

The surrounding landscape shapes the abundance of *Sphaerophoria scripta* and *Melanostoma mellinum* (Diptera: Syrphidae) in Portuguese vineyards

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Abstract

1. The intensification of urban and agricultural use in the landscape is the major driver of biodiversity loss and the consequent decrease of ecosystem services provided by insects. Syrphids are important ecosystem service providers, including pest regulation, pollination, and matter decomposition.
2. Understanding how the surrounding landscape to crops affects syrphids is essential to implementing strategies to reverse the negative effects of the agricultural landscape's simplification.
3. This study describes the Syrphidae community in Portuguese vineyards and the response of the most abundant species, *Sphaerophoria scripta* Linnaeus, 1758, and *Melanostoma mellinum* Linnaeus, 1758, to the landscape composition and configuration within a gradient of distances (500, 1000, and 2000 m) from the sampled vineyards.
4. The presence of seminatural habitats and other crops in the surrounding landscape increased both species at the largest distance, whereas the presence of artificial territory, olive orchards, and vineyards reduce *M. mellinum* at some of the buffers.
5. Increasing seminatural habitats in the vineyards surrounding landscape (2000 m) and, potentially, introducing nature-friendly practices in the principal crops around vineyards may favour syrphid abundance.

KEYWORDS

agricultural landscapes, *Melanostoma mellinum*, seminatural habitats, *Sphaerophoria scripta*, *Vitis vinifera*

INTRODUCTION

The landscape is crucial to insects' diversity and abundance by providing shelter, food, and overwintering places. Specific landscape structures may drive an increase in the activity of ecosystem services provided by insects. In turn, it may reduce the damage caused by agricultural pests and, consequently, a reduction of phytosanitary

treatments carried out on crops (Bartual et al., 2019; Thomson & Hoffmann, 2009).

Syrphids (Syrphidae: Diptera) are providers of multiple ecosystem services. The larvae of some species are voracious predators of insects and agricultural pests (Belcari & Raspi, 1989; Bellefeuille et al., 2019; Dunn et al., 2020; Hopper et al., 2011; Sacchetti, 1990), while others are decomposers (Martínez-Falcón et al., 2012; Speight, 2017).

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The adults feed on nectar and pollen in flower plants (Rotheray & Gilbert, 2011; Villa et al., 2021), acting as pollinators (Doyle et al., 2020; Klecka et al., 2018; Raguso, 2020; Saunders, 2018). In addition, syrphids can also play an important role as bioindicators, as they have been proven useful in evaluating environmental health (Sommaggio & Burgio, 2014; Souza et al., 2014; Velli et al., 2010).

Syrphidae is one of the largest families of Diptera, with more than 6000 species described worldwide (Brown, 2009), of which 970 are described in Europe (Gaytán et al., 2020). However, the ecological characterization of Mediterranean syrphids communities is scarce, with few studies focussing on the effect of landscape variables on the abundance and richness (e.g., Herrault et al., 2016; Jovičić et al., 2017; Santos et al., 2018). The Mediterranean can feature a great diversity of syrphids because it has a wide range of habitats for the development of the larvae and floristic resources for adults (Gaytán et al., 2020).

Vineyards are among the oldest and most emblematic crops in the Mediterranean landscapes (Fraga et al., 2017). In this crop, syrphids prey on aphids, mealybugs, and other soft-bodied insects (Rodríguez-Gasol et al., 2020). Moreover, there are reports of syrphids, namely *Xanthandrus comtus* (Harris, 1780), preying on *Lobesia botrana* (Denis & Schiffermüller, 1775) larvae, which is considered one of the main pests of the vineyards in the Mediterranean region (Belcari & Raspi, 1989; Martín-Vertedor et al., 2010). Furthermore, syrphids can play an essential role in wildflower pollination of the adjacent vegetation and inter-rows of the vineyards (Doyle et al., 2020). This vegetation may provide resources for other natural enemies and favour predation and parasitism on vineyard's pests (e.g., Rusch et al., 2017; Thomson & Hoffmann, 2009, 2013).

In the last years, global biodiversity has declined at an alarming rate, frequently associated with human activity (Karp et al., 2012; Raven & Wagner, 2021; Stoate et al., 2009). Besides abiotic and biotic parameters, human activity is a determining factor in shaping the landscape (Jovičić et al., 2017), which often results in the intensification of agricultural and urban land use and the consequent fragmentation of seminatural habitats (hereafter SNH). Such fragmentation has been reported as the main element for declining natural enemies and pollinators (Aronson et al., 2017; Bianchi et al., 2006; Emmerson et al., 2016; Gardiner et al., 2009; Persson et al., 2020). Vineyards, as a monoculture, could represent a potential threat to regional biodiversity due to the constant expansion, replacement of native habitats, and simplification of the surrounding landscape (Underwood et al., 2009).

According to Jauker et al. (2009), syrphids are not particularly susceptible to agricultural intensification. However, they can still benefit from a lower management intensity at the landscape scale (Kleijn & Van Langevelde, 2006; Meyer et al., 2009; Schirmel et al., 2018). The diversity of habitats, complex shapes of land patches, and landscape composition are the main factors responsible for increasing the diversity and abundance of pollinators and natural enemies (Christine et al., 2019; Santos et al., 2018). For some syrphids, such diverse habitats are essential to switch between foraging, mating, overwintering, and larval habitats. In addition, due to larvae' highly differentiated feeding habits, syrphids depend on specific habitats that can be scarce in agricultural landscapes (Moquet et al., 2018).

In terms of spatial scales, insect species richness response to their landscape context depends on the analysed scale (Stoms, 1994). For example, Haenke et al. (2009) and Power et al. (2016) reported that adults of syrphids could respond to the landscape up to 4 km. Kleijn and Van Langevelde (2006) and Meyer et al. (2009) stated that syrphids are optimally related to landscape composition at spatial scales between 500 and 1500 m. Some syrphids are very mobile, making them sensitive to large spatial scale conditions (Smith et al., 2008), while other syrphids species are considered nonmigrants (Speight, 2008). Migrant syrphids can disperse up to 400 m in 1 day, whereas nonmigrants rarely disperse more than 50 m (Wratten et al., 2003).

Therefore, understanding how the configuration and composition of the landscape, within a gradient of distances, shapes the richness and abundance of syrphids in the Portuguese vineyards is extremely important to implement strategies to enhance these insects within the agricultural landscape. Strategies such as enhancing crop diversity and increasing SNH in the landscape for more food resources and habitats for nesting and dispersal might support the syrphids community (Fahrig et al., 2011; Raderschall et al., 2021).

This work aimed to describe the Syrphidae community in Portuguese vineyards and determine the effect of the landscape context on the most abundant species. For that, (i) the Syrphid community was described; and (ii) the response of the most abundant species to the landscape structure within a gradient of distances from the vineyards was analysed.

MATERIALS AND METHODS

Study area

For this study, 35 vineyards distributed in mainland Portugal (Figure 1) were selected. From that, 21 were sampled in 2018 and 35 in 2019. All vineyards were under sustainable producing systems (integrated or organic), and the vegetation ground cover was maintained in the inter-rows during the sampling periods. The information regarding each vineyard is available in the Table S1.

Sampling methods

The sampling occurs in three periods, early summer, summer, and autumn (Table S1). In each vineyard, in an area of 1 ha, 20 samples, 10 for the canopy and 10 for the vegetation ground cover, were taken, using a standard entomological sweep at three different sample dates in two consecutive years. Each sample consisted of 50 sweeps of the canopy and 10 sweeps of the herbaceous vegetation ground cover. The net contents were transferred into a plastic bag, and diethyl ether (PanReac AppliChem ITW Reagents, USA) was added to kill the arthropods. All samples were frozen at -20°C . Syrphids were separated under a stereomicroscope and conserved in ethanol 96% for further identification. The adults were identified up to the species

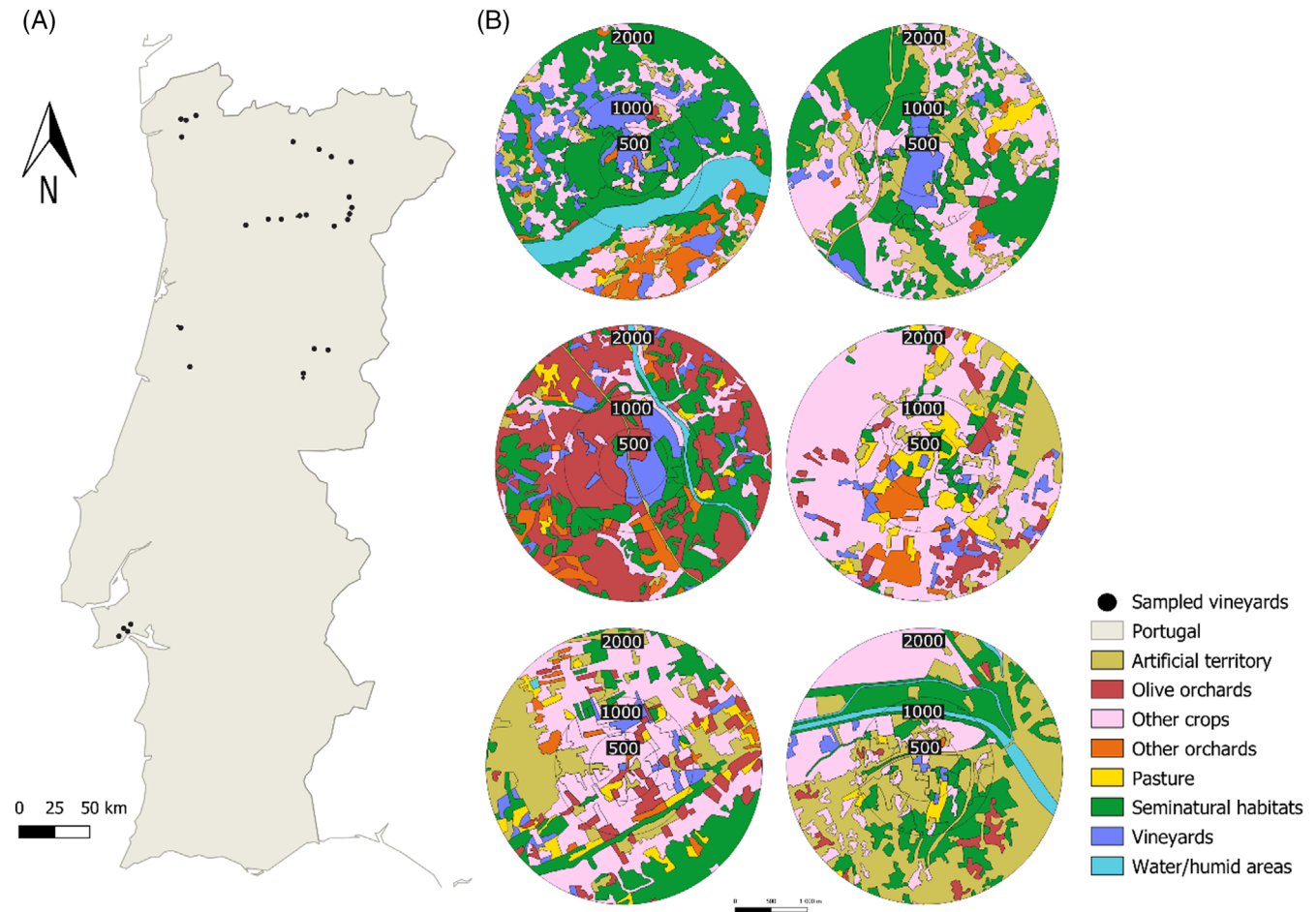


FIGURE 1 (a) Location of the sampled vineyards in Portugal. (b) Examples of land cover categories with different spatial scales (500, 1000, and 2000 m). Maps projected in ETRS89/PT-TM06.

level using entomological keys (Gilbert, 1986; Speight, 2020; Thompson & Rotheray, 1998).

Landscape variables

The response of the abundance of *Sphaerophoria scripta* Linnaeus, 1758 and *Melanostoma mellinum* Linnaeus, 1758 (please, see Results: Syrphids), the most abundant species, to the landscape structure within a gradient of distances (500, 1000, and 2000 m radii, hereinafter referred to as buffers) from the vineyards were analysed (Figure S1). For that, landscape configuration and composition metrics were calculated within each buffer constructed around each vineyard. Overlapping vineyards were excluded to avoid spatial autocorrelation. Thus, 16, 15, and 13 vineyards in 2018 and 20, 20, and 17 vineyards in 2019 were selected respectively for 500, 1000, and 2000 m buffers. The map “Carta de Uso e Ocupação do Solo de Portugal Continental para 2018” (COS 2018) (DGT, 2018) was used to obtain the land uses and respective areas within each buffer. Buffers were constructed using the spatial scale, intersect and aggregate functions from the “raster” package (Hijmans, 2021), and the msexplode

function from “rmapshaper” package (Teucher & Russell, 2021). To obtain more accurate landscape variables, the small polygons (<25 m² because the resolution of orthophotos for COS 2018 is 25 m²) generated in the spatial scale edges during the intersection process were merged to a larger adjacent polygon using ARCGIS, version 10.3.1 (ESRI, Redlands, California). Then, landscape variables were calculated using the software Patch Analyst for ARCGIS.

The land-use classes considered to calculate the landscape metrics were: vineyards, SNH (i.e., forest—mainly *Quercus* sp., *Pinus* sp., and *Castanea sativa* Mill. and Mediterranean scrublands) (DGT, 2018), olive orchards, other crops (i.e., herbaceous crops), other orchards (i.e., woody crops, excluding vineyards and olive orchards), pasture, bared areas (i.e., with low or no vegetation), artificial territory (i.e., urban territory or buildings), and water/humid areas.

The landscape-level metrics calculated for further analysis were the Simpson’s diversity index (SEI) to quantify the landscape composition, which represents the probability that any land types selected at random would be different types, and the mean patch fractal dimension (MPFD) to quantify the degree of configuration complexity of the landscape. This metric measures the complexity of a polygon by relating perimeter and area (McGarigal & Marks, 1995). At the class level,

the considered landscape metrics were: the areas of artificial territories, olive orchards, vineyards, other crops, and SNH because of their variability across regions (in the case of artificial territories, olive orchards, vineyards, other crops) or because of their potential importance for syrphids (in the case of SNH).

Response to landscape variables

The response of *S. scripta* and *M. mellinum* abundance to landscape variables at the different buffers was analysed using a series of separated generalized mixed models (GLMMs) (one model for each buffer—500, 1000, and 2000 m). Elevation was included as an explanatory variable because it can determine the Syrphids community (Haslett, 1997). Thus, the following explanatory variables were considered for the model's construction: the coordinates of the sampling sites (longitude and latitude), SEI, MPFD, areas of artificial territories, olive orchards, vineyards, other crops, and SNH, the elevation, the year (two levels: 2018 and 2019), the strata (two levels: vegetal ground cover and canopy). Only samples from the early summer period were considered due to the small numbers of syrphids in the other sampling dates. Before running the models, the standardized continuous explanatory variables were selected for each spatial scale to avoid multicollinearity. For that: (i) three principal component analyses (PCAs) were constructed with the correlation matrix of the landscape metrics, one for each spatial scale (Figure S1). The PCA function from the “FactoMineR” package (Lê et al., 2008) was used to visualize the contribution to the variance of the explanatory variables and their relations. The correlation biplot of the two first PCs was drawn using the `fviz_pca_biplot` function from the “factoextra” package (Kassambara & Mundt, 2020). (ii) The Pearson

correlations were calculated using the function `cor` from base R (R Core Team, 2021) (Figure S2). Pearson correlations were lower than 0.7 in all cases. (iii) A higher variance inflation factor (VIF) than 3 was not allowed, minimizing potential model misspecifications (Dormann et al., 2013). When multicollinearity among explanatory variables was found, the variables with more potential biological meaning for syrphids were maintained in the models.

Poisson (for count data), negative binomial—linear (`nbinom1`), or quadratic (`nbinom2`) parameterization—to account for overdispersion or zero-inflated (Poisson or `nbinom1`) to account for zero inflation distributions (Bolker, 2021) were used for the models. The distribution used for each model is indicated in the results section. The backward selection was performed until all explanatory variables were significant or the model validation failed. The most explanatory model (keeping a higher number of explanatory variables) within $<2 \Delta AIC$ (Akaike Information Criterion) was selected (Burnham & Anderson, 2004). The function `glmmTMB` from the “glmmTMB” package was used for fitting the models (Brooks et al., 2017). Models were validated using the `simulateResiduals` function from “DHARMA” package (Hartig, 2021).

RESULTS

Syrphids

In the sampled vineyards, 549 syrphids (Syrphidae: Diptera) were recovered in 2018 and 2019. Early summer was the period with a higher abundance of syrphids (251 in 2018 and 242 in 2019) (Table 1). Whereas in summer (24 in 2018 and 2 in 2019) and autumn (25 in 2018 and 5 in 2019), the abundance was lower. Seven syrphid

TABLE 1 Abundance of Syrphidae species found in the canopy (C) and herbaceous vegetation cover (H) in the sampled vines in early summer of 2018 and 2019.

Syrphid species	FG	Early summer 2018			Early summer 2019			Total
		C	H	Total	C	H	Total	
<i>Eristalis tenax</i> Linnaeus, 1758	Sp/P		1 (1, 0)	1 (1, 0)				1 (1, 0)
<i>Eupeodes corollae</i> Fabricius, 1794	Pr/P	1 (0, 1)		1 (0, 1)				1 (0, 1)
<i>Melanostoma mellinum</i> Linnaeus, 1758	Pr/P	50 (25, 25)	34 (19, 15)	84 (44, 40)	8 (3, 5)	12 (7, 5)	20 (10, 10)	104 (54, 50)
<i>Paragus quadrifasciatus</i> Meigen, 1822	Pr/P	4 (1, 3)	4 (3, 1)	8 (4, 4)				8 (4, 4)
<i>Sphaerophoria rueppelli</i> Wiedemann, 1830	Pr/P		1 (1, 0)	1 (1, 0)		3 (0, 3)	3 (0, 3)	4 (1, 3)
<i>Sphaerophoria scripta</i> Linnaeus, 1758	Pr/P	74 (42, 32)	81 (48, 33)	155 (90, 65)	37 (22, 15)	182 (91, 91)	219 (113, 106)	374 (203, 171)
<i>Syrphus vitripennis</i> Meigen, 1822	Pr/P	1 (1, 0)		1 (1, 0)				1 (1, 0)
Total		130 (69, 61)	121 (72, 49)	251 (141, 110)	45 (25, 20)	197 (98, 99)	242 (123, 119)	493 (264, 229)

Note: The functional group (FG) is indicated (Sp: Saprophytic larva; P: Pollinator adult; Pr: Predatory larva). The number of females and males is shown between brackets: (number of females, number of males).

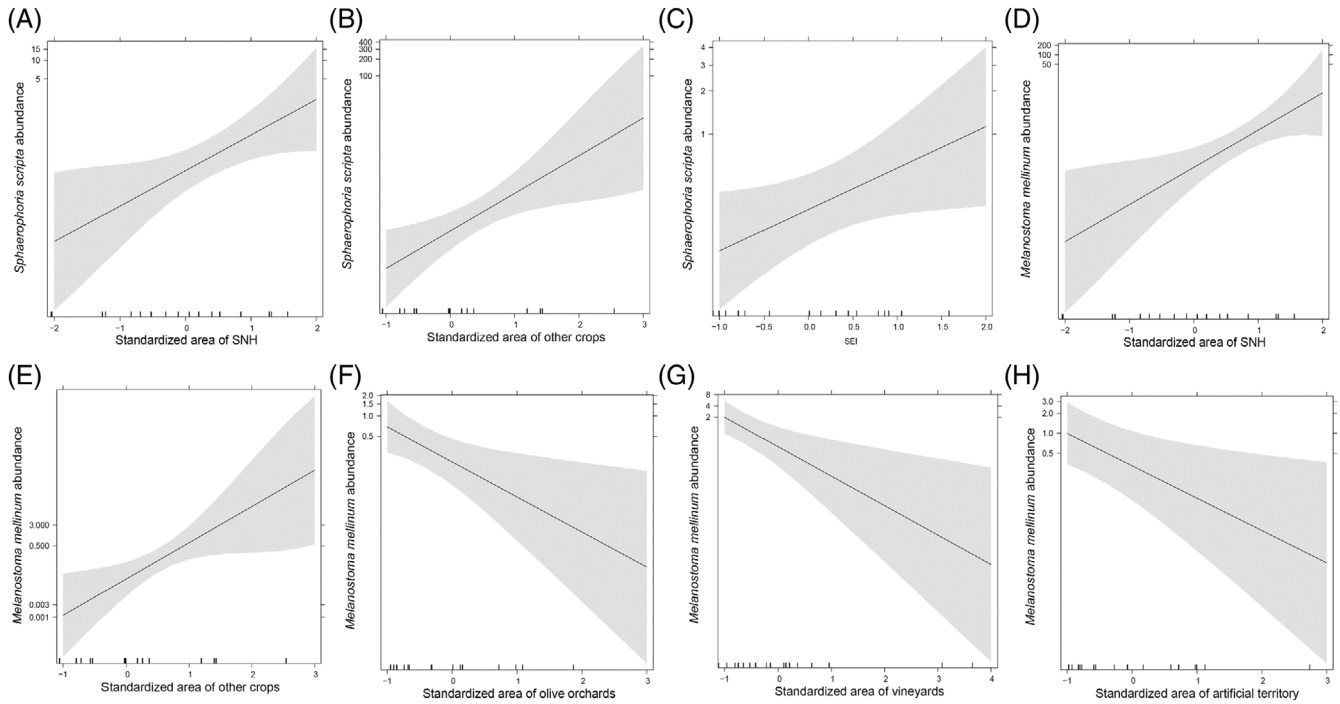


FIGURE 2 Response of *S. scripta* to seminatural habitats (SNH) (a), other crops (b) at the 2000 m buffer and Simpson diversity index (c) at the 500 m buffer; and response of *M. mellinum* to SNH (d), other crops (e) at the 2000 m buffer, to olive orchards (f) at 500 m and to artificial territory (g) and vineyards (h) at the 100 m buffer.

TABLE 2 GLMMs outputs testing the response of *Sphaerophoria scripta* abundance, to landscape composition and configuration variables at five spatial scales (500, 1000, and 2000 m).

Spatial scale	Distribution	Variables	Landscape structure			
			Estimate	SE	z	p
500	nbinom2	(Intercept)	-0.1943	0.4476	-0.434	0.664
		Latitude	0.6395	0.3745	1.707	0.088
		SEI	0.9014	0.5126	1.759	0.079
		Olive orchards	-0.4142	0.3201	-1.294	0.196
		SNH	0.2857	0.3721	0.768	0.443
		Year 2019 (vs. 2018)	-2.2506	0.7162	-3.142	0.002
1000	nbinom2	(Intercept)	-0.5534	0.4636	-1.194	0.233
		Latitude	0.7634	0.3731	2.046	0.041
		SEI	-0.4877	0.3557	-1.371	0.170
		Year 2019 (vs. 2018)	-1.7297	0.7073	-2.446	0.014
2000	nbinom2	(Intercept)	-0.3748	0.4404	-0.851	0.395
		Latitude	0.6730	0.3438	1.957	0.050
		Other crops	1.5407	0.5502	2.800	0.005
		SNH	1.3008	0.5366	2.424	0.015
		Year 2019 (vs. 2018)	-2.4011	0.7602	-3.159	0.002

Note: Year—2018 and 2019.

Abbreviations: SEI, Simpson diversity index; SNH, seminatural habitats.

species were identified in the early summer period (Table 1). The most abundant were *S. scripta* followed by *M. mellinum* (Figure S3), dominating the specimens recovered in early summer. In the summer

sampling, the species *S. scripta* (13 in 2018 and 1 in 2019), *M. mellinum* (11 in 2018), and *Episyrphus balteatus* De Geer, 1776 (1 in 2019) were captured. In the autumn, the species *S. scripta* (2 in 2018

TABLE 3 GLMMs outputs testing the response of *Melanostoma mellinum* abundance, to landscape composition and configuration variables at three spatial scales (500, 1000, and 2000 m).

Spatial scale	Distribution	Variables	Landscape structure			
			Estimate	SE	z	p
500	nbinom2	(Intercept)	−1.2554	0.3994	−3.14	0.002
		Latitude	0.2019	0.2778	0.73	0.467
		SEI	0.3839	0.2858	1.34	0.179
		Artificial territory	−0.3438	0.3476	−0.99	0.323
		Olive orchards	−0.6277	0.3800	−1.65	0.099
		Year 2019 (vs. 2018)	−1.3379	0.5182	−2.58	0.010
1000	nbinom1	(Intercept)	0.8252	0.4112	2.01	0.045
		Latitude	1.2940	0.3458	3.74	<0.001
		Artificial territories	−1.1167	0.4579	−2.44	0.015
		Olive orchards	−0.6232	0.4029	−1.55	0.122
		Vineyards	−1.8051	0.6446	−2.80	0.005
		Year 2019 (vs. 2018)	−2.7430	0.7132	−3.85	<0.001
		Strata ground cover (vs. canopy)	−0.7471	0.4434	−1.69	0.092
2000	nbinom1	(Intercept)	−1.9254	0.6000	−3.21	0.001
		Latitude	1.0089	0.5250	1.92	0.055
		Olive orchards	1.2270	0.7807	1.57	0.116
		Other crops	3.1514	1.2557	2.51	0.012
		SNH	2.7043	1.0262	2.64	0.008
		Elevation	−1.3055	0.8545	−1.53	0.127
		Year 2019 (vs. 2018)	−2.9215	1.1342	−2.58	0.010

Note: Year—2018 and 2019; Strata—vegetal ground cover and canopy. Abbreviations: SEI, Simpson diversity index; SNH, seminatural habitats.

and 1 in 2019), *M. mellinum* (11 in 2018 and 2 in 2019), *E. balteatus* (1 in 2018), *Paragus quadrifasciatus* (Meigen, 1822) (1 in 2019), and *Platycheirus albimanus* (Fabricius, 1781) (1 in 2019) were collected.

Explanatory variables selection

Regarding the 500 and 1000 m buffers, the final models included: latitude, SEI, artificial territories, olive orchards, vineyards, SNH, elevation, year, and strata. MPFD, other crops, and longitude were excluded from the models because SNH was negatively correlated with MPFD and other crops and because longitude was negatively correlated with elevation (Figure S1A,B). The maximum VIF among the continuous variables was 2.82, and 1.84 for 1000, and 500 m buffers, respectively.

The final model for the 2000 m buffer included latitude, olive orchards, other crops, vineyards, SNH, elevation, year, and strata. Longitude, SEI, MPFD, and artificial territories were excluded from the model because longitude was negatively correlated with artificial territories, other crops, and SEI and positively correlated with elevation and olive orchards. Moreover, MPFD was positively correlated with vineyards (Figure S1C). The maximum VIF among the continuous variables was 2.26.

Syrphid response to landscape structure

Generally, the abundance of the most representative species, *S. scripta* and *M. mellinum* of syrphids, increased in the north of the country and showed higher values in 2018 than in 2019.

The presence of SNH and other crops increased the abundance of both species at 2000 m buffer (Figure 2, Tables 2 and 3). Though not significant, there was a positive trend on *S. scripta* by SEI at 500 m. The presence of artificial territory and vineyards (at 1000 m), and olive orchards (at 500 m), showed a general tendency to reduce *M. mellinum* (Table 3).

DISCUSSION

Previous studies revealed the importance of the landscape structure on insect species abundance, diversity, and composition (e.g., Adams et al., 2020; Medeiros et al., 2019; Steffan-Dewenter et al., 2002; Toivonen et al., 2022; Warzecha et al., 2021). Here, we investigated how the landscape structure affects the abundance of the most representative species in Portuguese vineyards. We found several landscape features to drive the abundance and the richness of syrphids mainly at large scales (2000 m).

Our results indicated that syrphids were more abundant and richer in early July, most likely because the majority of plants bloom in spring, whereas in summer and autumn, syrphids would remain in diapause, concurring with Salveter (1998), Speight (2014), and Villa et al. (2021). However, a relatively low number of species were identified compared with other studies in the vineyard (e.g., Gonçalves et al., 2015; Pétremand et al., 2017; Sommaggio & Burgio, 2014). This low richness may be related to the sampling dates (early summer and autumn, instead of early spring). *S. scripta* and *M. mellinum* were the most abundant syrphids, in agreement with previous studies carried out in the Mediterranean region (Ricarte et al., 2011; Sabater & García, 2008; Villa et al., 2021). Larvae of both species are aphidophagous while adults feed on pollen and are active from the beginning of the spring to the middle of the autumn (Speight, 2017).

Our results suggest that high proportions of SNH in the landscape significantly increase the abundance of *S. scripta* and *M. mellinum* in the vineyards, particularly when the SNH are at the largest scale (2000 m). SNH can provide important resources to syrphids, such as alternative hosts or prey, pollen, or nectar (Landis et al., 2000). They may also be overwintering habitats and refuges from disturbance (Pffiffer & Luka, 2000). In accordance with the present results, Jauker et al. (2009) described that the abundance of syrphids increased with the distance to the SNH. Whereas several studies have only reported the positive effect of SNH on syrphids abundance and richness on lower distances to the main crop (e.g., Beduschi et al., 2018; Kleijn & Van Langevelde, 2006; Krimmer et al., 2019; Moquet et al., 2018). Our results could be related to the quality and type of the SNH in close proximity to the sampled vineyards. SNH in this study were mainly composed of forests of *Quercus* sp., *Pinus* sp., and *C. sativa* Mill., and Mediterranean scrublands (DGT, 2018). These habitats contain plants that bloom in July such as the trees *C. sativa* and *Sambucus nigra* L. or the scrubs *Daphne gnidium* L., *Cytisus* sp., *Genista* sp., *Rubus* sp. and *Erica* sp., all of them are well-known food resources for syrphids (e.g., Villa et al., 2021; Wojciechowicz-Żytka & Jankowska, 2016). Accordingly, to Kleijn and Van Langevelde (2006), Meyer et al. (2009), and Schirmel et al. (2018), syrphids depend on floral resources for adults, such as the quantity and quality of pollen and nectar, as well as the type of the SNH (woody or herbaceous) and on the presence of requirements for larval development. Additionally, the main sampled syrphids are aphidophagous, and such individuals exhibit long-distance dispersal behaviour and movements associated with life-cycle stages and seasonality (Arrignon et al., 2007; Meyer et al., 2009), justifying the higher effect of large scales.

The high presence of other crops (e.g., field crops, outdoor horticultural crops, and outdoor flower crops) (DGT, 2018) in the landscape also positively influenced the abundance and richness of syrphids and the most representative species in the 2000 m buffer. Aphids are a common pest in horticultural crops (Van Emden & Harrington, 2017). Because the most abundant species are aphidophagous, syrphids could recourse to these cultures for food. Moreover, outdoor flower crops may also provide pollen and nectar to the adult's syrphids.

Artificial territory, vineyards (at 1000 m buffer), and olive orchards (at 500 m buffer) in the landscape negatively affected the abundance of *M. mellinum*. The artificial territory is one of the significant drivers of biodiversity loss, given the destruction and fragmentation of the habitats (Aronson et al., 2017; Persson et al., 2020). Although urban areas may provide beneficial habitats to flower-visiting insects (e.g., parks, gardens, SNH fragments, and brownfields) (Aronson et al., 2017; Baldock et al., 2019; Hall et al., 2017; Persson et al., 2020), the buildings and roads that shape the artificial territory function as barriers that fragment the foraging landscapes of pollinators (Buchholz et al., 2020; Jha, 2015; Johansson et al., 2018).

Within the study area, vineyards are typically intensively managed agricultural systems. The inter-row herbaceous vegetation is controlled by pre- or post-weed emergence herbicides or mechanical methods (soil tillage). Additionally, vineyards are also subjected to a series of phytosanitary treatments. Such cultural practices are well known to negatively affect biodiversity at multiple trophic levels (Peris-Felipo et al., 2021; Pétremand et al., 2017).

Regarding the olive groves, contrary to what was previously reported by Villa et al. (2021), our results indicate that the presence of this crop in the landscape had a weak negative effect on the abundance of *M. mellinum*. In the study conducted by Villa et al. (2021), all the olive groves sampled had spontaneous ground cover vegetation. The vegetation cover in the agrosystems provides shelter and vital floral resources for the syrphids. Such resources can contribute to syrphids' growth, development, reproduction, and survival (Albrecht et al., 2021). However, in Portugal, the olive orchards are mainly under rainfed conditions (Fraga et al., 2021) and intensely subjected to soil and ground cover vegetation management to minimize competition for water and nutrients (Zipori et al., 2020), which may have triggered our results.

Diverse landscapes can facilitate the movement of syrphids between optimal habitats and provide several suitable sites for adults and larvae to grow, contributing to a more diverse community of syrphids (Burgio & Sommaggio, 2007; Hendrickx et al., 2007; Kleijn & Van Langevelde, 2006; Schirmel et al., 2018). Our results suggest that landscape diversity may positively influence *S. scripta* at 500 m, although with a weak significance. Similarly, Meyer et al. (2009) and Wratten et al. (2003) only reported a positive correlation between landscape diversity and syrphid abundance at smaller buffers (200 and 250 m, respectively).

Lefebvre et al. (2018) reported that elevation is an important factor in shaping the syrphid community; however, our results indicated that altitude does not influence *S. scripta* and *M. mellinum*. Furthermore, in our work, vineyards have a lower elevation than Lefebvre et al. (2018), so the effect may not be noticeable.

CONCLUSION

Despite the growing knowledge of the effect of the landscape structure in the arthropod community, we described for the first time the influence of the landscape context on two abundant species of syrphids, *S. scripta* and *M. mellinum*, in Portuguese vineyards.

First, our results suggest that the landscape composition, through the presence of SNH and other crops around vineyards, contributes to the abundance of the studied species at the larger buffer (2000 m), and those increasing areas of SNH at the largest buffer may enhance the syrphid community within this agroecosystem. Second, our results suggest that land use, like the increase of urban areas and the intensification of agriculture in the landscape (although not consistently across buffers), may contribute to reducing syrphids within vineyards. In this context, further studies should address if the application of sustainable management practices on the main perennial crops (such as vineyards and olive groves) in the landscape enhances syrphids and consequently benefit the ecological services they provide.

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CONFLICT OF INTEREST

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

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Vineyards' information: sampling dates (2018 and 2019), metric characteristics, and management data.

Figure S1. PCA biplot for the landscape metrics at 500 (A), 1000 (B), 2000 (C), m spatial scales. SEI—Simpson diversity index; MPFD—mean patch fractal dimension; AT—artificial territory; Oth—Other crops; Oli—Olive crops; Vin—Vineyards; SNH—seminatural habitats; Ele—elevation; Y—Latitude; X—Longitude.

Figure S2. Pearson correlations among landscape variables at 500 (A), 1000 (B), 2000 (D) m spatial scales. SEI—Simpson diversity index; MPFD—mean patch fractal dimension; AT—artificial territory; Oth—Other crops; Oli—Olive orchards; Vin—Vineyards; SNH—seminatural habitats; Ele—elevation; Y—Latitude; X—Longitude.

Figure S3. Number of specimens of *Melanostoma mellinum* and *Sphaerophoria scripta* captured per vineyard. Points represent the number of captures per sample.

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