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# Natural vegetation and bug abundance promote insectivorous bat activity in macadamia orchards, South Africa

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ABSTRACT

Accelerating land use change is associated with the loss of species and their ecosystem services. South Africa is the world's largest producer of macadamias and the industry continues to grow. Insectivorous bat species are important for pest control, but bat populations are declining. Therefore, proactive management of bat communities in agricultural landscapes is essential. We acoustically monitored bats and used light traps to catch arthropods during one annual cycle, sampling five macadamia orchards monthly in Limpopo, South Africa. We used GIS and R to analyse both the general bat and foraging bat activity of the two main foraging guilds (open-air/clutter edge guild) in different land use types and total activity with respect to arthropod abundances. Overall clutter edge guild activity (number of passes) decreased with macadamia and orchard (all other fruit) cover in the high season and increased with bush cover and distance to settlements (potential roosts) in the low season. Open-air guild activity increased with fallow cover in the high season. Foraging activity (feeding buzzes) of the clutter edge guild increased with bush cover over the whole year. Total activity (both guilds) increased with abundance of true bugs, including the main macadamia pests, and bush cover.

In conclusion, natural and semi-natural vegetation promote bat activity in macadamia orchards, and potentially bats' provision of the ecosystem service of pest control. In times of accelerating land use change, remnants of natural vegetation are important refuges and need to be maintained or restored. The installation of bathouses might further improve bat activity.

## 1. Introduction

The broad appreciation of the 'ecosystem services' concept has led to a growing understanding of the monetary benefits provided by wildlife such as bats (Ghanem and Voigt, 2012; Millennium Ecosystem Assessment, 2005; Voigt and Kingston, 2016; Wallace, 2007). Several studies have emphasized the economic importance of insectivorous bat species for agricultural pest control (Boyles et al., 2011; Cleveland et al., 2006; Kunz et al., 2011; Lopez-Hoffmann et al., 2014; Maas et al., 2013; Puig-Montserrat et al., 2015; Wanger et al., 2014). For example, Boyles et al. (2011) suggested that the annual value of insectivorous bats to agriculture in the United States is about 22.9$ billion (USD). Similarly, it is proposed that the combined annual value of bats and birds for pest control is about 730$ (USD) per hectare in tropical cacao plantations (Maas et al., 2013). Puig-Montserrat et al. (2015) estimated the value of insectivorous bats in a Mediterranean rice plantation to be no < 21€ (Euro) per hectare. Furthermore, insectivorous bats can limit the need for pesticide use and, thereby, increase the value of agricultural products such as cotton (Federico et al., 2008). In return, a decrease in pesticide use has been suggested to lead to more stable predator populations such as bats, birds and spiders and, therefore, a better long-term control of pest species (Knight and Gurr, 2007; Taylor et al., 2013b; Taylor et al., 2018). Hence, promoting high bat activity in agricultural landscapes could not only improve the livelihood of farmers but potentially decrease the use of pesticides while maintaining crop yields.

While bats provide a variety of valuable ecosystem services such as pest control (Ducummon, 2000; Fenton, 1997; Kalka et al., 2008; Leelapaibul et al., 2005; McCracken et al., 2012; Williams-Guillen et al., 2008), about one quarter of all bat species are threatened with extinction and their numbers keep decreasing at an alarming rate (Boyles et al., 2011; Jones et al., 2003; Mickleburgh et al., 2002). This decline is mainly attributed to the loss and fragmentation of habitats, roost sites and feeding opportunities, with agricultural intensification and related

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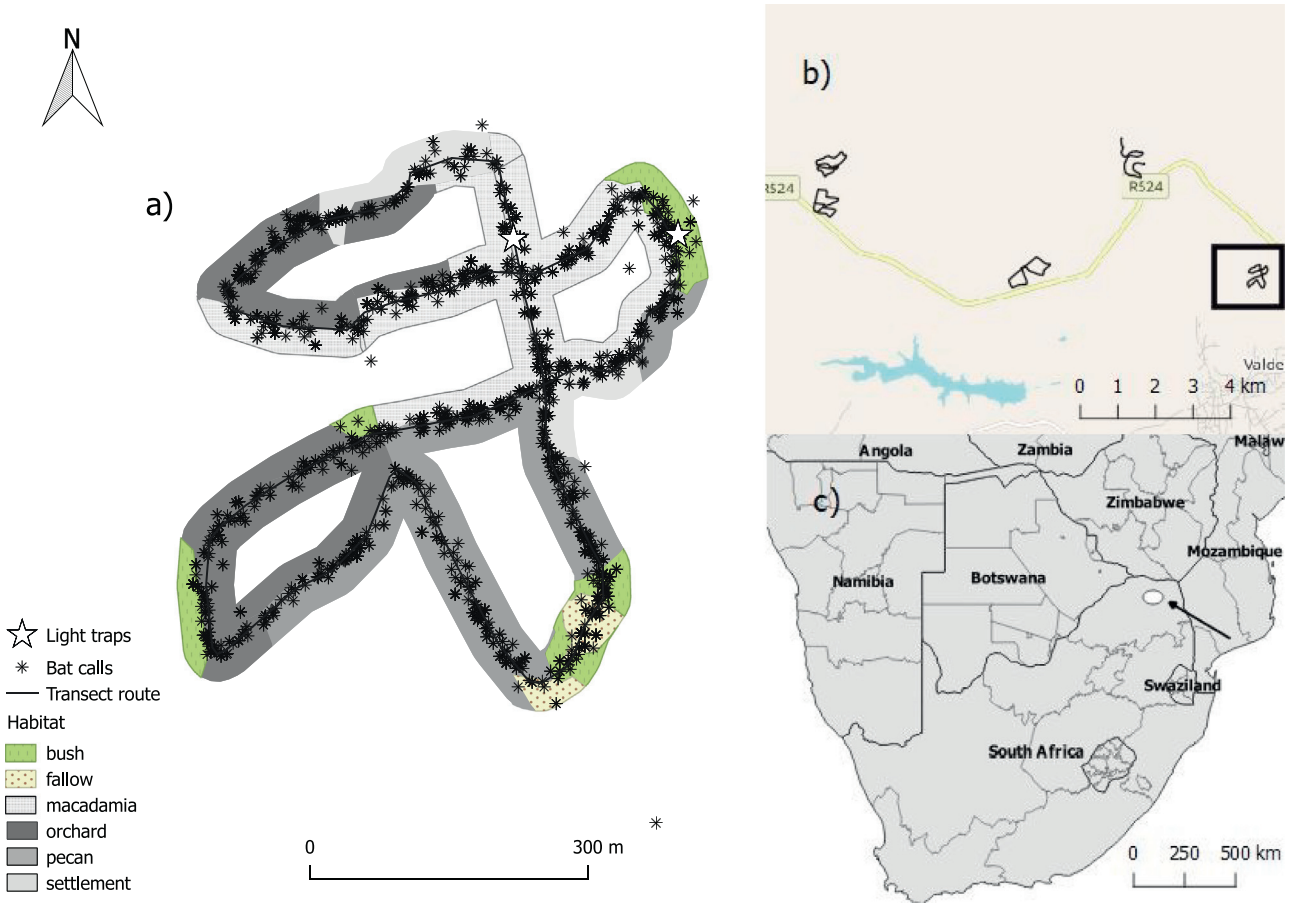


**Fig. 1.** Map of the study area showing a) one of the transects with the different habitat types within the 30 m buffer and all bat calls (passes) recorded during one annual cycle b) all five transects with the detailed example (rectangle) and c) the location of the study area (white circle) in Levubu, Limpopo, South Africa.

land use changes being by far the most frequent threat listed for bats in some 550 IUCN Red List bat species accounts (see Fig. 1.3 in Voigt and Kingston, 2016). Loss and degradation of natural habitats is predicted to accelerate until 2050 (Foley et al., 2005; Tilman et al., 2001; Tscharntke et al., 2012).

With 28,000 ha of land covered by macadamia orchards (SAMAC, 2017), South Africa is the world's leading producer of macadamia nuts since 2014, accounting for an annual production of over 44 thousand tons in 2014 and 46 thousand tons in 2015 (DAFF, 2016; Taylor et al., 2018). The South African macadamia industry continues to grow with a minimum of 1900 ha planted in 2016 alone (DAFF, 2016).

The current annual loss from insect pest damage to macadamia crop has been recently estimated at 200 million ZAR or about 17 million USD (Taylor et al., 2018; Schoeman, 2009). Pest damage is mainly related to 'unsound kernel', meaning that the macadamia nut in the shell is damaged by pest insect species while ripening on the tree. The major pest species known to the South African macadamia industry are several different stinkbug (Family *Pentatomidae*) and moth (Family *Tortricidae*) species (De Villiers and Joubert, 2003).

The recent avoided cost model of Taylor et al. (2018) suggests that the monetary value of insectivorous bat species for the macadamia industry of South Africa, by suppressing stinkbug pest species, is between 59 and 139$ (USD) per hectare. Looking at the results of the dietary analysis of bat faecal pellets on macadamia orchards by Taylor et al. (2013b, 2018) or pecan orchards by Brown et al. (2015) it is reasonable to assume that the role of bats is equally important in suppressing other major pest species such as certain *Lepidoptera*.

Given the ongoing growth of the South African macadamia industry and the assumed decline of South African bat populations based on studies from other parts of the world (Voigt and Kingston, 2016), proactive management of bats is indispensable to sustain their long-term ecosystem services (Cumming et al., 2014; Taylor et al., 2013b; Tuttle et al., 2013). However, most African bat species are poorly studied and there is scarce information about their habitat use, foraging ecology or roost site preferences (Monadjem et al., 2009; Taylor, 2000). Likewise, 15% of southern African bat species are listed under Data Deficient by the IUCN (Monadjem et al., 2010). In general, there is particular lack of knowledge on how to conserve bats in conventional (intensive) agricultural systems especially if those are located in biodiversity hotspot areas (Park, 2015).

Taylor et al. (2013a) found no significant difference in bat activity between riparian vegetation and macadamia orchards in South Africa, although the preference of bats for this more natural land use type has been established previously (Grindal et al., 1999; Medina et al., 2007; Monadjem and Reside, 2008). Similarly, a radio- tracking study in Swaziland showing that open-air bats prefer foraging on sugarcane fields in comparison with more natural habitats in the vicinity (Noer et al., 2012). This might be linked to seasonal prey availability as Taylor et al. (2013a) showed that, to some degree, there is an overlap in the peak of pest insects and an increased bat activity in macadamia orchards. Likewise, higher bat activity on organic farms as opposed to conventional farms may result from higher food availability and better habitat quality (Park, 2015; Wickramasinghe et al., 2003). Natural habitats in the vicinity of agriculture, providing connectivity, and the presence of water seem to benefit bat foraging activity (Crisol-Martínez et al., 2016; Fuentes-Montemayor et al., 2011; Park, 2015). Although artificial, waterbodies in general, are suggested to be important foraging habitats supporting a much higher bat activity than the land use