



Herbaceous cover management in olive groves can be important for aerial-feeding birds. A case study in southern Spain

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ABSTRACT

The European Olive (*Olea europaea*) is a widely cultivated tree throughout the Mediterranean Basin where it plays an important economic, social and cultural role. Given the extensive area occupied by olive groves, which are known to be ecologically important for many animals, species diversity and abundance may be affected by the type of herbaceous vegetation management applied. Here, we investigate the effect of vegetation treatment (mechanical or chemical management of herbaceous cover, or bare soil) on bird abundance with a particular focus on six aerial-feeding (AF) bird species – Common (*Apus apus*) and Pallid Swifts (*A. pallidus*), Alpine Swift (*Tachymarptis melba*), Barn Swallow (*Hirundo rustica*), Red-rumped Swallow (*Cecropis daurica*), and the Common House Martin (*Delichon urbicum*). Using point counts, we recorded all birds (AF and non-AF birds) heard and observed in three separate olive grove plots subjected to the different herbaceous cover treatments. Our results show that plots with herbaceous cover hosted a higher number of bird species, including insectivorous and AF species, as well as a greater abundance of total birds, insectivorous birds, and AF birds, compared to the bare soil plot. The abundance of AF bird was significantly higher in the two plots with herbaceous cover compared to the plot with bare soil. During the post-nuptial migration period, AF birds—together with other species—were also among the dominant species in the two plots with herbaceous cover, whereas in the bare soil plot, none of the six species was dominant. Our results suggest that olive groves can be important for AF birds, a group not traditionally included in studies of bird communities in olive farms. We suggest that farmers and policy makers, as the main actors in olive farming, should consider the impact of the different management techniques on AF bird populations.

1. Introduction

Over the past few decades, bird species associated with farmland have declined in several European countries (Chamberlain et al., 2000, Wretenberg et al., 2006, Reif et al., 2008, SEO/Birdlife, 2020, Busch et al., 2020). This decline has been largely attributed to changes in agricultural techniques and intensification in production (Eurostat, 2015). The main processes associated with agricultural intensification and, consequently, with the decline of farmland birds can be summarised as: 1) the landscape homogenisation due to a decrease in crop diversity and the reduction of hedgerows and patches of natural vegetation and 2) the massive use of agro-chemicals both pesticides and fertilizers (Newton, 2004, Reif, 2013).

The European olive (*Olea europaea*) traditionally grown in the

Mediterranean Basin is widely cultivated for the production of both oil and table olives. This crop plays an important economic, social and cultural role in many Mediterranean countries (Ventura et al., 2019). In 2018, the area of olive groves worldwide was approximately 11.5 million ha (Vilar & Pereira, 2018) and an average 162,000 ha of new olive groves are planted each year to meet the emerging needs of the market (Vilar & Pereira, 2018).

Cultivation techniques used in olive orchards are primarily directed at enhancing plant productivity. Andalusia (southern Spain) is the main region in the world for olive oil and table olive production (Ojeda-Rivera et al., 2018). Land management systems in olive cultivation range from tillage (to improve water infiltration), to various combinations of mechanical treatments (no-tillage with bare soil, semi-tillage and conservation tillage) to more intensive chemical or mechanical methods to

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remove the competition from herbaceous vegetation (Pastor et al., 2001). In Andalusia 63 % of the olive groves are cultivated in a traditional manner, i.e. herbaceous vegetation among the olive trees is removed using chemical and mechanical methods to expose the bare soil throughout the year (Gómez-Limón & Barreiro-Hurlé, 2012). In addition, approximately 32 % of olive groves in the region are managed under organic farming techniques, which include maintaining herbaceous cover and applying minimal tillage (Gómez-Limón & Barreiro-Hurlé, 2012). The different farming techniques used in olive orchard management can affect the abundance and variety of bird species observed in olive groves (Rey et al., 2019, Morgado et al., 2020). This aspect is particularly important, as olive grove management can significantly contribute to biodiversity conservation for several reasons. First, olive groves are widely distributed across a key biodiversity hotspot in Europe (Myers et al., 2000). Second, their wooded structure provides a potential refuge for numerous animal species, including both invertebrates and vertebrates (Castro et al., 2017, 2019; Duarte & Farfán, 2023; de la Torre et al., 2025). Third, olive groves facilitate the temporary use of the habitat by wildlife and enhance connectivity between habitat patches, supporting the mobility of many animals and plants (Rey et al., 2019). Furthermore, the extensive area occupied by olive groves in Andalusia further increase their ecological relevance, as many animal species are particularly abundant in this type of agroecosystem (Muñoz-Cobo et al., 2001a, b; Duarte et al., 2009; Farfán et al., 2012).

Given the vast areas now occupied by olive groves worldwide, it is imperative to identify cultivation practices that are both environmentally sustainable (Guerrero-Casado et al., 2021) and capable of delivering socio-economic returns and ecosystem benefits (Alonso & Guzmán, 2006, Zurlini et al., 2014, López-Pintor et al., 2018). For example, the conservation of insectivorous birds through habitat improvement could play a key role in the control of pests that cause substantial economic damage in olive groves (Rey Benayas et al., 2017, Martínez-Núñez et al., 2020, 2021). As far as we are aware, this is the

first study to examine the effects of different land treatment types on habitat use by six aerial feeding (AF) birds whose diets consist exclusively of flying invertebrates; the Common Swift (*Apus apus*), Pallid Swift (*A. pallidus*), Alpine Swift (*Tachymarptis melba*), Barn Swallow (*Hirundo rustica*), Red-rumped Swallow (*Cecropis daurica*), and the Common House Martin (*Delichon urbicum*). The impact of agricultural land uses on these species has not been previously explored, as they are birds mainly linked to urban environments (Huhtalo & Järvinen, 1977, Morell & Suárez, 2013, SEO/Birdlife, 2020). We conducted a preliminary investigation into how herbaceous vegetation management in olive groves affects bird abundance, with a specific focus on AF birds. Our central hypothesis was that the type of management treatment is directly related to the abundance and dominance of AF birds. The underlying assumption is that treatments maintaining herbaceous cover support a greater abundance of flying invertebrates and, therefore, a higher presence of AF birds. To test these relationships, we assessed the abundance and dominance of AF birds in three olive grove plots, two with herbaceous cover and one with bare soil.

2. Materials and methods

2.1. Study area

The study was carried out in the northeastern region of Málaga province (Andalusia, southern Spain) (Fig. 1). Similarly to Duarte et al. (2014), we selected a 2-hectare plot in three different olive groves. In all three cases the olive groves were rainfed, with a density of around 100 trees per hectare and an age of more than 40 years. Each olive grove was subjected to a different management treatment, all representing the most commonly used land treatments in Andalusian olive groves (Gómez-Limón & Barreiro-Hurlé, 2012). The three plots are described below:

Plot 1 Chemical Treatment (CT): the herbaceous cover is maintained, and managed by chemical treatment. Pesticides are applied once a year,

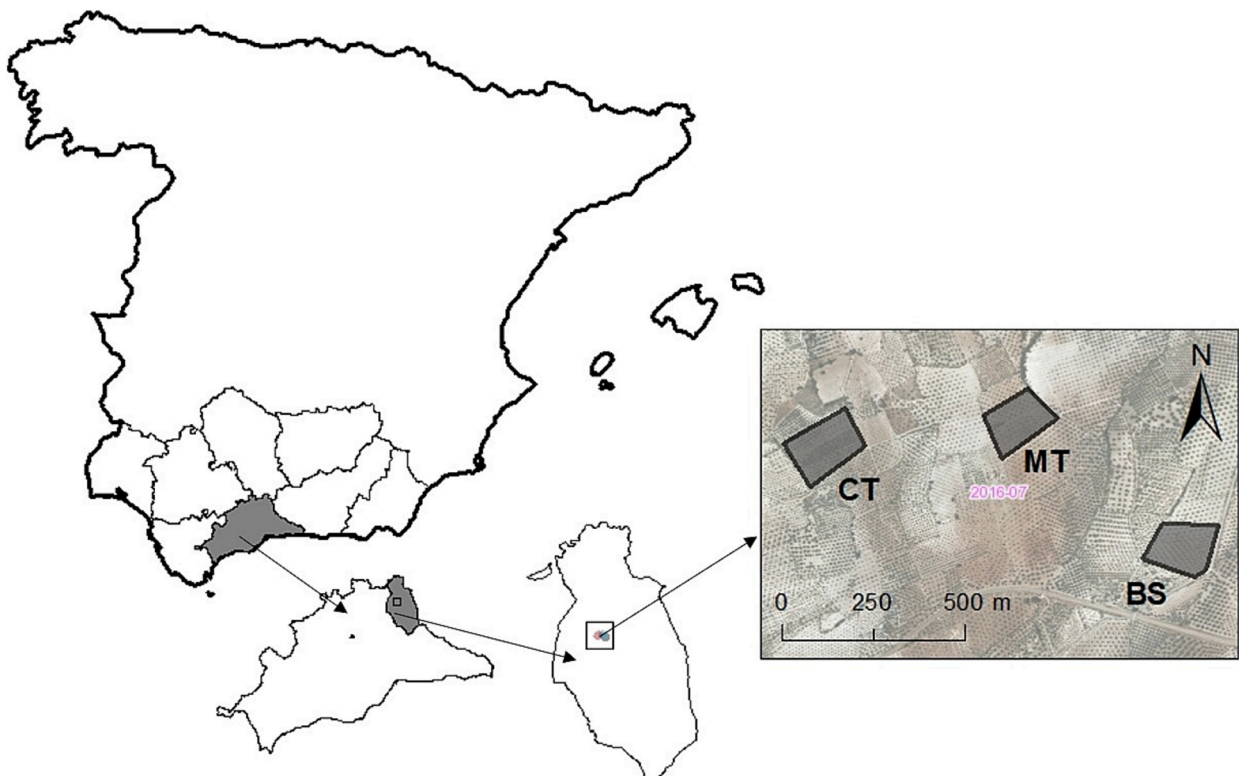


Fig. 1. Location of the study area in the north-eastern region of Málaga province (Andalusia, southern Spain). The three olive groves (CT, chemical treatment; MT, mechanical treatment; BS, bare soil) are shown.

in early spring, when vegetation emerges. During the rest of the year, no treatment is applied to remove the herbaceous cover.

Plot 2 Mechanical Treatment (MT): the herbaceous cover is maintained and managed only by mechanical treatment. Tillage is applied in early spring to remove emergent vegetation. During the rest of the year, no treatment is carried out to remove the herbaceous cover.

Plot 3 Bare Soil (BS): in which vegetation is removed using chemical and mechanical treatments, resulting in bare soil throughout the year. Pesticides are applied in autumn, with the first rains, and in spring, after vegetation emerges. The rest of the year, except during the olive harvesting period (September–November), the land is ploughed with agricultural machinery to keep the soil bare.

The three plots were similar in terms of landscape components, including proximity to human infrastructure, vegetation on the plot margins consisting mainly of elmleaf blackberry (*Rubus ulmifolius*), as well as plant species present within the plot dominated by wall-rocket (*Diplotaxis sp.*) and grasses (Family *Poaceae*).

2.2. Bird monitoring

To determine the relative abundance of birds, we used point counts (Reynolds et al., 1980, Tellería, 1986, Bibby et al., 2000), standing at a predetermined location and counting all birds seen through binoculars or heard during a set of time. Bird counts were conducted in each of the three plots from April to September 2019, a time span encompassing the breeding and post-nuptial periods. With a similar approach used by Duarte et al. (2014), in each plot we established a fixed sampling point for the entire study period, located at an elevated position to ensure good visibility. The 2-hectare plots were delineated around these points. We differentiated between insectivorous and non-insectivorous species. Within the former group, we further classified birds as aerial feeder (AF) and non-aerial feeder (non-AF). In the case of AF birds, we recorded the Common House Martin, Barn Swallow, Red-rumped Swallow, Alpine Swift and Common/Pallid Swifts; the latter two species were grouped as Swifts due to the difficulty in differentiating them in flight. For these six species, we only recorded individuals actively foraging at low flight altitudes (less than 20 m) over the plots, and birds flying higher or following a straight flight path were excluded (Jones et al., 2005). Each observation session lasted 40 min in each plot in the late afternoon, 2 h before sunset, to standardize detectability and maximize contacts with aerial feeder birds, as this is the time of day when they are most active. All bird species detected during each session were recorded using the same point-count protocol. For non-insectivorous species and non-AF species, we took specific precautions to avoid double counting; individual birds that remained visible within the plot, were perched, or whose movements could be reliably tracked were counted only once. This approach follows standard recommendations for fixed-point bird censuses (Bibby et al., 2000; Tellería, 1986). To avoid double counting of AF birds, we only retained the maximum number of AF birds observed simultaneously during each 40-minute session. We conducted seven monthly samples in each plot evenly distributed throughout the month. In each visit, the sampling order of the plots was conducted following a rotating schedule.

2.3. Data analysis

To characterize the bird community in each study plot we used two different variables:

1. Abundance: total number of individuals of each species.
2. Monthly Dominance (D): defined for each month as the number of species (including insectivorous and non-insectivorous species) with the greatest abundance, calculated from the formula (Margalef 1980):

$$D = e^H \quad (1)$$

where e is the base of the Napierian logarithm and H' is the result of the Shannon's diversity index (Margalef 1980, Vargas et al. 2006):

$$H' = -\sum p_i \times \log p_i = n_i/N \quad (2)$$

where n_i represents the abundance of each species in each study plot and N is the sum of the abundances of all species observed in each study plot.

The result of the equation (1) is a positive number that represents the number of species with the highest abundance in a community and provides information on which species are the most abundant throughout the study period. The identification of the n species that become part of D in each month and in each study plot was carried out by selecting the n most abundant species (Ríos-Saldaña et al., 2018).

To assess the effect of treatment type and month on both abundance and dominance, we used Bayesian Generalized Linear Mixed Models (GLMMs). Abundance was modeled using a Poisson distribution to account for overdispersion in count data, while dominance was modeled using a Poisson distribution given its discrete nature. In both models, treatment (chemical, mechanical, bare soil) and month (April to September) were included as fixed effects, and point count was included as a random intercept to account for repeated measures and spatial variation among sampling sites. The models were implemented in R (version 4.4.1.; R Core Team, 2025) using the brms package (Bürkner, 2021), and fitted using Markov Chain Monte Carlo sampling (NUTS algorithm). The models were fitted using four independent chains, each with 8000 iterations. Parallel computation was utilized by assigning four cores to expedite sampling. Additionally, we increased the adapt delta parameter to 0.95 to reduce divergent transitions and ensure accurate convergence.

Posterior distributions were summarized using mean estimates and 95 % credible intervals (CI). Convergence diagnostics, such as the potential scale reduction factor (Rhat), effective sample sizes (Bulk ESS and Tail ESS) (Gelman & Rubin, 1992), and Bayesian R^2 (Gelman et al., 2019), were used to evaluate the quality of the model fitting and ensure the reliability of parameter estimates. Pairwise comparisons between treatments were performed by computing the posterior distribution of the differences, and significance was inferred when 95 % credible intervals exclude zero.

3. Results

The observed number of insectivorous and AF birds species, as well as the total abundance of birds per plot are shown in Table 1. Both the number of insectivorous species and the overall abundance of birds, including insectivorous birds and specifically AF birds, were higher in plots with herbaceous cover (CT and MT) compared to the bare soil plot (BS).

According to the model, bird abundance increased significantly in plots with herbaceous cover, with estimated coefficients of 3.01 for CT (95 % CI: 2.00 to 4.05) and 2.55 for MT (95 % CI: 1.50 to 3.62), relative to BS. A clear seasonal pattern was also detected, with abundance progressively increasing from May to August, followed by a sharp decline in September (Coefficient = -2.99, 95 % CI: -5.56 to -0.80). The model explained a substantial proportion of the variation in bird abundance ($BR^2 = 0.89$) (Table 2).

No significant differences in abundance were found between CT and MT plots, as the posterior mean difference was 0.46 (95 % CI: -0.41 to 1.28).

Regarding dominance, the model showed that plots with herbaceous cover also had higher values than BS. Dominance increased by 0.44 units in CT (95 % CI: 0.09 to 0.99) and by 0.50 units in MT (95 % CI: 0.03 to 1.05), compared to BS. Monthly effects on dominance were not significant, as the 95 % credible intervals for all month coefficients overlapped zero in all cases. The model showed even high explanatory power for dominance ($BR^2 = 0.78$) (Table 2).

AF bird species were present during the breeding and post-nuptial

Table 1

Birds observed during the study period. Values are presented separately for each treatment type and summed (total). N: total number of birds; N IB: number of individuals of insectivorous birds (including aerial feeder birds). We indicate the number of insectivorous species in square brackets; N AFB: number of individuals of aerial feeder birds.

Treatment type	N	N IB	<i>Apus apus/pallidus</i>	<i>Delichon urbicum</i>	<i>Hirundo rustica</i>	<i>Cecropis daurica</i>	<i>Tachymarptis melba</i>	N AFB	% (N AFB/N IB) x100
Bare soil	1,244	968 [13]	26	1	5	0	0	32	3.3
Chemical treatment	9,610	4,874 [21]	203	208	165	0	0	576	11.8
Mechanical treatment	8,888	4,233 [22]	258	149	76	7	1	491	11.6
Total	19,742	10,075 [22]	487	358	246	7	1	1,099	10.9

Table 2

Bayesian models used to assess the effects of treatment and time on AF bird abundance and species dominance. We present the variable coefficients and standard error (SE) for each model. April was used as the reference month. Significant 95 % CI-values (without 0) are highlighted in bold. The percentage of explained deviance of the model (i.e. percentage of the variability explained by each model “BR²”) is shown. At convergence, Rhat = 1.

Model	Variables	Coefficient	SE	95 % CI	Rhat	BR ²
AF Birds Abundance	Sampling point (Random)	0.93	0.20	(0.61–1.40)	1.00	89 %
	MT Plot	2.55	0.53	(1.50–3.62)	1.00	89 %
	CT Plot	3.01	0.51	(2.00–4.05)	1.00	89 %
	May	1.80	0.67	(0.48–3.07)	1.00	89 %
	June	1.48	0.65	(0.18–2.72)	1.00	89 %
	July	4.03	0.65	(2.75–5.56)	1.00	89 %
	August	3.30	0.63	(2.06–4.53)	1.00	89 %
	September	–2.99	1.22	(–5.56– –0.80)	1.00	89 %
	Dominance	Sampling point (Random)	0.10	0.08	(0.01–0.29)	1.00
MT Plot		0.50	0.27	(0.03–1.05)	1.00	78 %
CT Plot		0.44	0.27	(0.09–0.99)	1.00	78 %
May		0.13	0.37	(–0.58–0.86)	1.00	78 %
June		0.14	0.36	(–0.56–0.85)	1.00	78 %
July		–0.01	0.39	(–0.76–0.74)	1.00	78 %
August		0.13	0.37	(–0.60–0.88)	1.00	78 %
September		0.14	0.38	(–0.61–0.88)	1.00	78 %

migration period (April to August) and were among the dominant species in plots with herbaceous cover. Common/Pallid Swifts were dominant in CT and MT plots, whereas the Common House Martin was dominant only in MT plots (Table 3, Fig. 2).

The abundance of all bird species (Appendix 1) was significantly influenced by the type of ground cover treatment (Appendix 2). Plots with herbaceous cover, whether managed chemically (Coefficient = 1.90, 95 % CI = [1.61, 2.18]) or mechanically (Coefficient = 1.49, 95 % CI = [1.20, 1.78]), exhibited higher bird abundance compared to plots without herbaceous cover (BS). In contrast, no clear temporal trend was observed, as monthly coefficients had wide credible intervals that

overlapping zero. The model explained a substantial proportion of variance in bird abundance (BR² = 0.81).

When comparing directly the mean abundance between the two herbaceous cover, chemically and mechanically managed plots, the posterior mean difference was 0.40 (95 % CI = [–0.12, 0.68]), the credible interval overlapped zero, indicating no statistical difference.

4. Discussion

Our results show that from April to August the six species of AF birds were present in olive crops, although *Cecropis daurica* and *Tachymarptis*

Table 3

Dominant species over the study period in each plot. Dominance: number of species with the greatest abundance. Italics: Aerial Feeder Birds (AFB).

Month	Chemical treatment		Mechanical treatment		Bare soil	
	Dominance	Dominant species	Dominance	Dominant species	Dominance	Dominant species
April	3	Common blackbird	3	Common blackbird	1	Common blackbird
		Common chaffinch		Common chaffinch		
		European serin		European serin		
May	3	Common blackbird	3	Common blackbird	2	Common blackbird
		Common chaffinch		Iberian magpie		Sardinian warbler
		Iberian magpie		European goldfinch		
June	3	Common blackbird	3	Common black bird	2	Common blackbird
		House sparrow		European serin		Sardinian warbler
		Iberian magpie		European goldfinch		
July	2	<i>Common/pallid swift</i>	3	<i>Common house martin</i>	2	Common blackbird
		Iberian magpie		<i>Common/pallid swift</i>		Iberian magpie
				Iberian magpie		
August	3	Common blackbird	3	<i>Common/pallid swift</i>	2	Common blackbird
		House sparrow		Common blackbird		Sardinian warbler
		European goldfinch		European goldfinch		
September	3	Common chaffinch	3	Common blackbird	2	Common blackbird
		European serin		Common chaffinch		Sardinian warbler
		European goldfinch		European goldfinch		

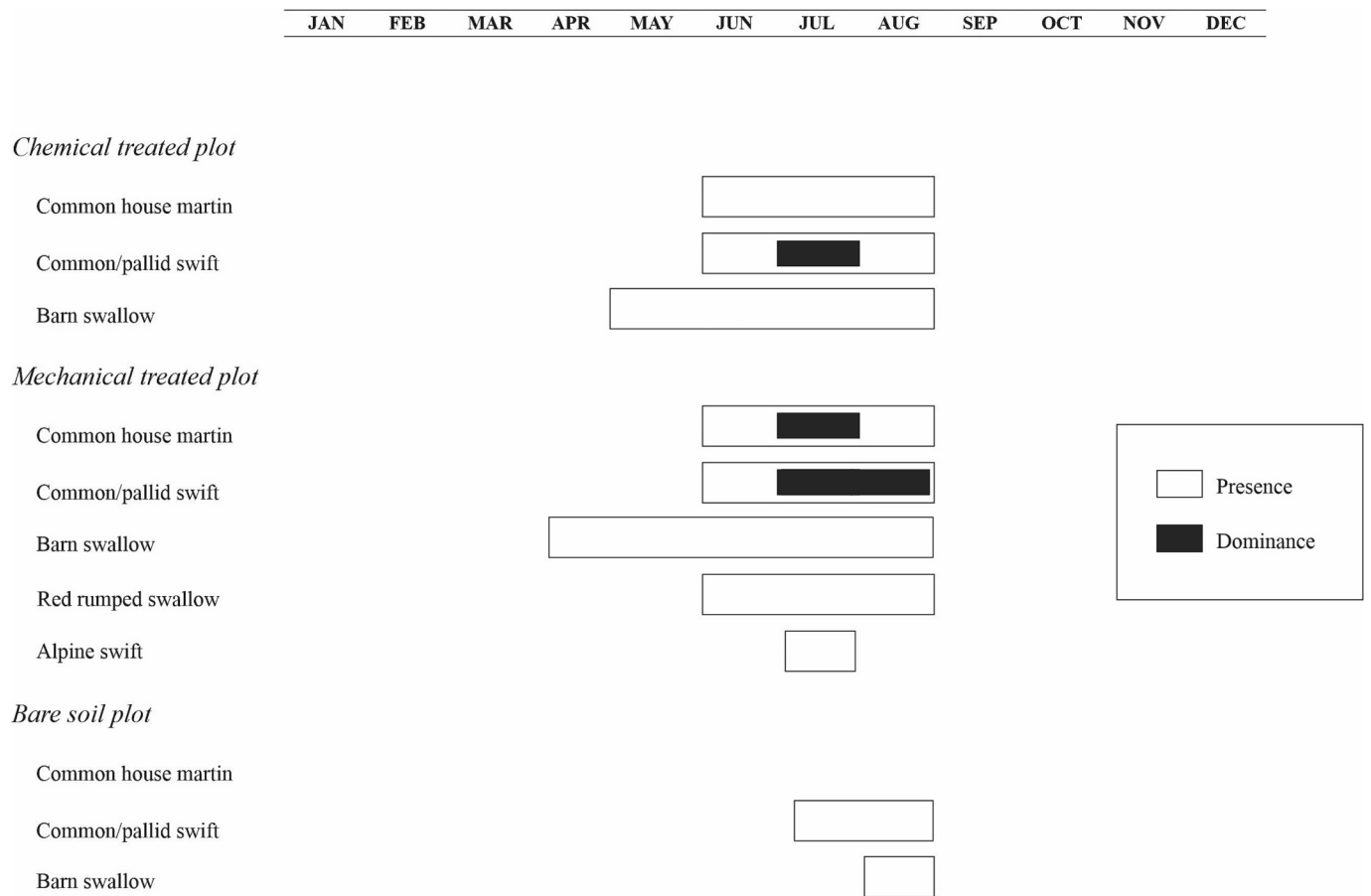


Fig. 2. Months in which Swifts (*Apus apus/pallidus*), Common House Martins (*Delichon urbicum*), Alpine Swift (*Tachymarptis melba*), Barn Swallows (*Hirundo rustica*) and Red Rumped Swallows (*Cecropis daurica*) were present and were dominant species.

melba occurred in low numbers. AF birds used olive groves as feeding areas during the study period, which included the breeding season and postnuptial migration. In addition, our study suggests the importance of herbaceous vegetation management in determining the abundance of AF birds in olive groves. We found that maintaining herbaceous cover significantly increases the abundance of these birds in olive groves. Our results are in agreement with those obtained by other authors, such as Duarte et al. (2014) who also showed in a study carried out in vineyards with similar treatments the value of maintaining the herbaceous cover for insectivorous birds. Castro-Caro et al. (2015) demonstrated that hedgerows and ground covers increased the abundance and richness of passerine communities in olive groves, particularly insectivorous species. Solomou and Sfougaris (2011) showed that organic olive groves support higher densities of breeding birds than traditionally managed ones. Herbaceous ground cover favours bird abundance, including aerial feeders, by increasing the availability of insects, especially flying ones (Kragten et al., 2011, Carpio et al., 2019, de la Torre et al., 2025). These findings suggest that maintaining vegetation along field boundaries and in inter-row areas can play a critical role in promoting biodiversity (Duarte et al., 2009). Moreover, different authors have shown that the herbaceous cover is also an important factor in the productivity of the olive grove itself, even favouring cultivation, contrary to traditional perceptions (Pastor et al., 2001, Alonso & Guzmán, 2006).

Farmers worldwide invest over US\$ 100 million in pest control, with approximately 50 % allocated to insecticides (Montiel-Bueno & Jones, 2002). Rey Benayas et al. (2017) have shown that the conservation of insectivorous birds can assist in controlling olive pests such as the olive fly (*Bactrocera oleae*), which causes great economic losses, by reducing the quantity and quality of the olive oil (Rey Benayas & Meltzer, 2017).

Similarly, Martínez-Núñez et al. (2020, 2021) highlighted that encouraging the presence of insectivorous birds in olive groves through habitat improvements could enhance their role in pest control. Despite the growing evidence of the benefits of biodiversity in agricultural systems, including insectivorous birds (Paredes & Campos, 2013, Rey Benayas et al., 2017), birds have been traditionally persecuted or overlooked in agricultural management (Cerri et al., 2017).

AF birds have not been associated with olive farming, as they have been primarily studied in urban environments (Molina & Casaux, 2022; Prieta Díaz, 2022; Marzal, 2022). This oversight may underestimate the role these birds can play in reducing pest loads in olive groves. In fact, other studies have shown that the presence of Swifts, Swallows and House Martins coincides with periods of peak activity of adult olive fruit flies (*Bactrocera oleae* (Gmelin) (Diptera: Tephritidae) (Yokoyama et al., 2006; Zalom et al., 2009), one of the main pests affecting olive groves yields and oil quality (Broumas et al., 2002), and could help in the control of this and other olive pests.

Numerous species, including several of conservation concern, rely heavily on agricultural landscapes for their survival. These environments provide critical habitat for feeding, nesting, and migratory stop-over. Agricultural ecosystems, particularly traditional low-intensity farmlands, have been recognized by the European Union as biodiversity hotspots and are therefore considered a conservation priority (Eurostat, 2015). However, agricultural intensification and landscape homogenization have led to significant declines in farmland bird populations in recent decades (Gregory et al., 2019; Busch et al., 2020). In this context, promoting farming practices that enhance biodiversity—both on the ground and in the air—is essential. This includes strategies such as maintaining herbaceous cover, preserving hedgerows, reducing

pesticide use, and supporting agro-ecological approaches. By adopting such measures, farmers can contribute meaningfully to reversing biodiversity loss. Therefore, such farming practices should be encouraged.

A limitation of our study is the lack of plot-level replication, as only one plot for each treatment type was monitored. Having said that, and with the required prudence, our results suggest that retaining herbaceous cover amidst trees in olive groves may increase overall bird abundance, including AF birds, within this agricultural system. Future research should investigate how the spatial distribution and density of herbaceous cover influence bird numbers, to better inform strategies aimed at improving the environmental sustainability of economically important woody crops such as the olive.

5. Financial support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix

Appendix 1. Species and number of individuals observed in the sampled plots

Bare soil		Chemical treatment		Mechanical treatment	
<i>Turdus merula</i>	606	<i>Turdus merula</i>	1364	<i>Fringilla coelebs</i>	1381
<i>Sylvia melanocephala</i>	147	<i>Fringilla coelebs</i>	1054	<i>Turdus merula</i>	1270
<i>Cyanopica cooki</i>	72	<i>Carduelis carduelis</i>	1052	<i>Carduelis carduelis</i>	954
<i>Carduelis carduelis</i>	58	<i>Passer domesticus</i>	901	<i>Serinus serinus</i>	789
<i>Erithacus rubecula</i>	52	<i>Cyanopica cooki</i>	798	<i>Passer domesticus</i>	635
<i>Columba palumbus</i>	47	<i>Serinus serinus</i>	776	<i>Phylloscopus collybita</i>	626
<i>Sturnus vulgaris</i>	43	<i>Sylvia melanocephala</i>	615	<i>Sylvia melanocephala</i>	524
<i>Serinus serinus</i>	35	<i>Phylloscopus collybita</i>	568	<i>Cyanopica cooki</i>	481
<i>Fringilla coelebs</i>	29	<i>Erithacus rubecula</i>	281	<i>Columba palumbus</i>	297
<i>Apus apus/pallidus</i>	26	<i>Columba palumbus</i>	274	<i>Apus apus/pallidus</i>	258
<i>Passer domesticus</i>	24	<i>Delichon urbicum</i>	208	<i>Erithacus rubecula</i>	232
<i>Streptopelia decaocto</i>	22	<i>Sturnus vulgaris</i>	203	<i>Sturnus vulgaris</i>	158
<i>Galerida cristata</i>	20	<i>Apus apus/pallidus</i>	203	<i>Delichon urbicum</i>	149
<i>Parus major</i>	14	<i>Turdus philomelos</i>	192	<i>Parus major</i>	149
<i>Chloris chloris</i>	11	<i>Parus major</i>	163	<i>Chloris chloris</i>	148
<i>Phoenicurus ochruros</i>	9	<i>Chloris chloris</i>	151	<i>Sylvia atricapilla</i>	110
<i>Phylloscopus collybita</i>	8	<i>Hirundo rustica</i>	132	<i>Phoenicurus ochruros</i>	104
<i>Hirundo rustica</i>	5	<i>Streptopelia turtur</i>	124	<i>Alectoris rufa</i>	100
<i>Turdus philomelos</i>	5	<i>Sylvia atricapilla</i>	113	<i>Turdus philomelos</i>	100
<i>Upupa epops</i>	3	<i>Alectoris rufa</i>	103	<i>Hirundo rustica</i>	76
<i>Athene noctua</i>	3	<i>Phoenicurus ochruros</i>	100	<i>Streptopelia turtur</i>	72
<i>Streptopelia turtur</i>	3	<i>Streptopelia decaocto</i>	61	<i>Streptopelia decaocto</i>	57
<i>Delichon urbicum</i>	1	<i>Galerida cristata</i>	46	<i>Cyanistes caeruleus</i>	56
<i>Buteo buteo</i>	1	<i>Cyanistes caeruleus</i>	36	<i>Galerida cristata</i>	34
		<i>Upupa epops</i>	22	<i>Athene noctua</i>	31
		<i>Merops apiaster</i>	21	<i>Upupa epops</i>	26
		<i>Spinus spinus</i>	15	<i>Merops apiaster</i>	13
		<i>Falco tinnunculus</i>	8	<i>Spinus spinus</i>	12
		<i>Athene noctua</i>	5	<i>Corvus corax</i>	11
		<i>Corvus corax</i>	5	<i>Cuculus canorus</i>	10
		<i>Cuculus canorus</i>	4	<i>Falco tinnunculus</i>	8
		<i>Buteo buteo</i>	4	<i>Cecropis daurica</i>	7
		<i>Motacilla alba</i>	3	<i>Motacilla alba</i>	4
		<i>Lanius senator</i>	2	<i>Turdus viscivorus</i>	2
		<i>Cecropis daurica</i>	2	<i>Lanius senator</i>	1
		<i>Turdus viscivorus</i>	1	<i>Buteo buteo</i>	1
				<i>Accipiter nisus</i>	1
				<i>Tachymarpis melba</i>	1
Total number of birds	1,244		9,610		8,888

CRedit authorship contribution statement

Inmaculada Navarro: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Miguel Ángel Farfán:** Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Julia E. Fa:** Formal analysis, Investigation, Supervision, Writing – review & editing. **Antonio-Román Muñoz:** Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

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

Appendix 2. Bayesian model used to assess the effects of treatment and time on abundance of all bird species. We present the variable coefficients and standard error (SE) for each model. April was used as the reference month. Significant 95 % CI-values (without 0) are highlighted in bold. The percentage of explained deviance of the model (i.e. Percentage of the variability explained by each model “BR²”) is shown. At convergence, Rhat = 1

Model	Variables	Coefficient	SE	95 % CI	Rhat	BR ²
Birds Abundance	Sampling point (Random)	0.34	0.05	(0.25–0.45)	1.00	81 %
	MT Plot	1.49	0.15	(1.20–1.78)	1.00	81 %
	CT Plot	1.90	0.14	(1.61–2.18)	1.00	81 %
	May	0.01	0.20	(–0.41–0.39)	1.00	81 %
	June	0.21	0.20	(–0.08–0.72)	1.00	81 %
	July	0.32	0.21	(–0.08–0.72)	1.00	81 %
	August	4.43	0.19	(–0.58–0.23)	1.00	81 %

Data availability

Data will be made available on request.

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