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Spatial structure of olive groves and scrublands affects *Bactrocera oleae* abundance: a multi-scale analysis

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Abstract

Environmentally friendly measures are needed to achieve natural pest control. A relationship between landscape structure and *Bactrocera oleae*, the main olive grove pest, indicated a general association between complex landscapes and reduced abundance of the insect. In this work we have characterised the relationship between spatial structure of specific land uses and the olive fruit fly abundance at different scales (from 600 to 2000 m radius). We paid special attention to the dominant land use in the studied area, the olive crop, and the surrounding natural land uses.

In the landscape analysed the spatial arrangement of olive and scrubland patches showed a gradient of situations from areas with an abundance of olive area distributed in very few patches close to each other to landscapes with less olive area arranged in many patches and with larger scrubland areas. Linear mixed-effects models showed that the abundance of *B. oleae* is positively related to the proximity of olive patches at all studied scales. However, other landscape characteristics (total area of olive groves and scrublands) were differentially related to pest abundance depending on considered scales. According to the obtained results it is advisable to plan olive groves at a 1000–1500 m radius spatial scale, in which the role of scrublands regarding *B. oleae* population is favoured. The best planning option for the olive grove landscape is discussed in the “Land sharing-Land sparing” context.

Zusammenfassung

Umweltfreundliche Maßnahmen werden benötigt, um eine natürliche Schädlingskontrolle zu erreichen. Die Beziehung zwischen Landschaftsstruktur und *Bactrocera oleae*, des wichtigsten Olivenschädlings, zeigte eine generelle Verbindung zwischen komplexen Landschaften und reduzierter Abundanz der Fliege. In dieser Arbeit charakterisierten wir die Beziehung zwischen der räumlichen Struktur der Landnutzung und der Abundanz der Olivenbohrfliege auf unterschiedlichen Skalen (Radien von 600 bis 2000 m). Besondere Beachtung schenkten wir der dominierenden Landnutzungsform, Olivenanbau, und den naturnahen Landschaftselementen in der Umgebung. In der untersuchten Landschaft bildete das räumliche Arrangement der Oliven- und Gebüschflächen einen Gradienten von Gebieten mit wenigen großen Olivenflächen hin zu Gebieten mit geringerem Olivenanteil, wobei zahlreiche kleine Anbauflächen mit größeren Gebüschflächen abwechselten. Lineare gemischte Modelle zeigten,

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dass auf allen Skalen die Abundanz von *B. oleae* positiv mit der Nähe der Olivenflächen verknüpft war. Indessen waren andere Landschaftsmerkmale (Gesamtflächen der Olivenhaine und Gebüschvegetation) auf unterschiedlichen Skalen unterschiedlich mit der Abundanz des Schädlings verknüpft. Nach unseren Ergebnissen sollten Olivenhaine auf einer Skala mit 1000 bis 1500 m Radius geplant werden, wo der Einfluss der Gebüschvegetation auf *B. oleae* begünstigt ist. Die optimale Planungsalternative für die Olivenhainlandschaft wird im Kontext des "land sharing" und "land sparing" diskutiert.

Keywords: Conservation biological control; Land sharing; Land sparing; Olive fruit fly; Pest; Spatial scales

Introduction

Biodiversity conservation in croplands under the frame of sustainable agriculture requires maximizing the use of environmentally friendly management methods and an adequate spatial planning. These requirements have given a major impetus to research on conservation biological control, including the relationship between landscape structure and abundance and diversity of natural enemies, pest control (Drapela, Frank, Heer, Moser, & Zaller, 2011; Scheid, Thies, & Tscharntke, 2011; D'Alberto, Hoffmann, & Thomson, 2012), and effects of scale (Bennett & Gratton, 2012; Caballero-Lopez et al., 2012; Hermann, Brunner, Hann, Wrbka, & Kromp, 2013). The biodiversity associated with agricultural landscapes provides a beneficial ecological service for pest control. Many studies acknowledge a positive relationship between the biodiversity of a landscape and its level of spatial heterogeneity, because the presence of different land uses and land covers provide a variety and complexity of habitats that would enhance biodiversity (Rescia et al., 1994; Benton, Vickery, & Wilson, 2003; Fahrig et al., 2011).

The spatial planning in agricultural landscapes, where the most appropriate relationship between spatial heterogeneity, agricultural production and biodiversity conservation is sought, continues to generate a considerable debate. Basically two options of farming system planning and management at the landscape scale are proposed: one is the land-sharing option and the other the land-sparing option (Green, Cornell, Scharlemann, & Balmford, 2005; Phalan, Balmford, Green, & Scharlemann, 2011; Tscharntke et al., 2012). In short, the land sharing strategy implies to integrate agricultural production and biodiversity conservation on the same land and the land sparing scheme separates high-yield farming, maintaining protected natural areas (such as unmodified habitats or medium and short-term abandoned croplands) from conversion to agriculture. Some authors support the land-sharing option (Daily, 2001) and others the land-sparing strategy (Phalan et al., 2011), but, probably, as Tscharntke et al. (2012) pointed out, the essential disjunctive would be whether farming and conservation land management should be separated or integrated and on what scale is applicable each option according to the needs of each region. Thus, the specific analysis at different scales of the spatial structure of olive landscapes, related to the main olive pest, *Bactrocera oleae*, *(Rossi) (Diptera: Tephritidae)* is interesting in the context of linking agriculture with biodiversity conservation. Also, knowing the effect of the spatial structure of natural areas in agricultural landscapes is important, especially of those land uses which potentially contribute to conservation biological control of the olive fruit fly. The proportion of natural area present in an agricultural landscape is important for different insects. For example, natural areas have an effect on different types of pollinators (Steffan-Dewenter, Munzenberg, Burger, Thies, & Tscharntke, 2002) and parasitism was shown to be facilitated by a high proportion of natural habitats (Thies & Tscharntke, 1999; Eilers & Klein, 2009; Rusch, Valantin-Morison, Sarthou, & Roger-Estrade, 2011). Although the total proportion of patches of natural area did not have a significant effect on abundance and damage of the olive fruit fly (Ortega and Pascual 2014), it is possible that a certain proportion of these patches can serve as reservoirs of natural enemies of the pest and analysing them individually could reveal an effect on pest abundance to the crop. Previous works have shown a landscape effect on *B. oleae* parasitoids and its implications for conservation biological control (Boccaccio & Petacchi, 2009), and the effect of ground cover vegetation on its natural enemies (Paredes, Cayuela, & Campos, 2013). There are numerous natural enemies of the olive fruit fly, although none of them provides sufficient pest control (Neuenschwander, Michelakis, & Kapatos, 1986; González-Nuñez, 2008). However, it appears that the most significant natural control of *B. oleae* is provided by generalist predators (ants, ground beetles, rove beetles and spiders) that feed on larvae and pupae in the soil (Cavalloro & Delrio, 1976; Bigler, Delucchi, Neuenschwander, & Michelakis, 1986; Morris, Campos, Kidd, Jervis, & Symondson, 1999; Orsini, Daane, Sime, & Nelson, 2007). Regarding parasitism, some native species of larval ectoparasitoids are reported from *B. oleae* in European Mediterranean countries such as *Eupelmus urozonus, Eurytoma martellii and Pnigalio spp* (Alexandrakis, 1986; Celada, 2000). In Spain, *Psyttalia concolor*, a larval endoparasitoid, was introduced to control *B. oleae*, (Jiménez-Álvarez, Castillo, & Lorite, 1990).

In our previous work we studied the relationship between landscape structure and the olive fruit fly *B. oleae* (Ortega & Pascual, 2014). Significant negative correlations between abundance of *B. oleae* and Shannon Landscape Diversity, and