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Research Paper

Insectivorous bats in semi-arid agroecosystems – effects on foraging activity and implications for insect pest control

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ABSTRACT

Insectivorous bats populate habitats that adjoin or overlap with agricultural lands, and tend to use cultivated land for foraging and commuting. The goal of the study was to assess the principal factors influencing the activity and species richness of insectivorous bats in a semi-arid Mediterranean agroecosystem. We hypothesized that bat activity and species richness are influenced by the anthropogenic factors that are typical of agroecosystems, such as fragmentation of the landscape and loss of natural habitat, agrochemical use, presence of powerlines and roads, and proximity to urban areas. We recorded bats in a diversified semi-arid Mediterranean agroecosystem in 2012 and 2013 and estimated the effect of various anthropogenic and environmental factors on their activity. The proportion of natural and semi-natural habitats at the landscape and at the plot scale were the most important predictors of total bat activity, and of the activity the two most common species recorded, *Pipistrellus kuhlii* and *Tadarida teniotis*, both known to be synanthropic. Indeed, *P. kuhlii* had a positive association with the proximity to bodies of water and to settlements. Total bat activity was negatively associated with the use of agrochemicals. Thus, in line with our predictions, both the proportion of natural land cover in the environment and the use of agrochemicals play an important role in determining bat distribution in agricultural environments. Ecological inferences based on our results can be used to develop management schemes, such as restoring patches of natural vegetation near and within farmlands, to increase the suitability of agroecosystems as habitats for insectivorous bats. These could contribute both to the protection of endangered bat species and to bio-control of insect pests.

1. Introduction

Insectivorous bats that use cultivated land for foraging may play an important role in regulating nocturnal insect populations in natural and agricultural ecosystems (Boyles et al., 2011; Williams-Guillén et al., 2016). Over the recent decades, as environment-friendly pest control became more prevalent, research has focused on methods to enhance the activity of arthropod pest control agents (Barbosa, 1998; Rusch et al., 2017). However, methods designed to enhance the activity of insectivorous bats for pest control purposes have scarcely been developed (but see Brown et al., 2015). Lack of ecological information regarding many species of bats is probably the main factor that limits practical research aimed to integrate insectivorous bats as conservation bio-control agents (Kunz et al., 2011). Specifically, information is needed on bat foraging behavior in agricultural lands, since many ecological processes in these habitats differ from those of natural habitats (Gliessman, 1998; Tscharntke et al., 2012).

Several factors can influence insectivorous bat activity in agricultural lands. Insectivorous bats are affected by agrochemicals directly, through poisoning (Bayat et al., 2014) and possibly indirectly through the negative effect that pesticides exert on insect populations (e.g. Pisa et al., 2015). A few studies showed that bats prefer organic farms over non-organic farms (e.g. Wickramasinghe et al., 2004), while others showed no difference in bat activity between organic and non-organic farms (Pocock and Jennings, 2008). To our best knowledge, a quantitative analysis is lacking on the effect of agrochemical use on foraging patterns of bats in agroecosystems.

Human settlements in proximity to agroecosystems can alter bat activity both positively and negatively (Williams-Guillén et al., 2016). Bat species are generally categorized into three groups, according to their response to urban environment (reviewed by Russo and Ancillotto, 2015): Avoiders (e.g. most Rhinolophids) are affected by the scarcity of natural roosts and food resources in urban environments (Russo et al., 2002) or by disturbances such as artificial illumination (Boldogh et al., 2007); adapters (e.g. *Tadarida teniotis*) are able to exploit some resources in the urban environment (e.g. roosting sites; Marques et al.,

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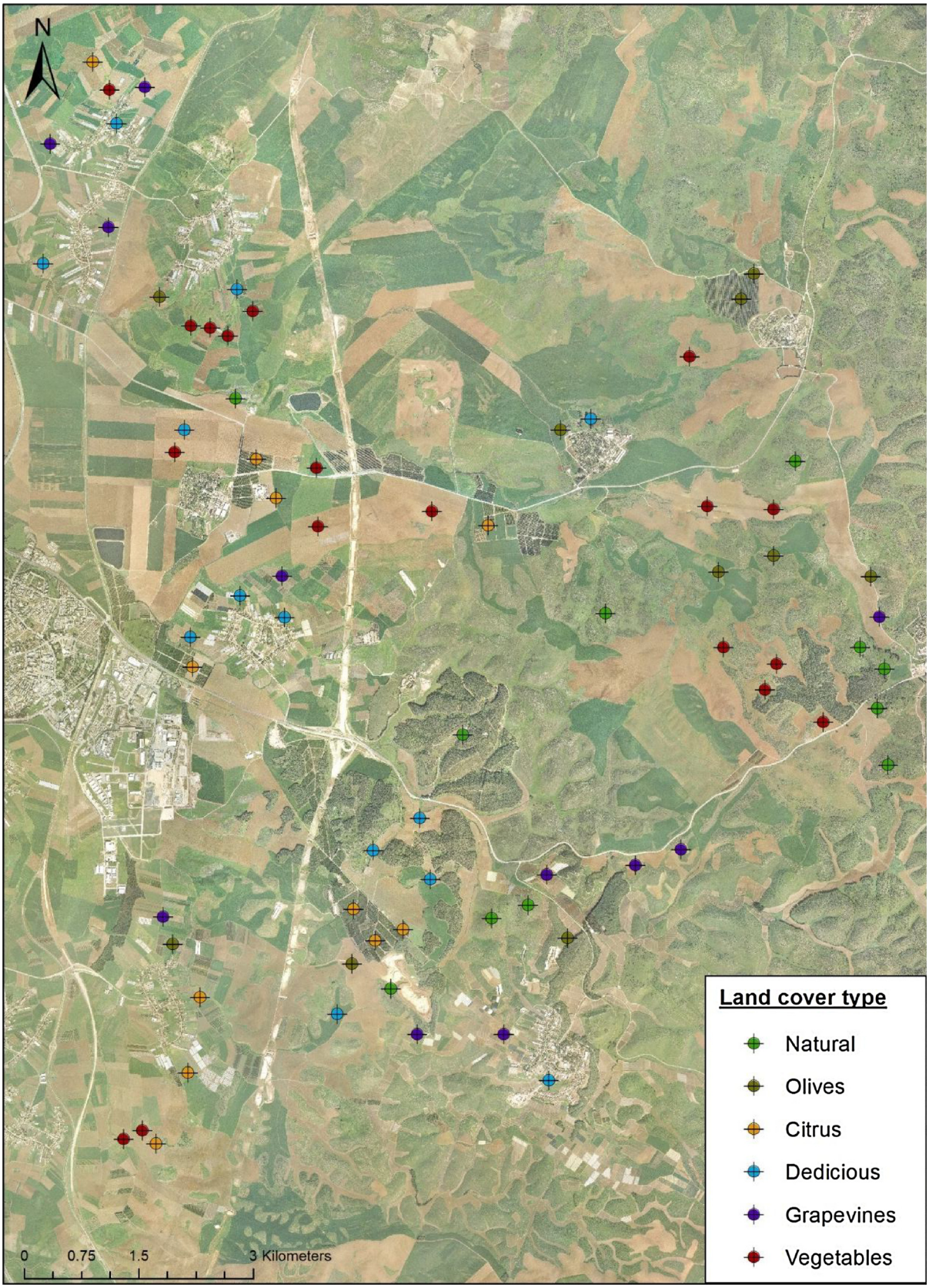

Fig. 1. Distribution of sampling points of the research area in the southern Judea plains, Israel. Points were produced using ArcGIS 10.2 software (ESRI).

2004); and exploiters (e.g. *Pipistrellus kuhlii*) are able to exploit novel resources in urban environments, for example foraging at street lamps (Rydell and Racey, 1995), outcompeting other bats. Other factors, such as roads and powerlines may affect bat activity. Roads and their associated traffic have various distance-dependent negative effects on bats such as a barrier to movement (Zurcher et al., 2010) and increased