Ecology and distribution of the European Roller *Coracias garrulus* in a recently recolonized area of Northern Italy

Alessandro Ghiggi

Abstract - This study reports the first data on the ecology and distribution patterns of a population of Eurasian Roller *Coracias garrulus* breeding in the province of Alessandria in northwestern Italy. The research was conducted between 2017 and 2021. 13 pairs were found, 12 of which were confirmed to be breeding. The species primarily chose to nest in natural cavities in White poplar *Populus alba*, with nesting observed to a lesser extent in Black poplar *Populus nigra*, Turkey Oak *Quercus cerris* and in one case sandy river banks. The home range of each pair is mostly within pluriannual stable meadows and arable crops; on average it extends over 0,92 km² with values that seems to oscillate according to the degree of fragmentation and isolation of patches of stable meadows: this can be explained by the lower availability of arthropods (consisting mostly of Orthoptera) found in mosaics of alternating meadows interspersed with annual crops. In such conditions, a low density of pairs was observed, along with an increase in territorial boundaries and greater distance between the nests. In the sectors characterised by large, multi-annual stable meadows, with more diverse and abundant entomofauna, supporting a higher number of breeding pairs, a significant contraction of home ranges is observed, with an increased concentration of nesting sites, and higher intraspecific tolerance. Between 2019 and 2021 a total of 17 artificial nest boxes were installed, 3 of which have been successfully occupied. Given the continuous anthropogenic transformation these territories are regularly facing, sometimes subtracting potential nesting or feeding sites due to crop rotation, coppicing, ex-novo construction of ground solar panel systems on agricultural land, etc., in order to protect and conserve this population of European Roller, it is desirable to put in place a greater number of artificial nest structures together with monitoring aimed at protecting the biodiversity of the territory.

Keywords: European roller, Alessandria, breeding, Piedmont, ecology, distribution, habitat fragmentation.

Riassunto - Ecologia e distribuzione della ghiandaia marina *Coracias garrulus* in un'area recentemente ricolonizzata dell'Italia settentrionale.

Vengono riportati i primi dati sulla selezione dell'habitat e le dinamiche di distribuzione di una popolazione di ghiandaia marina *Coracias garrulus* nidificante in provincia di Alessandria. L'indagine è stata svolta tra il 2017 e il 2021. Sono state individuate 13 coppie di cui 12 nidificanti accertate. La specie seleziona principalmente cavità naturali in pioppo bianco *Populus alba*, secondariamente in misura minore pioppo nero *Populus nigra*, cerro *Quercus cerris* e, in un solo caso, rive sabbiose. Gli home range ricadono perlopiù in prati stabili pluriennali e seminativi annuali e si estendono in media per circa 0,92 km² con valori che sembrano oscillare in base al grado di frammentazione e isolamento delle *patches* in seno ai prati stabili: questo può trovare spiegazione nella minore disponibilità di artropodi (rappresentata nel complesso da Ortotteri) riscontrata all'interno di mosaici di prati alternati e colture annuali, dove si registra una bassa densità di coppie, un incremento dei confini territoriali e una maggiore distanza tra i nidi. Nei settori caratterizzati da ampi prati stabili pluriennali, ricchi di entomofauna, elemento in grado di garantire foraggiamento per un maggior numero di coppie, si osserva una sensibile contrazione degli home range, una maggiore concentrazione di siti di nidificazione nonché una maggiore tolleranza intraspecifica. Tra il 2019 e il 2021 sono state installate 17 strutture nido artificiali, 3 delle quali occupate con successo. Data la continua trasformazione antropogenica cui vanno incontro questi territori talora sottraendo potenziali siti di nidificazione o di alimentazione per avvicendamento colturale, ceduazione, costruzione ex-novo di impianti fotovoltaici su terreni agricoli, ecc., al fine di proteggere e conservare questa popolazione di ghiandaia marina è auspicabile la messa in posto di un maggior numero di strutture nido artificiali unitamente a monitoraggi volti a tutelare la biodiversità del territorio.

Parole chiave: ghiandaia marina, Alessandria, nidificazione, Piemonte, ecologia, distribuzione, frammentazione habitat.

INTRODUCTION

The European Roller *Coracias garrulus* is a polytypic species with a Euro-Turanian-Mediterranean distribution, associated with flat and hilly xeric environments and nesting in natural or artificial cavities (Brichetti & Fracasso, 2007). In Italy it is included on the Red List of breeding birds, where it is considered vulnerable (Rondinini *et al*, 2013). In Piedmont, according to the current literature, this species has been found to nest again for the past 14 years (Gatti, 2008; Silvano, 2010; Ghiggi, 2016; GPSO, 2017) after an absence of more than 70 years since the last report in 1937 by Rubatto in Torino Chieri. All these recent reports fall within the Alessandria province and mostly refer to isolated pairs. Below are the results of a survey carried out in the five-year period of 2017-2021, following an observation reported by the author in 2016 concerning a breeding pair in the municipality of Sezzadio (AL). A sample area in the province of Alessandria, with bioclimatic and environmental characteristics suitable for the settlement of *Coracias garrulus*, was examined in order to study the species' ecological preferences

Via dei Tasso 30, 16167 Sant'Ilario (Genova), Italia.
E-mail: aleghiggi88@gmail.com

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and distribution dynamics. To date, specific studies of this kind are lacking for Piedmont.

STUDY AREA

The study area was framed in a perimeter of approximately 76 km² between the province's two main river basins of the Bormida and Orba, at altitudes ranging from 114 to 325 m asl, overlapping, to varying degrees, the administrative boundaries of 11 municipalities in the Province of Alessandria (among the main ones by extension: Sezzadio, Predosa and Carpeneto).

About 58% of the area in the western sectors is characterized by gentle hills. The remaining 42% of those to the east are stretches of plains. The geology consists of coverings of fluvial deposits from the Alessandria basin (sand, gravel and clay), which date back to the Pleistocene and Holocene eras; the latter are dominated by debris flows located mainly along the current beds of the main streams and secondary canals. The environment mainly consists of extensive or mosaic non-irrigated crops and vineyards, interspersed with extensive wooded portions in linear formations on the edges of fields. The climate, according to the climatic classification proposed by Bagnouls & Gaussen (1957), falls into the xerothermal category, with one or two dry months in summer and, based on rainfall regime, into the sublittoral-Apennine type (Mennella, 1972 in Camerano *et al.*, 2010), recording at least one dry month in summer (July, sometimes even June). The forest coverage in the northern sectors primarily comprises coppices of Black locust *Robinia pseudoacacia* mixed with thermophilic broadleaves. In the southernmost sectors the Turkey oak *Quercus cerris* predominates on the oldest alluvial terraces, with these forests consisting of more or less pure mesoxerophilic oak grove interspersed with thermophilic species (Hornbeam *Carpinus betulus*, Manna ash *Fraxinus ornus*, Wild service tree *Sorbus torminalis*, Cherry *Prunus avium*, Hawthorn *Crataegus monogyna*, Core *Corylus avellana*, *etc.*) and riparian species (White Poplar *Populus alba*, Black Poplar *Populus nigra*, *Salix spp.*, *etc.*) in association with torrential riverbeds and artificial reservoirs.

MATERIAL AND METHODS

Bird survey

The research was conducted from 2017 to 2021, between the end of April and the end of September, carrying out weekly surveys on foot or by off-road vehicle using optical instruments of 8, 15 and 32 times magnification. Observations were carried out mainly in the early morning, late afternoon and evening hours, in an effort to avoid the midday sun and the associated high temperatures and insolation. The data collected at the end of each season, concerning the number of individuals and the types of activities, were geolocated, reported in tables and uploaded as point layers on cartographic processing software (QGIS 3.10 a Coruña). A table similar to the one reported by Baghino *et al.*, (2006) was compiled for each newly discovered nest (Tab. 1), with the following variables: type of nest, distance from nearest nest (taking into account only active nests in year X), maximum distance covered by the observed nest, height of the cavity from the ground, area of cavity entrance, exposure aspect of the cavity in sexagesimal degrees of the cavity. Potentially invasive measurements for breeding pairs were collected after the young had hatched. Kernel density estimation at 95% (Finch, 2016; Cannarella *et al.*, 2019) was used to obtain a picture of the distribution of breeding pairs, based on direct observations of intraspecific interactions and antagonisms. The analysis of habitat composition was based on an examination of thematic cartography from a regional Piedmont database (Geoportale.piemonte.it), with any inaccuracies and/or gaps resolved with meticulous field surveys. To compare differences in structure between the main land cover categories within a home range, a paired sample *t*-test was conducted taking into account the landscape metrics proposed by Monti *et. al.* (2019): number of patches (NP), mean patch size (MPS), mean perimeter/shape ratio (MPSR) and edge density (ED). In order to find a correlation between the land cover structure and the spatial distribution and extension of home ranges of breeding pairs (Andrén, 1994; George & Dobkin, 2002; Flowers *et al.*, 2020), the linear regression method was used (QED Statistics software). Geographical data were extracted using the LecoS Plugin (Duarte, 2014; Jung, 2016) of QGIS.

Arthropod availability

During the 2021 breeding season, a parallel survey was carried out to test the potential correlation between the distribution of the European roller and food availability, represented by Arthropod abundance (Aviles & Costillo, 1998). For that purpose, transects of 50x2 m (Tiefenbach, 2009) were established on ten sample areas identified within ten types of crops, evenly distributed between the two main categories of land use, on which fell the greatest number of total observations (N=626) related to feeding individuals: pluriannual stable meadows (N=192), arable crops (N=144). The samples were taken by means of a clipping net (Gobbi & Latella, 2011); every 10 steps on average, the vegetation was inspected, and the arthropods observed were identified at order level for the Insecta and class level for Arachnida. This technique does not take into account the availability of insects in trees, hedges and most of those in flight. For the purposes of analysis two size categories were selected: 10-20 mm and >20 mm (Aviles & Costillo, 1998; Tiefenbach, 2009). The two-sided Mann-Whitney U-test and Shannon Diversity Index was used (QED Statistics software).

Artificial nests

Based on the data obtained in previous years, between 2019 and 2021, 13 nest-trunks and 5 nest-boxes were constructed according to the methods reported by Premuda *et al.* (2011) and placed in territories as yet unoccupied or close to those already occupied.

Tab. 1 - Results of the measurements collected in 17 nesting sites of European roller. / Risultati delle misurazioni ottenute in 17 siti di nidificazione della ghiandaia marina.

Site ID Codice del sito di nidificazione	**Year of the discovery** Anno della scoperta	**Distance to nearest nest (m)** Distanza dal nido più prossimo (m)	**Max. distance from the nest observed (m)** Distanza massima dal nido osservata (m)	**KDE 95% (Km²)** Stima Densità di Kernel (Km²)	**Location of the nest** Ubicazione del nido	**Hole area (mm²)** Area del foro di ingresso (mm²)	**Cavity height from the ground (m)** Altezza della cavità da terra (m)	**Aspect (°)** Esposizione (°)
BS	2016	1470	670	1.09	White poplar	35.73	5.5	240
VL I	2017	140	-	0.20	White poplar	29.68	5.8	95
VL II	2018	140	-	0.13	White poplar	30.34	8.6	68
SW	2018	1068	780	1.44	White poplar	25.52	4.6	110
MT	2018	752	940	-	Black poplar (dry)	37.69	4.13	100
MG I	2018	1458	485	-	Black poplar (dry)	-	-	-
TO I	2019	650	-	-	Nest-trunk on Turkey oak	56.72	5.6	85
MG I (2nd site)	2019	507	-	0.86	Black poplar (dry)	-	-	-
CA	2020	400	570	0.86	Nest-trunk on Turkey oak	56.72	8.5	325
TO II	2020	405	-	0.78	Nest-trunk on Turkey oak	56.72	5.6	90
MG II	2020	507	610	1.12	White poplar	34.1	5.3	103
CF	2020	1470	1460	1.97	White poplar	30.63	4.8	210
SZ	2020	2575	790	1.06	Turkey oak	33.19	5.65	300
SZ (2nd site)	2021	1545	-	-	Poplar sp. (dry)	-	-	-
MT (2nd site)	2021	560	-	1.38	Poplar sp. (dry)	35.74	5.2	240
VL III	2021	205	1475	0.18	White poplar	65.33	5.2	70
TP	2021	1545	-	-	Sandstone bench	44	3.3	85

RESULTS AND DISCUSSION

From 2017 to 2021, from a total number of 17 nesting sites, 13 breeding pairs were found, 12 of which were confirmed to be breeding, from a total number of 17 nesting sites. During 5 years of research, pair density per square kilometer inside the study area increased by about 0.03 pairs/km² on average (Fig. 1).

The European Roller shows a marked preference for natural cavities in tree trunks, favouring old nests of European green woodpecker (*Picus viridis*). Most pairs chose to nest in White poplar *Populus alba* (N=7), more specifically large isolated trees along the edges of wooded areas or on the banks of artificial basins. To a lesser extent, dead or decaying individuals of Black poplar *Populus nigra* (N=5) were chosen as nest sites. In only one case, during the 2020 breeding season, a Turkey oak was occupied, more specifically a former Green woodpecker nest inside a large Turkey oak, with a trunk diameter of around 2 m, on the edge of a Turkey oak wood. At the end of August 2021 an isolated case of nesting in a sandstone bank was observed. In this case the entrance to the nesting chamber was located in close proximity to other cavity entrances belonging to a colony of Bee eaters *Merops apiaster*. Frequency and type of chosen cavities mirror the data already reported by several European researchers (Kovacs *et al.*, 2008).

The average ground clearance of nest holes was found to be 5.28 m ±0.40 *SE* (range: 3.3-8.6; N=11): the lowest value (3.3 m) refers to the pair nesting in the sandstone bank. The three artificial nest boxes were excluded from this analysis, as were a natural cavity in a dead Poplar *sp.*, felled in autumn by the landowner at the end of a breeding

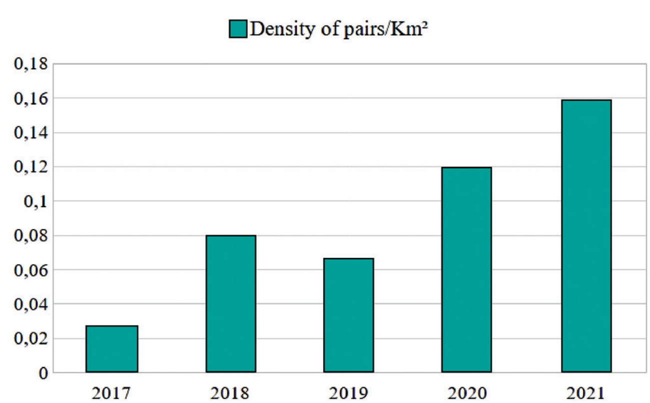

Fig. 1 - Density of breeding pairs per square kilometre in the study area during the 5 breeding seasons. / Densità delle coppie nidificanti per chilometro quadrato all'interno dell'area di studio nelle 5 stagioni riproduttive.

season, and a site on private property. The entrance hole chosen by the pairs had an average area of 36.54 mm² ±3.23 *SE* (range: 25.53-65.34; N=11).

The average aspect of the nest hole was found to be 148.41 ±23.9 *SE* (range: 68-300; N=12), with a south-easterly aspect favoured. Average distance between nests was found to be 0.91 km ±0.16 *SE* (range: 0.14-2.58; N=17). In a study in nothern Anatolia, Arslan & Arslan (2019) report an average value of 1,2 km, on a sample population similar to the one studied here. The home range (95% kernel density) extends on average for roughly 0.92 km² ±0.18 *SE* (range: 0.12-1.96; N=12); however, this value should be considered within the limits of direct observations and the difficulties involved in intercepting the long commuting journeys sometimes undertaken to access remote hunting territories during the chick-rearing period. Data about maximum average commute distance concerns only a few observations (N=9), the average of which is around 0.86 km ±0.12 *SE* (range: 0.49-1.47). These values do not differ much from those reported by other authors for individuals equipped with GPS systems (Finch, 2016; Cannarella *et al.*, 2019). Figure 2 depicts the composition of the twelve home ranges, identifying seven categories of land cover: pluriannual stable meadows, pastures and fallow land, forest cover, rivers and streams, artificial reservoirs, arable land, vineyards, paved roads and carriageways, buildings and other urban structures. The territories occupied by pairs are mostly in stable meadows (41% mean 0.41 ±0.07 *SE* (range: 0.03-0.82; N=12)) and arable lands (31% mean 0.31 ±0.06 *SE* (range: 0-0.61; N=12)).

The paired *t*-test (see Tab. 2) between the mean values of the two main land cover types indicates significant differences in the number of patches (NP), which is significantly larger where there are arable crops (*M*=41.5; *SD*=35.53) compared to stable meadows (*M*=19.83; *SD*=20.04). On the other hand, the mean patch size (MPS) is smaller in arable crops (*M*=0.79; *SD*=0.53) than in stable meadows (*M*=2.32; *SD*=1.83). Moreover, a closer look on the geometry of the patches reveals a greater mean perimeter/shape ratio (MPSR) within the stable meadows (*M*=0.60; *SD*=0.47) compared to the patches within ara-

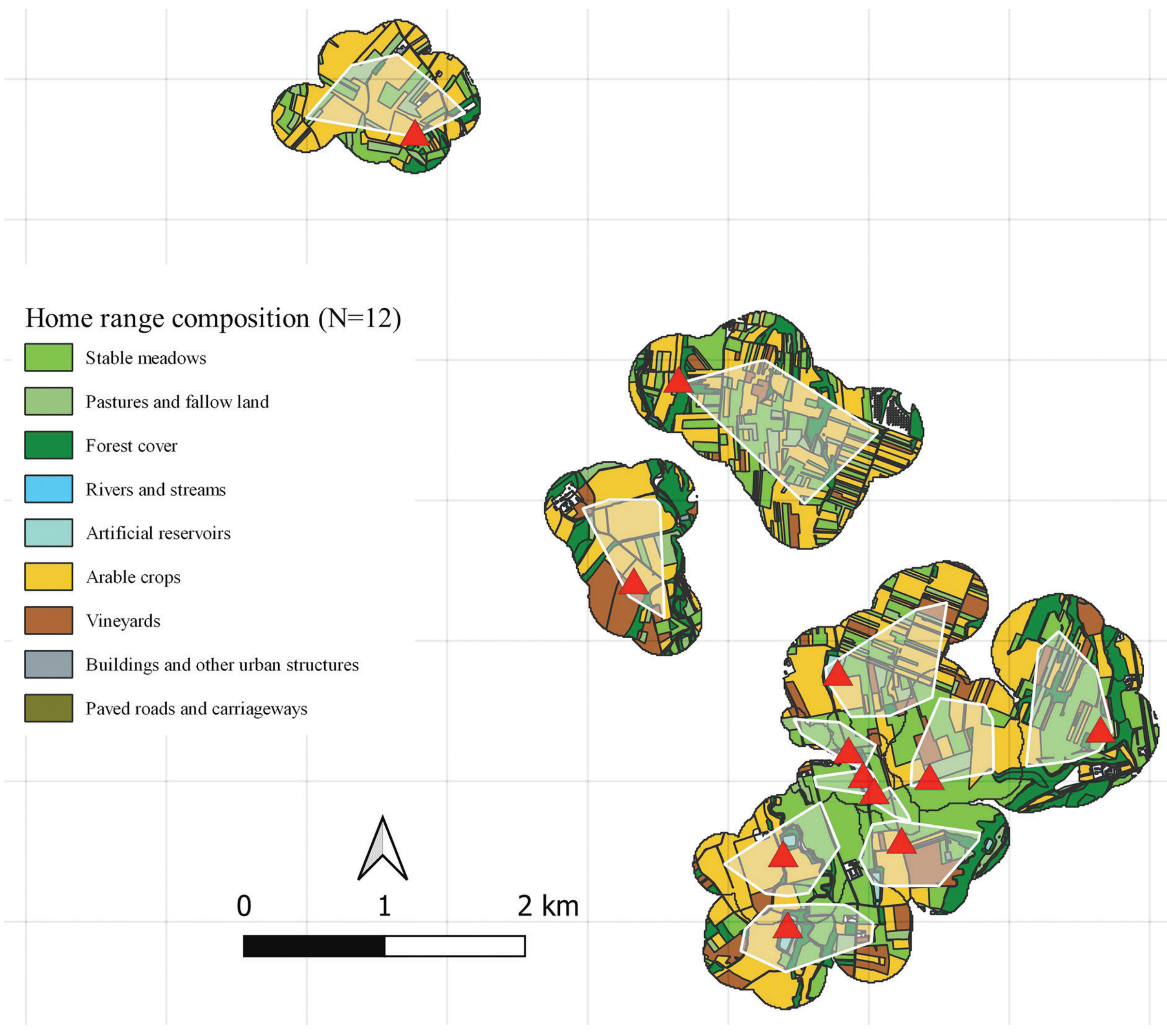

Fig. 2 - Foraging home range of the breeding pairs (N=12) represented by 95% density kernel. White shapes represent minimum convex polygons and filled red triangles the nest-sites. / Home range delle coppie (N=12) rappresentati dalle densità di Kernel al 95%. Le forme bianche rappresentano i minimi poligoni convessi e i triangoli rossi i siti di nidificazione.

Tab. 2 - Results of the paired sample t-test between the two main land cover categories found within the home ranges using four landscape metrics (Monti *et. al.*, 2019): number of patches (NP), mean patch size (MPS), mean perimeter/shape ratio (MPSR) and edge density (ED). / Risultati del t-test a campioni accoppiati tra le due principali categorie di uso del suolo riscontrate all'interno degli home range utilizzando quattro tipologie di misurazione del paesaggio (Monti *et. al*., 2019): numero delle patches (NP), dimensione media della patch (MPS), rapporto perimetro/area della patch (MPSR), densità dei bordi (ED).

		Paired samples t-test							
		Paired differences							
					95% Confidence Interval of the Difference				
		Mean	*StD*	*SE*	*Lower*	*Upper*	*t*	*df*	*Sig.(2-tailed)*
NP	Stable meadows - Arable crops	-21.6667	19.46714	5.619680425	-2.753687	46.087087	-3.8555	11	0.002
MPSR	Stable meadows - Arable crops	0.363830539	0.428856825	0.104013058	0.07380315	0.65390285	-2.93904	11	0.013
MPS (Ha)	Stable meadows - Arable crops	1.53365	1.841188	0.4465536	0.3897986	2.6775014	-2.8855	11	0.015
ED	Stable meadows - Arable crops	-0.00065	0.0126	0.00305	-0.0060468	0.0073468	0.177	11	0.431

ble crops (M=0.23; SD=0.13). There are no significant differences in edge density (ED) between the mean figure for stable meadows (M=0.015; SD=0.007) and arable crops (M=0.016; SD=0.009).

By focusing on pluriannual stable meadows, the extension of home ranges seems to be proportional to the increase in the number of patches (NP) in which they fall ($r2$ = 0.71, F(1.10) = 24.13, $p < 0.001$) while MPS and MPSR do not seem to be significantly correlated. The distance between nests seems to be proportional to the increase in the ratio of the MPSR ($r2$ = .65, F(1.10) = 18.75, p = 0.001); MPS and NP are not significantly correlated (Fig. 3). However, in the small sample of population examined (of recent expansion) and the lack of available nesting sites in the study area (see Conclusion chapter) the weak statistical correlation found should be sought. A further investigation in the years to come could return more solid results.

Stable meadows present, overall, with a low degree of fragmentation, resulting from large interconnected patches, especially within the south-eastern sectors, the first to have been recolonized by the European roller and characterised by a greater concentration of breeding pairs (i.e. minimum distance between the nests), with a partial overlap of the home ranges boundaries and a greater intra-specific tolerance. Individuals in that area do not need to waste precious energy on long-range foraging trips away from their nest site because of a greater trophic availability (see next chapter).

In the recently recolonized north-western sectors characterised by mosaics of annual crops and small-scale alternating meadows interspersed with residential buildings, there is a more fragmented distribution pattern along with greater distances between nests and an absence of overlap between home-ranges.

In the northern and north-eastern sectors, where intensive and extensive annual arable crops prevail, breeding pairs are not reported at the time of writing (2022).

The arrival dates of the breeding individuals fall within a temporal window that stretches from late April (24^{th} April providing the earliest observation during the study period) to the first ten days of May.

Arthropod availability

Between the end of April and the end of August 2021 ten transects were made for each day after two decades for a total of seven days. Within pluriannual stable meadows, five patches were chosen based on the differing composition of their herbaceous layer. For arable crops, five patches were selected to be most representative of the crops grown that year: wheat, rye, alfalfa, alternating meadow, vineyard.

The median of the 10-20 mm samples taken under stable meadows is significantly greater than that of arable crops (U=10; $p<0.05$, Mann-Whitney U-Test). This is likely due to the characteristics of the multiannual stable meadows allowing various orders of insects to reproduce

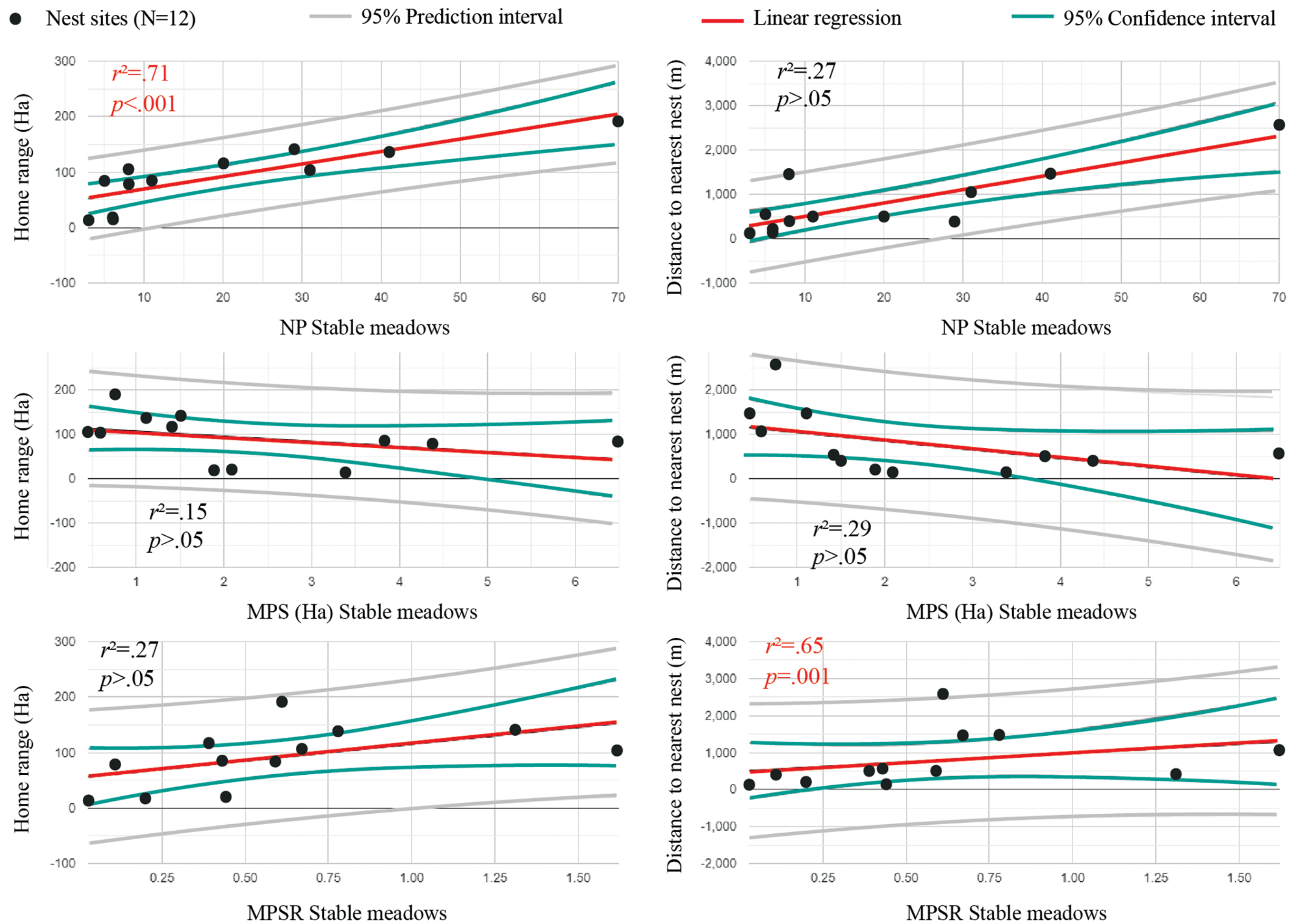

Fig. 3 - Relationship between the extension of the home ranges and the distance to the nearest nest (m) with the stable meadow fragmentation parameters which reported $p \leq 0.05$ from the *t*-test with arable crops: number of patches (NP), mean patch size (MPS), mean perimeter/shape ratio (MPSR). / Correlazione statistica che intercorre tra l'estensione degli home range e la distanza tra i nidi con i parametri di frammentazione del Prato stabile che hanno riportato valori di $p \leq 0.05$ dal *t*-test con i seminativi annuali: numero delle patches (NP), dimensione media della patch (MPS), rapporto perimetro/area della patch (MPSR).

and complete their biological cycle with lower levels of anthropic stress associated with agricultural activity during the mowing period (on average only one cut between the half of May and the first ten days of June) or, more rarely, fertilisation. There are no significant differences between the medians of the samples above 20 mm within the two categories (U=20; p>0.05, Mann Whitney U-Test). This result can be deduced from the analysis of the percentage frequencies reported: Catches comprised 95% Orthoptera (mainly Caelifera and Ensifera). These undertake daily medium to long range movements and can spill over to feeding areas (which may also consist of annual crops) far from their natal areas which primarily consist of wide patches of stable meadows, fallow land and pastures.

Based on the results obtained, Orthoptera seem to be the main source of nutrition for the species. This is supported by the repeated observation of birds with beakfuls of prey near the nests. Predation was also observed on typically arboreal Coleoptera such as European stag beetle *Lucanus cervus* and Rhyncota Cicada *sp.* which were caught in flight. More rarely, there were observations of predation on vertebrates such as Italian wall lizard *Podarcis siculus*.

Artificial nests

During the three years, three nest-trunks were successfully occupied by two pairs in the area with the highest density of individuals per km². In 2020, one of the two couples was forced to change structure due to the presence of breeding Eurasian scops owl *Otus scops* who occupied the nest before their arrival. Over the three years, around 17% of the total number of nest structures were successfully occupied.

CONCLUSIONS

The progressive recolonisation of the Alessandria province by the European roller may have begun in 2014, when some individuals were observed in the area, initially considered to be late migratory records or non-breeding

Tab. 3 - Arthropod catches results within pluriannual stable meadows and arable crops. / Risultato delle catture di Artropodi all'interno dei prati stabili pluriennali e dei seminativi annuali.

	Stable meadows Prati stabili							**Arable crops** Colture annuali					
Arthtropods Artropodi	**10-20mm**			**>20mm**				**10-20mm**			**>20mm**		
	N	%	*H'*	*N*	%	*H'*		*N*	%	*H'*	*N*	%	*H'*
Arachnida	77	0.084	0.21	2	0.014	0.01		31	0.069	0.18	0	0	0
Coleoptera	66	0.072	0.19	3	0.021	0.02		63	0.140	0.28	0	0	0
Diptera	255	0.280	0.36	4	0.029	0.02		13	0.029	0.10	0	0	0
Hemiptera	88	0.096	0.23	0	0	0		148	0.329	0.37	1	0.01	0.01
Hymenoptera	23	0.025	0.09	1	0.007	0.01		12	0.027	0.10	0	0	0
Lepidoptera	16	0.018	0.07	2	0.014	0.01		11	0.024	0.09	5	0.03	0.05
Lepidoptera (larvae)	29	0.032	0.11	8	0.057	0.04		4	0.009	0.04	0	0	0
Neuroptera	5	0.005	0.03	0	0	0		4	0.009	0.04	0	0	0
Orthoptera	351	0.385	0.37	105	0.750	0.25		164	0.364	0.37	147	0.95	0.37
Odonata	1	0.001	0.01	15	0.107	0.07		0	0	0	1	0.01	0
Dermaptera	1	0.001	0.01	0	0	0		0	0	0	0	0	0
TOT.	912		1.67	140		0.43		450		1.57	154		0.43

birds. Since the summer of 2017, the presence of several gregarious individuals was then recorded, who were seen feeding close to the areas now occupied by territorial pairs, suggestive of colonisation by immature or non-breeding birds from breeding areas located between Tuscany and Emilia. A gradual expansion from southern France is an alternative possibility deserving attention in future studies.

The territories under investigation display characteristics of land-use instability and fragility specific to the Po Valley. Failed breeding occasionally occurs as a result of the collapse of large dry or decaying poplars due to exposure to atmospheric agents or uncontrolled felling, leading to pairs that then struggle to find alternative sites. The ideal prerequisites of tree age and structure facilitating nesting are generally scarce, with forest cover instead mostly consisting of less ideal coppices of Turkey oak mixed with Black locust. The installation of more artificial nests could partly fill this gap.

Of more serious importance are the anthropogenic changes linked to land use, a natural tendency for agricultural soil. In pluriannual stable meadows, an essential prerequisite for the presence of this species, these include: the expiry of the minimum five-year period for its maintenance (Regulation (EU) No. 1307/2013) which may lead to the conversion into intensive annual crops, vineyards or

Fig. 4 - Typical nesting site of the European roller. / Tipico sito di nidificazione della ghiandaia marina. (Photo: / Foto:Alessandro Ghiggi):

hazelnut groves (often involving the use of desiccants or pesticides) resulting in the loss of principal foraging areas and the consequent loss of territory and trophic availability; ecological theory predicts that isolated habitat patches will experience greater rates of species loss and lower rates of recolonization compared to less isolated habitats (Collinge, 2000); the phasing-out of traditional agroforestry and pastoral activities, leaving space for invasive vegetation or construction; last but not least the new provisions of the Italian government on renewable energies (Legge 27 aprile 2022, n. 34) which provide, among other measures, incentives and shortcuts for the installation of ground-mounted solar farms on agricultural lands. The area under investigation has already experienced this kind of transformation, with solar farms both already installed and further ones planned. Solar farms result in land consumption and habitat fragmentation, and involve both the loss of favourable and suitable habitats as well as the risk of collision (Lammerant *et al.*, 2020; Kosciuch *et al.*, 2020). Fragmentation affects ecosystems by altering the conditions within a patch and the flow of resources (organisms, propagules, nutrients) among patches (Rutledge, 2003). In the long term these factors might well displace the breeding European roller pairs that today form the modest, but stable population in the Piedmont Region considered in this study.

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