

# Breeding ecology, helpers presence, habitat use and trophic activity of the Greater Short-toed Lark *Calandrella brachydactyla*: five years of study in Central Adriatic Italy

Marco Pantalone<sup>1,2\*</sup>, Simone Ottorino Bai<sup>1</sup>

**Abstract** - The Greater Short-toed Lark *Calandrella brachydactyla* is a migrant bird, considered of conservation concern, but poorly studied in Italy about his breeding ecology and habitat use. In this work, we aimed to study both of these components in the airfield of Fano (Central Italy, Marche, Pesaro-Urbino province). The study, relating to the 2018-2022 reproductive seasons, describes the nesting habitat used by the species, providing also data about the plants on which the species feed on. We hypothesized the importance of the choice of fenced areas for the less predation and we highlighted the presences of young helpers in the feeding of the second brood. Furthermore, we observed the formation of crèches for the young fledglings, controlled by some adult males. It's confirmed here a semi-colonial condition that leading to the formation of extra-family groups before migration. The study area turns out to be the main reproductive colony of the species in the Marche region, with an average density of 1.5 pairs per 10 ha (maximum 2.4), one of the best know in central Italy.

**Key words:** Greater Short-toed Lark, *Calandrella brachydactyla*, Marche, airport, helper, crèches.

**Riassunto** - Ecologia riproduttiva, presenza di helper, utilizzo dell'habitat e attività trofica della calandrella *Calandrella brachydactyla*: cinque anni di studio nell'Italia centrale adriatica.

La calandrella *Calandrella brachydactyla* è una specie migratrice di interesse conservazionistico, ma poco studiata in Italia riguardo alla sua ecologia riproduttiva e all'uso dell'habitat. In questo lavoro, ci siamo dedicati allo studio di entrambe queste componenti, nel campo di aviazione di Fano (Italia centrale, Marche, provincia di Pesaro-Urbino). Lo studio, relativo alle stagioni riproduttive 2018-2022, descrive l'habitat di nidificazione utilizzato dalla specie, fornendo anche dati sulle piante delle quali si nutre. si nutre la specie. Ipotizziamo l'importanza nella scelta di aree recintate a causa della minor predazione ed evidenziamo la presenza di giovani helper nell'alimentazione della seconda covata. Inoltre, abbiamo osservato la presenza

di asili per i giovani involati, controllati da alcuni maschi adulti. Si conferma qui la condizione semi-coloniale, che porta alla formazione di gruppi sovra familiari prima della migrazione. L'area oggetto di studio si rivela essere la principale colonia riproduttiva della specie nelle Marche, con una densità media di 1.5 coppie per 10 ha (maximum 2.4), una delle migliori conosciute del centro Italia.

**Parole chiave:** calandrella, *Calandrella brachydactyla*, Marche, aereoporto, helper, asili per juveniles.

## INTRODUCTION

The Greater Short-toed Lark *Calandrella brachydactyla* is a polytypical species, with a Euro-Centro-Asian-Mediterranean distribution (de Juana *et al.*, 2020; Collar *et al.*, 2022). It's a thermophilic species and likes arid plains, dry and warm environment, normally at low altitude (sea level to 600 m asl), with bare soil patches a short vegetation like salt fields, fallows, stubbles, grasslands or sandy terrains close to the edge of waterbodies, breeding also in vineyards, tobacco, sugar beet, potato, alfalfa or lavender fields (Brichetti & Fracasso, 2007, 2020; Gordo, 2020). This species show a semi-colonial nesting behaviour, but the presence of helpers and nurseries, in larks generally rare (Stey, 1988), are little know also due to the few dedicated studies. Instead it was tested the presence of cuckoldry and extra-pair paternity in this species (Sánchez *et al.*, 2004).

In Italy it's a regular migrant and breeder throughout the national territory, including some minor islands, but its distribution is not uniform, presenting wide gaps in its range (Brichetti & Fracasso, 2020). In the central regions of the peninsula it's more frequent in the Tyrrhenian side, scarce and localised on the eastern side, albeit with the presence of disjunct nuclei in the upper Adriatic and in the Po Valley (Brichetti & Fracasso, 2007). In the Marche region the species is considered a regular migrant and breeder (Giacchini, 2003), with identical phenology in the province of Pesaro-Urbino (Pantalone *et al.*, 2022), with high fidelity to very rare nesting areas. Bearing in mind that information on the reproductive biology of the Greater Short-toed Lark (hereafter Short-toed Lark) in Italy is generally scarce (Karaardıç & Özkan, 2013; Chiatante, 2022), the present research start to the presence of one of the historical breeding sites in the Urbino area, which has been documented since 1988 (Poggiani & Dionisi, 1988,

<sup>1</sup> Associazione naturalistica "Argonauta", Via P. Malatesta 2, 61032 Fano (Pesaro-Urbino), Italia.

E-mail: argonautafano@yahoo.it

<sup>2</sup> SOA - Stazione Ornitologica Abruzzese, Via A. De Nino 3, 65126 Pescara, Italia.

E-mail: stazioneornitologicaabruzzo@gmail.com

\* Corresponding author: pantalone.marco@libero.it

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2019; Pandolfi & Giacchini, 1995), corresponds to Fano airport (PU) and the territory immediately north of it. The aims of this work it's not only to study the habitat used by the species for breeding, the nesting and rearing period of youngs, the presence of semi and extra-familiar behaviour, but also to investigate the feeding habits of the Short-toed Lark. Such knowledge and understanding of the species' ecology and their habits, it's vital in order to apply adequate management schemes for its conservation (Sinclair *et al.*, 2006; Morrison & Mathewson, 2015; Zurdo *et al.*, 2023).

## STUDY AREA

The study area is located in Marches region, 10 m a.s.l. and 1 km from the Adriatic coast (central coordinates 43° 49' 27.70" N 13° 01' 22.15" E). It comprises the north-western part of Fano Airport (ha 21,4), the arable land and the fields of alfalfa *Medicago sativa* (ha 21,70) and the small areas of spontaneous vegetation (ha 2,48) immediately to the north of the latter, continuing over a total area of just over 50 ha. The remaining part of the airfield area, although mostly grassland, does not regularly host the Short-toed Lark, due to the disturbance caused by the activity of the runway and parachutists. The area referred to here as the airfield is characterised by the presence on its entire perimeter of a 2 m high wire fence topped by 30 cm of barbed wire, sloping towards the inside of the area. The fence has no passages or openings, with the exception of the two agricultural entrances, which are opened a few times a year for a few minutes.

## Vegetation

The herbaceous cover of the study area is around 92% (Tab. 1) and the reference alliance is *Inulo viscosae-Agropyron repentis* (post-crop formation widespread in uncultivated land and abandoned fields). Due to mowing and drought the effective herbaceous cover is reduced to 49,6% in July and August. Considering the presence of numerous different vegetation areas regularly used by the species, the area was divided into 3 distinct sectors (Fig. 1).

### A Inside the airfield

Extent ha 21.4. During the first years of the study, the area was cultivated with alfalfa, in recent years this cultivation has however been abandoned and other wild annual species have taken over, colonising the area. The lat-

ter, being fenced off and not accessible, did not allow for an accurate vegetation analysis, or indeed the sampling of all the main herbaceous species present. The study area, during the breeding period of the Short-toed Lark, is subjected to two mowings (mid-late April and late July), which makes the height of the vegetation variable, sparse and low in the very hot season and with a height of no more than 10-20 cm. During the study period, the area was only weeded in June 2020.

### B The large fields immediately north of the fence

Extent ha 21.7. The area was mowed twice during the breeding season of Short-toed Lark, in early April and in late May/early June, although the second mowing is not normally carried out in the case of high temperatures or a dry spring. The vegetation in this area is characterised by the dominance of *Bromopsis erecta* (Huds.) Fourr., *Bothriochloa ischaemum* (L.) Keng, *Dactylis glomerata*, *Lolium multiflorum* and *Lolium perenne*. The area has never been weeded.

### C Old hangar concrete basement

Extent ha 0.72. The area comprises the large concrete basement of the old airfield hangars, gradually recolonised by herbaceous species. It's arid grassy uncultivated land with a prevalence of *Arthemisia vulgaris* L., *Cichorium intybus* L., *Echium italicum* L., *Echium vulgare* L., *Salvia verbenaca* L. (S1). This sector is often used by the Short-toed Lark for trophic activity, due to the ease of finding the plants, seeds and insects on which the species feeds, which are easy to spot in this area due to the scattered vegetation and the concrete basement, which forces prey to move around in the open.

## Climatic characteristics

The study area has an annual rainfall of 750 mm and a yearly average temperature of 15.1° (Karger *et al.*, 2017). Winters are cold and summer are hot and dry. During the nesting seasons, average monthly temperature increases (during the study period, mean temperatures in April, May, June, July and August, 7.4, 11.3, 14.2, 16.8 and 17.1 C°, respectively) as does average monthly rainfall (during the study period 46, 53, 72, 76 and 107 mm, respectively) (Karger *et al.*, 2017). Between June and August, there are long periods of heat and no rain (with temperatures as high as 40°) and strong and sudden thunderstorms. In the study area normal wind direction is N/NE or SE/ESE.

Tab. 1 - Vegetation cover of the study area. / Copertura vegetazionale dell'area di studio.

| Land Cover Class   | Area (ha) | Area (%) |
|--|-----------|----------|
| Arable lands and dry grasslands                                | 43.09     | 84.80    |
| Fallows, shrublands, Mediterranean maquis and roadside margins | 1.08      | 2.13     |
| Hedgerows  | 1.47      | 2.89     |
| Roads  | 2.60      | 5.23     |
| Uncultivated lands   | 2.48      | 4.81     |
| Buildings  | 0.03      | 0.05     |

### Anthropogenic disturbance

The entire study area (excluding the part inside the airfield, which is only affected by medium to low daily aircraft activity) is characterised by constant anthropogenic disturbance (passage of cars, motorbikes and bicycles, runners, walkers with unleashed dogs and dog training from mid-August). The area inside the airfield and the large prairie immediately to the north are mowed every year by heavy machinery.

### Predator presence

The detection of predators present in the study area is important, considering the high percentage of nest predation involving larks in general, and the Short-toed Lark in particular (Yanes & Oñate, 1996; Karaardıç & Özkan, 2013). In terms of birds, there are few individuals of common kestrel *Falco tinnunculus*, common buzzard *Buteo buteo*, eurasian magpie *Pica pica* and hooded crow *Corvus corone cornix*, while numerous groups of



#### Areas of Interest



Study Area

#### Land Cover Classes

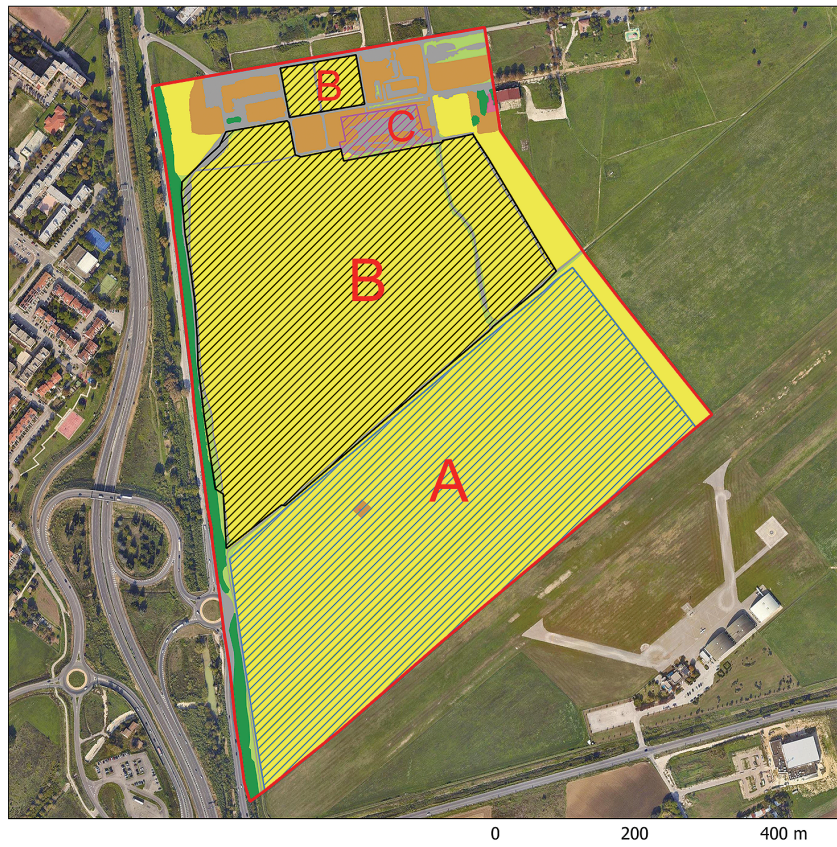
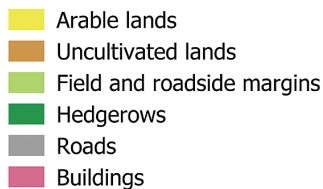


Fig. 1 - The study area in Fano (Marches, Central Italy)/ L'area di studio a Fano (Marche, Italia centrale).

yellow-legged gull *Larus michahellis* are often present, either resting or roosting (Poggiani & Dionisi, 2019; Bai & Pantalone, 2020). With regard to reptiles that could prey on ground nests, the presence of the green whip snake *Hierophis viridiflavus* and the Italian aesculapian snake *Zamenis longissimus* (Poggiani & Dionisi, 2020) are very scarce, which is also due to the regular mechanised grass cutting carried out in much of the study area. In terms of mammals present in the study area (Poggiani & Dionisi, 2015), the beech marten *Martes foina* and the least weasel *Mustela nivalis* (very rare) are present, in addition to the brown rat *Rattus norvegicus* and the European hedgehog *Erinaceus europaeus* (rare). All other terrestrial predators present, such as the red fox *Vulpes vulpes*, the wild boar *Sus scrofa* (rare in the study area) and above all the numerous unleashed and feral dogs *Canis familiaris*, cannot enter the airfield, but only move around the remaining part of the study area, due to the presence of the high fence. In contrast, feral cats *Felis catus*, which can easily cross the fence, are rather rare in the study area.

## MATERIAL AND METHODS

Field work was carried out from 15 March to 15 September in the period 2018-2022. Short-toed Larks were located through the systematic observation of the grassland ground vegetation, 2-3 days a week, 1 or 2 times a day, for 1-3 consecutive hours in the morning or in the afternoon (317 total hours of field observations), using the technique of non-standardised transects (Järvinen & Väisänen, 1975). We used 10x binoculars, 30-60x spotting scopes and digital cameras during the censuses. The study area allows access by car for a large part of its extension, making it possible to easily carry out close observations of the various individuals of Short-toed Lark, without disturbing them. For the location of nests random field transects and visual observation of adult behaviour were used, especially in the regular movements to the nest, related to the feeding of the chicks, also considering that for the larks a grid of 100 m, mean home-range size of 1 ha, was used (Brambilla & Rubolini, 2009; Guerrieri & Castaldi, 2010). For the estimation of density and identification of singing males, sampling was carried out by point count (Bibby *et al.*, 1992), using 4 randomly selected sample plots: the annual density of identified singers is calculated by dividing their number by the extension of the study area (50 ha). Eight to ten counts per plot were carried out each year from 30 March to 30 August, at 15-day intervals. For each session, lasting 10 minutes, the Short-toed Larks present in a circular area of 100 m radius were reported. In particular, for the species under study, individuals in territorial song were recorded from 30 March to 15 June each year. The inaccessibility of the sector A did not allow for the orientation of the nests to be determined (Herranz, 2004), also preventing the exact determination of the duration of hatching. For this reason, here we consider the incubation period between 12 and 14 days (Harrison, 1988; Karaardıç & Özkan, 2013) and the time elapsing from laying to fledging. Due to the same problem, we use the observation of fledged juve-

niles with plumage traces to establish the period of the first deposition (Shirihai & Svensson, 2018; Jenni & Winkler, 2020). The identification of adult males in various situations was possible thanks to prolonged observation on various occasions, which allowed them to be identified as such due to their singing and the territorial flights they carried out even in the presence of the crèches. In order to determine the minimum number of pairs present from the end-of-season (4<sup>th</sup> week of August-1<sup>st</sup> and 2<sup>nd</sup> week of September) flock count, an average of 3 fledged chicks per brood was considered (Karaardıç & Özkan, 2013), also taking into account that brood size increases in the middle of the breeding season and then decreases at the end (Suárez, 2005). We consider a total of 8 ind per pair (2 parents + 3 fledglings per brood) and divide by this number the final flock: therefore, we compare this number of possible pairs with the estimated pairs relating to each individual singing male. We underestimate the possible presence of the third broods to equalize the presence of non-reproductive or migratory individuals, taking into account that the latter are very few, based on relating data from the ringing stations active in the area (Spina & Volponi, 2008).

Finally, attention was also paid to climatic variables (average precipitation and temperature in the area), using data reported at a scale of 1 km<sup>2</sup> (average of 1979-2013) from the CHELSA (Climatologies at High resolution for the Earth's Land Surface Areas) climate data collection (Karger *et al.*, 2017). For the floristic list of the study area a starting sample area of 1 m<sup>2</sup> was chosen, with stable and uniform vegetation, subsequently enlarging the area depending on the presence of new species. Nine surveys, repeated in spring and autumn, were carried out on 20 sample areas. The life-forms and the choro-types are taken from Pignatti (1982) was referred to, updating the names according to Conti *et al.*, 2005, Bartolucci *et al.*, 2018 and Galasso *et al.*, 2018.

## RESULTS

Since 2012 the authors of this article have annually observed the presence of the species, with young in plumage or recently fledged, certifying continuous nesting over the last decade. With regard to the presence of other breeding Larks in the study area, a good number of pairs of Eurasian skylark *Alauda arvensis* should be noted.

### Arrival and departure

During the five-year period, the median date of the first observation of the species in the study area was 10 April (min 30 March / max 22 April), while the median date for the departure for the wintering areas was 31 August (min 20 August / max 17 September), always a few days before heavy storms or periods of atmospheric disturbance. Singing males were observed on the days immediately following the first annual sighting: the mean of singers observed during the study period at the beginning of the breeding season was  $4.4 \geq 1.14$  (min 3 / max 6).

### Breeding and helpers

During the present study, it was possible to determine between one and three delimited nesting areas for the species each year (used in the first or second brood), all falling exclusively within the airfield area (Fig. 1), at a distance of between 20 and 40 m from the fence: the inaccessibility of the site prevented close observation of the actual nests, although we were able to delimit nesting areas of 4 m<sup>2</sup>, within which they were placed with certainty, thanks to the visual observations of adult behaviour, and especially the repeated movements to feed chicks. All nesting areas were characterised by the presence of alfalfa in cespitose form, with a height of 15-30 cm. Through observations of fledged juveniles with plumage traces we have determine the period of first deposition at the beginning of May and fledging between the end of May and the beginning of June, while for the second brood, deposition took place in mid-June and fledging in July. It was not possible to determine with certainty whether in some years, for some of the pairs present in the area, there was also a third brood. Despite assiduous searches, no nests were ever found outside the airfield. During the rearing of the second brood, the activity of a juvenile Short-toed Lark belonging to the first brood was witnessed on two occasions (18 June 2019 and 22 June 2021), which repeatedly arrived with a beak full of food in one of the identified nesting areas, leaving it shortly afterwards with nothing.

### Extra-familial groups, nest defence and parental care

Throughout the entire study period, we observed the territorial but also semi-colonial behaviour of the Short-toed Lark. Starting from mid-June each year, extra-family groups of 6-10 recently fledged juveniles were observed feeding on the ground, under the control of 2-3 adult males. In the second half of July each year, the fledglings from the second brood of the pairs that occupied the given area were added to these groups, reaching 13-20 juveniles, albeit always controlled by the same number of adult males as the first brood. Depending on the years and the number of pairs present, between 1 and 4 nurseries were formed each year, the purpose of which seems to be to protect the young of the year: in fact, whenever a danger to the group was perceived, the adult guarding males made their presence clear, while the juveniles hid under clumps of tall, thick grass (a very different behaviour from the camouflage of a single individual, who, when a human approaches, initially turns around showing its camouflage back, then crouches and finally makes a short flight to move away). In addition to this protective attitude towards the fledged young, on 8 July 2021, upon the arrival of three magpie individuals near one of the identified nesting areas, 13 individuals (3 adult males and 10 juveniles of the first brood) flew up from the nearby field where they were feeding and all headed towards the corvids, attracting their attention; a group behaviour which can be traced back to the defence of a nest with brooding females or young. One of the adult males began to make circular flights about 8 metres above the ground, accompanied by vocalisations, to further distract the magpies. The ruse was successful but was not seen repeated

in the presence of kestrels or free-roaming dogs. Finally, every year, in the second half of August, all the family groups present in the study area were observed gathering in a single flock, with a mean of  $59.4 \pm 18.4$  (min 34 / max 85) individuals per year, feeding in clearly delimited areas and moving together, until they left as a group for their wintering quarters.

### Spatial ecology and density

Throughout the five-year study period, the Short-toed Lark was observed using different areas of the study area during the breeding season. In April and May, the species mainly frequented sector A (where the nesting sites are located) and sector B, using the wire netting marking the boundary of the airfield as a privileged perch, both for territorial singing and for returns to the nest (i.e. Giachini, 2007; Poggiani & Dionisi, 2019). In this period the percentage of observations was 42% in sector A and 56% in sector B (N=57). From June onwards, the fledged juveniles and adults (especially males) moved towards the end of this field and into sector C, where they could better identify seeds and insects, and in July and August most individuals could be observed in this area: in this period the percentage of observations was 7.6 % in sector A, 27 % in sector B and 65.3% in sector C (N=78). In the second half of August they tended to group together and could be seen in the concrete area, its outer perimeter and the small fields on the edge of the asphalt road more frequently: in this period the percentage of observation was 66% in sector C and 33% in sector B (N=60). With regard to the pairs present each year in the study area, their minimum number can be derived by taking into account the number of territorial singing males observed, the number of nesting areas identified and the size of the flock gathering all the extrafamilial groups in August. The mean of the minimum pairs per year was  $7.5 \pm 2.9$  (min 4 / max 12), with a maximum density of 2.4 pairs per 10 ha and an average density for the five-year study period of 1.5 pairs per 10 ha.

### Feeding

The characteristics of the study area allowed for very close observations of the species, making it possible to identify numerous plants on which the Short-toed Lark feeds. During the first few weeks of arrival at the nesting sites, the species fed largely on *Avena barbata* and *Avena sterilis*, which are among the few seeds available in April and early May, as well as the sprouts of various grasses. The species' general diet includes *Catapodium rigidum* (L.) C.E.Hubb, *Echium vulgare* (whose seeds it also uses as food) *Petrorhagia saxifraga* (L.) Link and *Plantago coronopus* (Fig. 2). The use of *Catapodium rigidum* (L.) C.E. Hubb, *Medicago sativa* L. and *Anethum foeniculum* L. to hide from predators or shelter from the sun was also frequently observed. In terms of invertebrates, the study area is rich in grasshoppers, hemipterans and beetles, but it was not possible to qualitatively determine the prey caught during the breeding season to feed the chicks.



Fig. 2 - Greater Short-toed Lark in trophic activity on *Plantago coronopus* (2021). / Calandrella in attività trofica su *Plantago coronopus* (2021). (Photo: / Foto: M. Pantalone).

## DISCUSSION

The study area fully meets the characteristics of the preferred nesting sites of the Short-toed lark, a species that prefers dry, steppe-like, arid lowland environments with the presence of non-irrigated crops (Chiatante, 2022), and grassy uncultivated land with low vegetation and stony denuded areas, characterised by very sparse or completely absent tree and shrub cover (Brichetti & Fracasso, 2007). The altitude, the proximity to the coast and the open habitat, which is characterised by a warm and dry climate, also fully respect the characteristics favoured by the species for nesting (Brichetti & Fracasso, 2007). Despite this, the herbaceous cover of the area under study is different from that generally preferred by the Short-toed Lark; which is usually less than 50-60% (Brichetti & Fracasso, 2007), and with a large percentage of bare soil (Suárez *et al.*, 2002). In the study area, the herbaceous cover is 95%, although in July and August it drops considerably, due to mowing with heavy machinery (to which the species seems indifferent) and high temperatures, thus acquiring, albeit temporarily and artificially (i.e. Pesente, 1991), characteristics of steppe or semi-sand, with low vegetation height, as preferred by the species (Suárez *et al.*, 2002). The presence of a alfalfa cultivation in the study area and the use of weed killers once annually and

solely in sector A, are two important factors in making the area suitable for the species (Brotons *et al.*, 2005; Chiatante, 2022): the first maintains the presence of low grass, allowing the species to locate food more easily; the lack of herbicide however allows the Short-toed Lark to have a more abundant source of invertebrates for its diet and to rear nestlings (Ottens *et al.*, 2014).

Apropos vegetation, in the Fano area the species does not use small areas of uncultivated land with the presence of *Artemisia vulgaris*, which is dominant in Spanish nesting territories (Yanes *et al.*, 1995), while *Teucrium* sp. are very rare in Fano, unlike in Iberian breeding areas (Suarez *et al.*, 1993; Yanes *et al.*, 1995). The study area in the Marche Region is situated directly on the border with one of the suitable territories indicated in the Italian habitat suitability model for the species (Londi *et al.*, 2009), albeit with the lowest value for occurrence probability (0 to 0.3), despite having a heterogeneous habitat layout and a varied landscape mosaic, characteristics favoured by larks (Bosco *et al.*, 2020). The Fano study also confirmed the cohabitation of the Short-toed Lark and the Skylark, as already indicated in other publications (Pesente, 1991; Brichetti & Fracasso, 2007). Since the Short-toed Lark is a migratory species, it's possible that it also uses the presence of resident species such as the Skylark (Chiatante,



Fig. 3 - Some juveniles from the first brood feeding in the crèche, controlled by some adults. / Alcuni juveniles della prima covata si nutrono in asilo, controllati da alcuni adulti. (Photo: / Foto: S.O. Bai).

2022) to establish its territory in the study area; bearing in mind that interspecific social attraction is a known phenomenon for grassland birds, linking it to better predator vigilance and/or to higher foraging efficiency guaranteed both by other species (Goodale & Kotagama, 2006). At the level of pre-nesting passages of the species in the Marches (Valentini, 1952) and in Italy (between late March and May, with a peak between late April and early May, but with the presence of stragglers until early June) and post-nesting passages (from mid-August to October, with a peak between September and early October, in Brichetti & Fracasso, 2020) our study confirm that the first arrivals in Fano are in the middle of April, while the departure was by end of August.

The beginning of the breeding season, identified in the five-year study period from the third week of April, also confirms the known nesting period for the species (Pesente, 1991; Karaardıç & Özkan, 2013). Also confirmed was the fact that this period lasts for more than three months (Suárez *et al.*, 2005; Brichetti & Fracasso, 2020) and the presence of a second brood (Harrison, 1988; Karaardıç & Özkan, 2013) or a replacement of the first (failed) brood, which was consistently observed in the five years of surveys, thanks to the observation of fledged youngs. Regarding the possibility of a third brood, on the other hand, no

data was collected on this subject, but there is the possibility that in some years of the five-year period one may have been carried to term, bearing in mind that the Short-toed Lark is a trans-Saharan migrant and therefore very dependent on annual local conditions, which are linked to migration dates (Sanz *et al.*, 2003). Notwithstanding, the possibility of a third brood remains very low, being present in other areas in only 13.5% of cases (Karaardıç & Özkan, 2013). The first brood in Fano occurred shortly after the first mowing in mid-April, while the second took place between the latter and the following mowing at the end of July and so, for a short period, sector A of the study area became unsuitable for nesting, mainly due to the difficult concealment of the nest. This could have led the species to move to sector B, in the small areas characterised by dry grassland (Wilson *et al.*, 1997), such as the edges of gravel roads or fencing, especially considering that these behaviours have been extensively studied in skylarks, which shift their choice between different types of crops or between crops and grassland (Chamberlain *et al.*, 1999; Wolff, 2005; Miguet *et al.*, 2013).

The location of the nests, always falling within the fenced area of the airfield, suggests the species' choice of a territory that provides protection from most terrestrial predators which pose a significant threat to ground-nesting

birds. In fact, the Short-toed Lark suffers a high predation rate, which can reach 70-80% during the incubation stage and even 100% during the nesting period (Suárez *et al.*, 1993). The main nest predators of Mediterranean larks are mostly nocturnal, and find the nests using olfactory cues (Yanes & Suárez, 1996a). From this point of view, the airfield fence, by preventing terrestrial predators (i.e., fox, wild boar, hedgehogs and, first of all, domestic dogs and cats) from accessing the nesting area, drastically reduces the predation rates of eggs and chicks in the nests (Karaardıç & Özkan, 2013). This consequentially increases significantly the reproductive success of the Short-toed Lark (Yanes & Oñate, 1996) confirming that, even in other ground nesting birds, nesting success should rather depend on factors such as shelter from unfavourable environmental conditions and visibility (Yanes *et al.*, 1995). The great attention paid by the species to protecting the nest and especially the brooding female, female is fundamental, considering that lifetime reproductive success in birds mainly depends on life-span (e.g. Newton, 1989) and that the loss of a nest is not as serious as that of an incubating female (Magnhagen, 1991). This seems further demonstrated by the group behaviour observed towards magpies within the airfield, but not repeated in the area outside the enclosure (i.e., regarding the numerous unleashed and feral dogs, which are often one of the main nest predators of larks Suárez *et al.*, 1993; Yanes & Oñate, 1996; Yanes & Suárez, 1996a). All this confirms the tendency of larks and of the Short-toed Lark to nest in safe sites (Yanes & Oñate, 1996), because the danger of predation makes the choice fall back on less accessible sites, which therefore also make it more difficult to capture the adult (Yanes *et al.*, 1995).

The choice of the Fano nesting site, which has been used continuously for at least a decade, has become counter-adaptive, because it guarantees very low predation at the nest and danger of capture for the incubating female (Yanes & Oñate, 1996). The presence of tufts of alfalfa in cespitose form, between 15 and 30 cm high in each of the nesting areas identified, confirms the species' preference for hemispherical chamaephytes with small leaves and open branches, which allow greater visibility between the branches for the female in the nest (Yanes *et al.*, 1995; Frolet, 2003). Sparse vegetation may decrease the predation risk (Whittingham & Evans, 2004) because elements such as tall or dense vegetation could hinder predator perception and thus delay an escape response from peril (Devereux *et al.*, 2006).

As far as the social relationships of the Short-toed Lark are concerned, this study manifesting the activity and presence of two juvenile intraspecific helpers (Skutch, 1935, 1961, 1976, 1999), observed twice during the study period, who, belonging to the first brood of the year, helped in the feeding of their younger brothers and sisters (Skutch, 1961, 1976). It must however be considered that these helpers could also come from the first brood of a nearby nest (Skutch, 1935), even though the minimum distance recorded between two nesting areas is 30 metres, not an impossible distance to cover by a lark. The presence of helpers could be an additional reproductive strategy (Skutch, 1961), originating from evolutionary conditioning related to the high predation mortality in the nest (Yanes

& Suárez, 1996b). This study highlighted the presence of scattered pairs in the Fano area, constituting a small, sparse colony, a characteristic known from the Short-toed Lark (Cramp, 1988; Pesente, 1991; Bricchetti & Fracasso, 2007). The observation of relationships and semi-colonial behaviour, however, revealed the existence of complex social relationships (Møller, 1991; Sánchez *et al.*, 2004), as has been highlighted in the few similar studies on the species (Sánchez *et al.*, 2004). In the event concerning the defence of the nesting area from magpies, the coordinated reaction of adults and juveniles can be placed either in the dynamics of semicolonial birds: as part of the mutual helper, they constitute a sort of standing guard, ever ready to drive undesirable visitors from the nesting area (Skutch, 1961). However, it should not be forgotten to be considered the possibility that there may be adult unmated (non-breeding) intraspecific helpers (Skutch, 1935, 1961, 1999).

Although the presence of mixed pairs could not be determined with certainty, and also considering the fact that parental care and nestling feeding in larks are provided by both sexes (Sánchez *et al.*, 2004), the formation of the small crèches observed annually, can be interpreted in terms of shared paternity. A male (but also a female, although the latter are less frequent as helpers, e.g. Cockburn, 1998), could look after fledged juveniles (that independently feeding) from several broods, in each of which there is one or more of its offspring (Sánchez *et al.*, 2004). The presence of extra-pairs has already been observed in the Short-toed Lark, with individuals with more than one mate and a brood with one female and two males as parents (Sánchez *et al.*, 2004). However, in many semi-colonial species, male-male encounters and chasing behaviours are common, and cuckoldry may be frequent within the family (Møller, 1991; Sánchez *et al.*, 2004). The crèches (Fig. 3) may also originate from the need to help the fledged young in their search for food, as they do not yet have the necessary experience to find it in sufficient quantities (Skutch, 1961). The latest social behaviour observed confirms the species' habit, between mid-August and early September, of bringing together in a single large flock the various family and non-family groups present in the study area, although not on the scale found in Sicily, when we observe groups of 100-150 individuals (Iapichino & Massa, 1989; Corso, 2005). In this pre-migratory phase, all individuals feed together in the same small, delimited areas, then depart together for post-nuptial migration.

With regard to density and space utilisation, in this study the values were higher (1.5 pairs/10 ha) than those recorded in 2007 in the provinces of Rome and Viterbo and in farmland across the Tolfetano, Cerite, Manziata area (1.2 pairs/10 ha) (Bernoni *et al.*, 2012), but lower than those found in Lazio (2.82 pairs/10 ha) at the end of the first decade of the 21<sup>st</sup> century (Sarrocchio *et al.*, 2015). Regarding the space use, it was found that, during the breeding season, the species occupies different areas of the studied territory, as already noted with the Skylarks (Chiatante, 2022). A preference was noted, especially in regard to juveniles, for frequenting bare areas with sparse vegetation for foraging (e.g. sector C, Fig. 1), probably due to the greater ease in identifying seeds.



Finally, the present study makes a contribution to the knowledge of the species' feeding habits: the Short-toed Lark's foraging behaviour consists of walking slowly while searching for seeds and invertebrates (Yanes & Suárez, 1996a). During the five-year study period the species was also seen feeding on vegetative parts, fresh leaves and buds (both during the nesting period and before migration), confirming that which has been previously observed by others (Brichetti & Fracasso, 2007). As pesticides are used once annually, the Fano airfield is also rich in invertebrates such as Orthoptera and Acrididae, in particular grasshoppers, beetles and hemipterans, all predominant invertebrate prey in the diet of the Short-toed Lark during the nesting period (Zurdo *et al.*, 2023). Despite this abundance and the close observation distance, not a single prey was identified during the period of the present study (e.g. Poggiani & Dionisi, 2020).

## CONCLUSIONS

Taking into account the considerable decrease suffered in Italy over the last twenty years (Massa & La Mantia, 2010; Rete Rurale Nazionale & LIPU, 2015; Brichetti & Fracasso, 2020) and the fact that in the Marches region (Valentini, 1952; Tellini, 1987) and in the province of Pesaro-Urbino (Pandolfi & Giacchini, 1995), the Short-toed Lark has long been a rare and scarce breeder, safeguarding and conserving the current characteristics of the Fano habitat is fundamental for the protection at regional level of the species, classified as EN (endangered) in Italy (Gustin *et al.*, 2019) and listed in Annex I of the EU Birds Directive 147/2009/EC concerning the conservation of wild birds (Nardelli *et al.*, 2015). The presence of the Short-toed Lark in Fano represents an important element of biodiversity for the Adriatic central Italy, and the local airfield has proved to be a particularly suitable territory for studying its biology. The species is strongly linked to this area mainly for three factors: the mowing in the periods preceding the first annual nesting which contribute, together with the arrival of the warm season, to creating the semi-steppe habitat preferred by the Short-toed Lark; the presence of a large fenced area, which preserves the females and nests from a large percentage of predations; the soft use of pesticides inside and outside the airfield, thus providing a good diversity and presence of insects, which is essential for the breeding of chicks. It would therefore be important to maintain the current mowing periods, so as not to damage the nesting of the species, while, on the contrary, the small urban woods installed in spring 2023 in sector B certainly appear to be harmful, considering that the Short-toed Lark, like most of the steppe and farmland birds, is threatened by afforestation (Onrubia & Andrés, 2005).

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#### SUPPORTING INFORMATION

Additional Supporting Information may be found online for this article.

S1: Floristic list of the sector C of the study area. / Elenco floristico delle specie presenti nel settore C dell'area di studio.