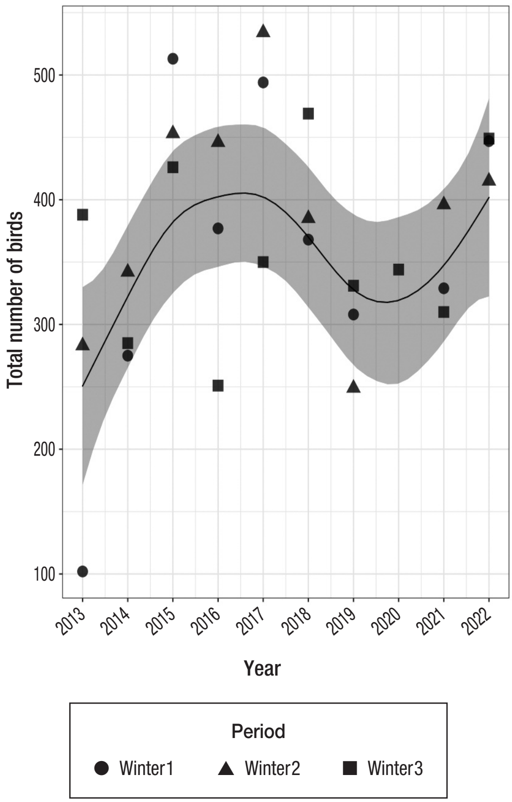

FIG. 2.—Scatterplot of annual Stone-curlew winter count totals in Grosseto province during 2013-2022. The fitted line represents the predicted values from a Generalized Additive Mixed Model with a Gaussian error distribution, developed to estimate the global trend of bird counts (shaded area = 95% CI; deviance explained = 39%). The estimated smooth term for the year was not significant ($F_{3.7, 23.3} = 2.6$, $p = 0.05$).
[Diagrama de dispersión del número total de Alcaravanes comunes contados cada año en la provincia de Grosseto durante el periodo 2013-2022. La línea ajustada representa los valores predichos por un modelo aditivo generalizado mixto (GAMM) con distribución de error gaussiana, desarrollado para estimar la tendencia general de los conteos (área sombreada = IC del 95%; desviación explicada = 39%). El término suavizado estimado para el año fue solo marginalmente significativo ($F_{3.7, 23.3} = 2.6$, $p = 0.05$) y no indicó una tendencia significativa en el periodo considerado.]

significance, likely due to sizable fluctuations in the counts, even when the data from 2020-2021 are not taken into account.

We also examined intra-seasonal variation by analysing the percentage change from the first survey period within each winter, considering only those roosts surveyed in all three periods (see Methods). The average data across all years showed a substantially stable population count within winter seasons. There was no consistent trend of increasing or decreasing bird numbers as winter progressed from December to January (Figure 3). However, there were within-winter season fluctuations in the counts, either increasing or decreasing, particularly in the Winter3 period. The correlation between the number of days with temperatures below 1ºC and changes in Winter3 counts (see Methods) was not statistically significant (Spearman's Rho = 0.26, p = 0.45, see Figure S3 in Supplementary material).

Roost type and disturbance factors

Most roosts (30%) were either in vineyards alone or in vineyards with adjacent cultivated fields; worked soil was used in 23% of cases, and sown land and pasture in 17% and 14%

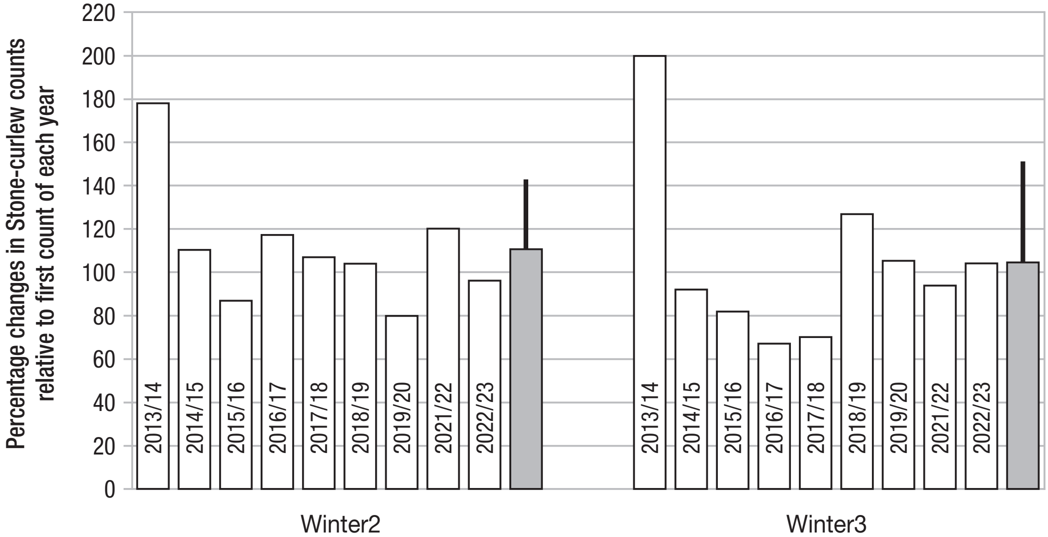

FIG. 3.—Annual percentage changes in Stone-curlew winter counts (white columns) relative to the first count of each year, set at 100%. Data are from roosts surveyed across all three winter periods. Winter 2020/21 was excluded due to incomplete coverage (see Table 1). Grey columns show mean percentages for the nine years during the Winter2 and Winter3 periods, with vertical black bars indicating the standard deviations of these means. For definitions of the winter periods, see Methods.
[Cambio porcentual en los conteos de aves dentro de cada temporada invernal (barras blancas). El primer conteo acumulado de cada año (Invierno1) se establece en 100. Los datos provienen de dormideros censados en los tres periodos invernales. El invierno 2020/21 fue excluido debido a datos incompletos causados por las restricciones por Covid-19 (véase Tabla 1). Las barras grises muestran los porcentajes promedio durante nueve años para los periodos Invierno2 e Invierno3, con barras verticales negras que indican las desviaciones estándar de estos promedios. Para las definiciones de los periodos invernales, véase Métodos.]

of cases, respectively (Figure 4). The hazelnut grove was used only in the first years of the survey, when the trees were very small and almost without branches because they had just been planted. During this period, the ground was kept bare of vegetation cover. Thereafter this roost site was abandoned as the trees grew and the ground became covered by a thick vegetation layer.

Over the course of 388 valid surveys conducted during the ten-year study period, we recorded all evident disturbance factors observed in the field. A total of 23 disturbance events were documented, representing 5.9% of the surveys. Of these, 12 events (3%) were hunting events (mainly wild boar hunting); seven (1.8%) involved farmers at work; two (0.5%) were caused by grazing livestock and two events (0.5%) were due to large earthmoving machines at work.

Tracking data and behaviour of roosting birds

All data on the movements and behaviour of the ten GPS-tagged birds refer to daylight hours, when Stone-curlews are typically inactive at their roosting sites (Table 2).

The high number of roost changes (a median of ~16 changes in 62 days) and the

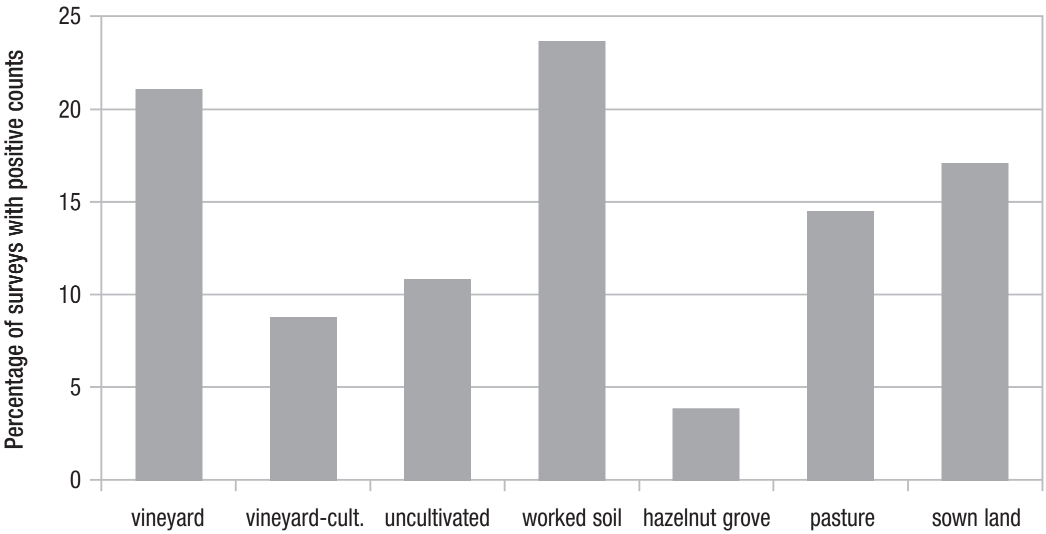

FIG. 4.—Land types at Stone-curlew roosts. Percentages of the total number of surveys with non-zero counts (n = 228). **Vineyard-cult.** = flock mainly settled in vineyards, but some birds are in an adjacent cultivated field; **worked soil** = ploughed soil, land prepared for sowing with a disc cutter machine, freshly sown land without vegetation growth, and uncultivated land treated with a disc cutter machine to remove wild vegetation cover; **hazelnut grove** = a recently planted crop with very small trees and bare soil.

[Tipos de hábitat de los dormideros del Alcaraván común. Porcentaje del número total de censos con conteos distintos de cero (n = 228). Viñedo-cult. = el bando de aves se asienta principalmente en viñedos, pero algunas aves se encuentran en un campo cultivado adyacente; suelo trabajado = terreno arado, suelo preparado para la siembra con gradas de discos, tierra recién sembrada sin crecimiento vegetal y terrenos no cultivados tratados con gradas de discos para eliminar la vegetación silvestre; avellanar = cultivo plantado recientemente con árboles muy pequeños y suelo despejado.]

TABLE 2

Mobility of GPS-tagged Stone-curlews at daytime roosts in winter (n = 10). Values are expressed as medians with bootstrap 95% confidence intervals for each parameter (see Methods). A **roost** is defined as a surveyed area of 25-35ha, located at least 2km apart (see Methods).
[Movilidad de los Alcaravanes comunes marcados con GPS durante los dormideros diurnos en invierno (n = 10). Roost = área censada de entre 25 y 35 ha, con una distancia mínima de aproximadamente 2 km entre diferentes dormideros (véase Métodos); N.º de cambios de dormidero = todos los cambios de dormidero realizados en diciembre y enero; N.º de dormideros diferentes = número de dormideros distintos ocupados en diciembre y enero; Días en dormideros habituales = días que las aves pasaron en áreas de descanso utilizadas habitualmente (> 6 días); Días en dormideros erráticos = días que las aves pasaron en áreas de descanso utilizadas durante menos de 7 días; Días en sitios no censados = días que las aves pasaron en sitios donde no se realizaron los censos programados; N.º de cambios al inicio del día = cambios de área de descanso realizados al comienzo del periodo diurno; N.º de cambios durante el día = cambios de área de descanso realizados durante el periodo diurno. Los valores se expresan como medianas con intervalos de confianza del 95% por bootstrap para cada parámetro (véase Métodos).]

Parameter	Median	95% CI (lower)	95% CI (upper)
N. roost changes	15.5	9.5	21.0
N. roosts occupied	6.5	5.0	8.0
N. days spent in roosts used for >6 days	60.9	58.0	61.6
N. days spent in roosts used for <7 days	1.1	0.3	2.6
N. days spent in unsurveyed sites	8.2	4.7	21.0
N. roost changes made at the start of the daylight period	9.5	6.0	11.0
N. roost changes made during the daylight	3.5	2.0	9.0

median number of different roosts used (~7) during December and January demonstrate a high level of mobility among roosts. At the same time, the long stays in habitual roosts (~61 days) confirms the birds' fidelity to well-known and traditional sites. However, it is important to note that we used a very strict criterion to define "erratic" non-habitual roosts: erratic roosts were occupied for a maximum of six consecutive or non-consecutive days during each winter period. The mean number of days spent by birds in unsurveyed sites was 8.2 (13%), a low but non-negligible figure, which highlights the difficulty of conducting an accurate census. Most roost changes occurred at the beginning of the daylight period (9.5), indicating that they were mainly unforced, free choices made by the birds. In contrast, the 3.5 changes made during daylight hours likely reflect significant disturbances that forced the birds to leave their roosts during their resting period.

DISCUSSION

The results of our ten-year survey of Stone-curlew winter roosts allow us to estimate the population trend in a well-defined geographic area (Grosseto province), one of the core zones for the species in Tuscany and Central Italy (Tellini Florenzano *et al.,* 1997; Giunchi & Meschini, 2022). The local population has been found to be mainly resident (Falchi *et al.,* 2023), implying that wintering birds are also likely to be present during the breeding season. This makes the Grosseto population a valuable case study for assessing long-term trends, as it is less influenced by interannual variation due to migratory movements. As such, we believe that our findings can serve as a reference for comparison in other contexts.

Our estimate shows that, over the last ten years, there has been no significant increasing or decreasing trend in the population size. However, both the overall survey results and the predicted values from the GAMM model, developed to estimate the global trend, clearly indicate considerable fluctuations within the count data. Moreover, the GAMM model result, which is very close to statistical significance, might suggest a weak but potentially meaningful 'signal'. The most likely cause of this weak signal is the alternating fluctuations in the count data. This variability may be explained through different hypotheses. The high count data might result from the late arrival of migratory birds. However, a recent study on Stone-curlew migration in the Mediterranean area (Falchi *et al.,* 2023) does not support this hypothesis. The departure and arrival dates of northern migratory birds are not compatible with our survey periods, and their target destinations are Sardinia, Sicily, and North Africa. Although their migratory routes pass over Central Italy, including Grosseto province (more so during spring than autumn migration), all known stopover sites in Tuscany have been recorded in spring, except for one site used by a single migratory bird that left the Grosseto area in January. Furthermore, 81% of the stopover sites are located far from our roost areas (>40km, see Supplementary material, Figure S4). It is important to note that Falchi *et al.* (2023) studied the migration of a limited –though not insignificant– number of tagged birds. Although their data do not support the hypothesis of late migratory birds arriving in the Grosseto area, these findings cannot be considered conclusive. Moreover, if the hypothesis of late migrants joining our population in winter was valid, we would expect to see an increasing trend in our count data from early December to January. Instead, as shown in Figure 3, there is no overall seasonal increase in the mean count data. On the contrary, we found consistent decreases in counts, particularly in some January surveys, along with instances of increases or no changes.

Another hypothesis to explain these data fluctuations is that some Stone-curlews leave the Grosseto area only during cold winters. Temperature is one of the most important variables known to affect the likelihood of migratory bird departure (Gordo, 2007; Burnside *et al.,* 2021; Falchi *et al.,* 2023); therefore we should expect an inverse correlation between the number of cold days and our January count data. On the contrary, the correlation is not significant, and, as stated above, the Stone-curlew population in the Grosseto area appears to be largely resident (Falchi *et al.,* 2023). Both of these facts do not suggest that some birds leave the area during cold winters.

The GPS data help to explain, at least in part, the variability in counts over the last ten years. Stone-curlews exhibited two contrasting behaviours: they showed remarkable fidelity to some roosting places that are regularly used for many years, but they also demonstrated great mobility among different roosts, and sometimes they used new places never selected before, albeit for a short period. Tagged birds spent an average of 8.2 days (13% of the monitored season) in sites that we did not survey for various reasons (see Methods). Since in past years we have discovered new roosts, it is reasonable to assume that we probably still do not know all the roost sites in the 4,500km^2 that comprise Grosseto province. Therefore, the most likely explanation for the variability in counts is that, on some survey days, we missed part of the bird population.

For the reasons mentioned above, a definitive estimate of the minimum and maximum number of birds wintering in the Grosseto area is not possible. In the last six years the minimum number was around 250-350 birds, while the maximum reached 534 in 2017. Given the high mobility and elusive behaviour of stone-curlews, as noted earlier, these figures probably underestimate the true size of the population, although we are confident that they are more accurate than those provided in a previous study (Dragonetti *et al.,* 2014), where the minimum ranged between 80-190 and the maximum recorded count was 290 birds across eight known roosts. That previous work also found a large annual fluctuation in recorded bird numbers, supporting the hypothesis that bird mobility and elusive behaviour lead to part of the population being missed in some surveys.

The timing of roost occupancy provides interesting insights into Stone-curlew behaviour: most roost changes occurred at the beginning of the daylight period, and therefore can be considered, in the majority of cases, unforced choices made by the birds. Nevertheless, a noticeable number of daylight roost changes were likely to have been driven by significant disturbance factors or predation attempts, as Stone-curlews tend to remain in the same roosting spot until sunset (Vaughan & Vaughan-Jennings, 2005). These forced departures corresponded, on average, to roughly 5% of the study period (62 days) for GPS-tagged birds.

Since the early 2000s, the agricultural landscape of Grosseto province has changed markedly: industrially managed vineyards expanded from 5,822ha in 2000 (Informazioni Statistiche, 2002) to 9,551ha in 2021 (+64%) (Del Bravo, 2022), while cereal cultivation declined by about 55%, and livestock (sheep, cattle, horses, goats) by about 37%. Over the same period, fodder crops and permanent meadows increased by about 24% (Regione Toscana Documenti, 2000; Regione Toscana Statistiche, 2021). Monitoring the population status and dynamics of this sensitive bird species is thus essential, given the substantial environmental changes it faces. Notably, vineyards now account for 30% of roosting sites, suggesting that the Stone-curlew has partially adapted to this expanding intensive crop. However, while vineyards may offer suitable winter roosts, they are also often used for nesting in spring, when intensive management frequently causes clutch losses (M. Dragonetti and D. Giunchi, pers. obs.). Another 30% of roosts are found in pastures and sown fields (mainly fodder crops), linked to livestock breeding. Despite a reduction in livestock numbers –mainly due to small farm closures– the increase in fodder and meadow areas, and the persistence of large-scale operations, support Stone-curlews by providing food during breeding (Giovacchini *et al.,* 2017) and aiding winter survival (Giovacchini *et al.,* 2012). A third key roosting habitat is worked soil (see Methods). Therefore, a diverse agricultural landscape, maintaining traditional practices like livestock breeding, is vital for the conservation of wintering Stone-curlews.

The negative impact of disturbing factors, affecting approximately 6% of the 388 roost surveys, was relatively low but not negligible. However, we emphasise that this figure represents only the most severe disturbances and closely aligns with GPS data on forced departures from roosts during daylight hours. However, it does not account for other disturbance events. For example, the survey itself is a mild disturbance that does not force birds to abandon the site but may slightly influence their behaviour. In this context, our basic information can serve as a resource for future research on the process of 'Threat Analysis' by facilitating the collection of quantitative data on various disturbance factors (Salafsky *et al.,* 2008; Audinet *et al.,* 2021; Bauer *et al.,* 2022; Battisti *et al.,* 2023). Specifically, the information related to anthropogenic disturbance caused by hunting aims to quantify a disruptive event, allowing for an assessment of its effects within a specific context (see attribute 'Intensity') in relation to different environmental components (Sousa, 1984; Battisti *et al.,* 2016). Even forms of disturbance linked to traditional land use, such as livestock grazing observed in our research, can be related to the ecology, distribution, and behaviour of this species. In fact, the presence of Stone-curlews in roosts is associated with vegetation height, leading to spatially and temporally variable impacts throughout the year (Green & Taylor, 1995).

In conclusion, the wintering population of Stone-curlews in the Grosseto province has not shown any significant numerical trend over the last decade and can be considered relatively stable, with a maximum estimated number of 500-600 birds. This figure is higher than previous estimates (Dragonetti *et al.,* 2014), but given the high mobility and elusive behaviour of Stone-curlews, we believe that the risk of underestimation is greater than that of overestimation. Since this population is predominantly resident, it is likely that the number of birds during the breeding season is of a similar magnitude.

The species has demonstrated remarkable resilience to the dramatic changes in the agricultural landscape that have occurred over the last two decades, sometimes even managing to exploit these changes to some extent. A long-term study of Stone-curlews in the Deux-Sèvres district (an intensively managed farmland area in the Poitou-Charentes Region of central-western France) by Gaget *et al.* (2019) reported a 26% decline in the local population over 14 years, with agricultural intensification cited as a key factor adversely affecting the sustainability of Stone-curlew populations. Several studies have documented strong declines in other Charadriiform species (Andres *et al.,* 2012; Studds *et al.,* 2017; Schekkerman *et al.,* 2018; Belo *et al.,* 2022), where the trend of declining numbers across all major flyways was largely attributed to habitat loss and human disturbance. Our data emphasise the importance of traditional farming practices, such as livestock breeding, fodder production, cereal cultivation and pasture retention, which fortunately remain significant in Grosseto province, for the survival of sensitive species like the Stone-curlew.

ACKNOWLEDGEMENTS.—This paper is dedicated to the memory of Alessia Mori and Angelo Meschini, and to their deep fondness for the Stone-curlew.

We would like to thank all the people who helped us in the field: P. Arzuffi, F. Avogadro, C. Caccamo, F. Corsi, M. Lamberti, C. Martelli, R. Sirna, S. Vignali. In particular, we would like to thank Azienda Bio-Agricola "La Selva" for financial support. The comments of two anonymous referees and the suggestions of Associate Editor Chiara Bettega greatly improved an earlier draft of the manuscript. All protocols involving animals were conducted in accordance with ethical standards and Italian regulations on animal welfare. All procedures were approved by the Italian Institute for Environmental Protection and Research (ISPRA).

AUTHOR CONTRIBUTIONS.—Marco Dragonetti supervised the overall study, conducted the fieldwork, and wrote the manuscript. Valentina Falchi, Fabrizio Farsi, Luca Passalacqua and Angela Picciau conducted the fieldwork and contributed to manuscript editing. Dimitri Giunchi performed the statistical analysis, applied GPS devices to the birds, directed GPS data acquisition, and edited the manuscript. Pietro Giovacchini supervised the overall study, directed and organised the fieldwork, and edited the manuscript.

Funding.—The study was partially supported by the University of Pisa, "Azienda Bio-Agricola La Selva" organic farm and the Gruppo Ornitologico Maremmano.

Disclosure statement.—No potential conflict of interest was reported by the author(s).

References

Archivio Meteo Storico Grosseto. MeteoRed Italia. Downloaded from https://www.ilmeteo.net/meteo_Grosseto-Europa-Italia-Grosseto--sactual-30011.html

Audinet, J.P., Baldrati, T., Bonelli, P., Cecilia, G., Giacomo, U.D., Panuccio, G. & Battisti, C. (2021). Searching the effectiveness within conservation projects: Applying the Swiss Cheese Theory to the creation of a supplementary feeding station for the Black Kite Milvus migrans in central Italy. *Avocetta,* 45: 183-191.

Baccetti, N., Dell'Antona, P., Magagnoli, P., Melega, L., Serra, L., Soldatini, C. & Zenatello, M. (2002). Risultati dei censimenti degli uccelli acquatici svernanti in Italia: distribuzione, stima e trend delle popolazioni nel 1991-2000. *Biologia e conservazione della fauna,* 111: 135-136.

Barron, D.G., Brawn, J.D. & Weatherhead, P.J. (2010). Meta-analysis of transmitter effects on avian behaviour and ecology. *Methods Ecol. Evol.,* 1: 180-187.

Battisti, C., Poeta, G. & Fanelli, G. (2016). An Introduction to Disturbance Ecology. A Road Map for Wildlife Management and Conservation. Springer International Publishing. Switzerland.

Battisti, C., Perchinelli, M., Vanadia, S., Giovacchini, P. & Marsili, L. (2023). Monitoring effectiveness of an operational project on two threatened landbirds: Applying a before-after threat analysis and threat reduction assessment. *Land,* 12: 464.

Bauer, H., Dickman, A., Chapron, G., Oriol-Cotterill, A., Nicholson, S.K., Sillero-Zubiri, C., Hunter, L., Lindsey, P. & Macdonald, D.W. (2022). Threat analysis for more effective lion conservation. *Oryx,* 56: 108-115.

Biondi, M., Pietrelli, L., Scrocca, R. & Meschini, A. (2011). New Stone-Curlew *Burhinus oedicnemus* wintering site in central Italy. *Wader Study Group Bulletin,* 118: 63-64.

BirdLife International (2017). European birds of conservation concern: populations, trends and national responsibilities. BirdLife International. Cambridge.

BirdLife International (2024). Species factsheet: *Burhinus oedicnemus*. Downloaded from https://datazone.birdlife.org/species/factsheet/eurasian-thick-knee-burhinus-oedicnemus (accessed on 03/03/2024).

Brichetti, P. & Fracasso, G. (2004). Ornitologia Italiana. Vol. 2. Alberto Perdisa Editore. Bologna.

Burnside, R.J., Salliss, D., Collar, N.J., Dolman, P.M. (2021). Birds use individually consistent temperature cues to time their migration departure. *Proc Natl Acad Sci USA,* 118: 1-7.

Coretta, S. (2023). tidygam: Tidy Prediction and Plotting of Generalised Additive Models. R package version 0.2.0. https://github.com/stefanocoretta/tidygam.

Cramp, S. & Simmons K.E.L. (1983). The birds of the western palearctic. Vol 3. Oxford University Press. Oxford.

Dedeban, E., Lagrange, P., Villers, A., Augiron, S., Chiron, D., Boussac, L., Martineau, A., Bouten, W. & Bretagnolle, V. (2025). Migration and wintering strategies of a Eurasian Stone-curlew (*Burhinus oedicnemus*) continental population, and their conservation implications. *Avian Conservation and Ecology,* 20: 5. https://doi.org/10.5751/ACE-02772-200105

Delany, S. (2005). Guidelines for participants in the International Waterbird Census (IWC). Consultation draft. Wetlands International. Bruxelles.

Delany, S., Scott, D., Dodman, T. & Stroud, D. (Eds.). (2009). An Atlas of Wader Populations in Africa and Western Eurasia. Wetlands International. Bruxelles.

Del Bravo, F. (2022). I numeri del vino in Toscana. ISMEA Regione Toscana. Firenze, p. 7.

Directive 2009/147/EC of the European Parliament and of the Council of 30 november 2009 on the conservation of wild birds. Annex I.

Dragonetti, M., Corsi, F., Farsi, F., Passalacqua, L. & Giovacchini, P. (2014). Roosting behaviour of Stone curlews *Burhinus oedicnemus* wintering in Central Italy. *Wader Study Group Bulletin,* 121: 1-6.

Eiserer, L.A. (1984). Communal roosting in birds. *Bird Behavior,* 5: 61-80.

Falchi, V., Cerritelli, G., Barbon, A., Catoni, C., Cutroneo, A., Dell'Omo, G., Dragonetti, M., Giovacchini, P., Meschini, A., *et al*. (2023). Inter and intra-population variability of the migratory behaviour of a short-distance partial migrant, the Eurasian Stone-curlew *Burhinus oedicnemus* (Charadriiformes, Burhinidae). *Journal of Ornithology,* 164: 85-100.

Giovacchini, P. & Stefanini, P. (2008). La Protezione della Natura in Toscana. Siti di Importanza Regionale e Fauna Vertebrata nella Provincia di Grosseto. Provincia di Grosseto, UOC Aree Protette e Biodiversità. Quaderni delle Aree Protette nº 3.

Giovacchini, P., Corsi, F., Farsi, F. & Dragonetti, M. (2012). Monitoraggio invernale dell'Occhione (*Burhinus oedicnemus*) in provincia di Grosseto con l'uso del playback. *Rivista Italiana di Ornitologia,* 82: 80-84.

Giovacchini, P., Dragonetti, M., Farsi, F. & Cianferoni, F. (2017). Winter Diet of Eurasian Stone-curlew, *Burhinus oedicnemus* (L., 1758) (Aves: Charadriiformes) in a Mediterranean Area (Tuscany, Central Italy). *Acta Zoologica Bulgarica,* 69: 323-326.

Giunchi, D., Caccamo, C., Mori, A., Fox, J.W., Rodriguez-Godoy, F., Baldaccini, N.E. & Pollonara, E. (2015). Pattern of non-breeding movements by Stone-curlews *Burhinus oedicnemus* breeding in Northern Italy. *Journal of Ornithology,* 156: 991-998.

Giunchi, D. & Meschini, A. (2022). Occhione. In R. Lardelli, G. Bogliani, P. Brichetti, E. Caprio, C. Celada, G. Conca, F. Fraticelli, M. Gustin, O. Janni, P. Pedrini, L. Puglisi, D. Rubolini, L. Ruggeri, F. Spina, R. Tinarelli, G. Calvi & M. Brambilla (a cura di). Atlante degli Uccelli Nidificanti in Italia, pp. 196-197. Edizioni Belvedere (Latina).

Gordo, O. (2007). Why are bird migration dates shifting? A review of weather and climate effects on avian migratory phenology. *Climate Research,* 35: 37-58.

Green, R.E. & Taylor, C.R. (1995). Changes in Stone Curlew *Burhinus oedicnemus* distribution and abundance and vegetation height on chalk grassland at Porton Down, Wiltshire. *Bird Study,* 42: 177-181.

Griffiths, R., Double, M.C., Orr, K. & Dawson, R.J.G. (1998). A DNA test to sex most birds. *Molecular Ecology,* 7: 1071-1075.

Gustin, M., Nardelli, R., Brichetti, P., Battistoni, A., Rondinini, C. & Teofili, C. (2021). Lista Rossa IUCN degli uccelli nidificanti in Italia 2021. Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Roma.

Hume, R. & Kirwan, G.M. (2020). Eurasian Thick-knee (*Burhinus oedicnemus*), version 1.0. In Birds of the World (Del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A. & De Juana, E., Editors). Cornell Lab of Ornithology. Ithaca. https://doi.org/10.2173/bow.eutkne1.01

Informazioni Statistiche (2002). Quinto censimento generale dell'Agricoltura – Risultati definitivi per la Toscana. Regione Toscana, Firenze. Supplemento 30, p. 10.

Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvanová, A. & Kalyakin, M.V. (2020). European breeding bird atlas 2: Distribution, abundance and change. European Bird Census Council (EBCC) and Lynx Edicions. Barcelona.

Kenward, R.E., Clarke, R.T., Hodder, K.H. & Walls, S.S. (2001). Density and linkage estimators of home range: nearest-neighbor clustering defines multinuclear cores. *Ecology,* 82: 1905-1920.

Mangiafico, S. (2023). rcompanion: Functions to Support Extension Education Program Evaluation. version 2.4.34. Rutgers Cooperative Extension. New Brunswick, New Jersey. https://CRAN.R-project.org/package=rcompanion

Nardelli, R., Andreotti, A., Bianchi, E., Brambilla, M., Brecciaroli, B., Celada, C., Dupré, E., Gustin, M., Longoni, V., *et al*. (2015). Rapporto sull'applicazione della Direttiva 147/2009/CE in Italia: dimensione, distribuzione e trend delle popolazioni di uccelli (2008-2013). ISPRA, Serie Rapporti 219/2015.

R Core Team (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna. https://www.R-project.org/

Rappole, J.H. & Tipton, A.R. (1991). New harrnless design for attachment of radio transmitters to small passerines. *J. Field Ornithol.,* 62: 335-337.

Rasmussen, P.C. & Anderton, J.C. (2005). Birds of South Asia: the Ripley guide. Smithsonian Institution, Washington D.C. and Lynx Edicions. Barcelona.

Regione Toscana Documenti (2000). 5° Censimento generale dell'Agricoltura. 22 Ottobre 2000. ISTAT. https://www.regione.toscana.it/documents/10180/479267/Volume%20completo%20-%20le%20caratteristiche%20strutturali%20delle%20aziende%20in%20Toscana/9021ba20-79c5-40b8-8644-fa9bb5d20a83

Regione Toscana Statistiche (2021). 7° Censimento generale dell'Agricoltura. 30 Luglio 2021. ISTAT. https://www.regione.toscana.it/-/7%C2%B0-censimento-generale-dell-agricoltura-i-risultati-definitivi?inheritRedirect=true&redirect=%2Fsearch%3Fq%3D7%25C2%25B0%2Bcensimento%2Bgenerale%26orderBy%3Dhits%26sortBy%3Ddesc%26type%3Dcom.liferay.journal.model.JournalArticle

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L.L., *et al*. (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology,* 22: 897-911.

Simoncini, A., Ramellini, S., Falaschi, M., Brambilla, M., Martineau, A., Massolo, A. & Giunchi, D. (2025). Steppe-land birds under global change: Insights from the Eurasian Stone-curlew (*Burhinus oedicnemus*) in the Western Palearctic. *Global Ecology and Conservation,* 58: e03478. https://doi.org/10.1016/j.gecco.2025.e03478

Sousa, W.P. (1984). The role of disturbance in natural communities. *Annual review of ecology and systematics,* 15: 353-391.

Spencer, R. (1982). Birds in winter – an outline. *Bird Study,* 29: 169-182.

Sutherland, W.J. (ed. 2006). Ecological census techniques: a handbook. Cambridge University Press. Cambridge.

Tellini Florenzano, G., Arcamone, E., Baccetti, N., Meschini, E. & Sposimo, P. (eds. 1997). Atlante degli uccelli nidificanti e svernanti in Toscana (1982-1992). Quaderni Mus. Stor. Nat. Monografie 1. Livorno.

Thieurmel, B. & Elmarhraoui, A. (2022). Suncalc: Compute Sun Position, Sunlight Phases, Moon Position and Lunar Phase. R package version 0.5.1, https://github.com/datastorm-open/suncalc

Tinarelli, R., Alessandria, G., Giovacchini, P., Gola, L., Ientile, R., Meschini, A., Nissardi, S., Parodi, R., Perco, F., *et al*. (2009). In Consistenza e distribuzione dell'occhione in italia: Aggiornamento al 2008. (Giunchi, D., Pollonara, E. & Baldaccini, N. E. Eds. Vol. 7, pp. 45-50). Consorzio del Parco Fluviale Regionale del Taro.

Vaughan, R. & Vaughan-Jennings, N. (2005). The Stone Curlew *Burhinus oedicnemus*. Isabelline Books. Cornwall.

Zenatello, M., Baccetti, N. & Borghesi, F. (2014). Risultati dei censimenti degli uccelli acquatici svernanti in Italia. Distribuzione, stima e trend delle popolazioni nel 2001-2010. ISPRA Serie Rapporti. 206/2014.

Wang, S. & Chu, L.M. (2021). Microhabitat characteristics related to seasonal roost switching: implications from a threatened and introduced cockatoo species in an urban landscape. *Avian Research,* 12: 35-44. https://doi.org/10.1186/s40657-021-00270-9

Wood, S.N. (2017). Generalized Additive Models: An Introduction with R (2nd edition). Chapman and Hall/CRC. Boca Raton.

Supplementary Electronic Material

Additional supporting information may be found in the online version of this article. See volume 73(1) on www.ardeola.org

[Disponible información adicional sobre este artículo en su versión en línea. Consulte el volumen 73(1) de nuestra revista digital en www.ardeola.org]

Figure S1. Daylight movements over eleven days of one GPS-tagged Stone-curlew in a habitually used roost; red dots represent GPS fixes (n = 73); yellow polygon indicates boundaries of the surveyed area of this roost site; white

polygons show adjacent fields regularly occupied by the flock during winters.
[Desplazamientos diurnos durante once días de un Alcaraván común marcado con GPS en un dormidero utilizado habitualmente; los puntos rojos representan las localizaciones GPS (n = 73); el polígono amarillo indica los límites del área censada de este dormidero; los polígonos blancos muestran los campos adyacentes ocupados regularmente por el grupo de aves durante las temporadas invernales.]

Figure S2. Daylight movements over two days of one GPS-tagged Stone-curlew in an erratic roost; orange dots = GPS fixes (n = 13); yellow polygon = approximate boundaries of the roost site.
[Desplazamientos diurnos durante dos días de un Alcaraván común marcado con GPS en un dormidero utilizado de forma errática; los puntos naranjas representan las localizaciones GPS (n = 13); el polígono amarillo indica los límites aproximados del área de descanso.]

Figure S3. Scatterplot of the number of days with minimum temperature below 1ºC and the percentage variation in annual January 3rd counts of roosting Stone-curlews (Dec 1 counts = 100%; see Methods). Spearman's rs (0.26) is not statistically significant.
[Correlación entre el número de días con una temperatura mínima inferior a 1ºC y la variación porcentual en los conteos anuales del 3 de enero de Alcaravanes comunes en dormideros (los conteos del 1 de diciembre se establecen en 100; véase Métodos). El coeficiente de Spearman (rs = 0.26) no es estadísticamente significativo.]

Figure S4. Stopover sites of eight GPS-tagged Stone-curlews. Blue symbols indicate sites outside the study area (Grosseto province); red symbols represent stopover sites during spring migration within the study area; the yellow symbol marks the only stopover site during winter within the study area (see text). Data from Falchi *et al*., 2023.
[Sitios de escala de ocho Alcaravanes comunes marcados con GPS. Los símbolos azules indican sitios fuera del área de estudio (provincia de Grosseto); los símbolos rojos representan sitios de escala durante la migración primaveral dentro del área de estudio; el símbolo amarillo marca el único sitio de escala durante el invierno dentro del área de estudio (véase el texto). Datos tomados de Falchi et al., *2023.]*

Received: January 8, 2025
Major revision: February 12, 2025
Accepted: May 26, 2025

Editor: Chiara Bettega