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Research paper

Pasture height and crop direction influence reptile movement in an agricultural matrix

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ABSTRACT

Tackling the global threat of habitat fragmentation on biodiversity requires knowledge of how species move within agricultural landscapes. However, the specific mechanisms influencing dispersal within such landscapes remain poorly understood. The objective of our study was to assess how matrix type (improved pasture, native pasture or crop) and structure (grass height) influence fine-scale reptile movement, as well as influences of crop sowing direction and setting-sun position. In an agricultural region of south-eastern Australia, we first released 20 individuals of an arboreal gecko (*Christinus marmoratus*) at set distances from trees to determine the distance at which they could perceive their tree habitat (perceptual range). We then translocated 36 individuals into six matrix environments within their perceptual range of isolated trees to examine how gecko movement was modified by the type and structure of the matrix. We also recorded crop sowing direction and setting-sun position and examined all recorded tracks using angular statistics. We found that geckos exhibited a perceptual range of 40–80m. Short matrix environments promoted direct movements towards trees, irrespective of matrix type. Furthermore, movements were significantly affected by crop sowing direction with individuals following the planted lines. Our study has three significant implications: (i) restoring mature tree spacing to 80 m apart will assist gecko movements, (ii) targeted management for low pasture height, such as by maintaining directional narrow strips of low vegetation among taller pastures, might assist movement and facilitate increased connectivity, (iii) directional sowing of crops between habitat patches presents a simple but potentially effective tool for reconnecting fragmented landscapes.

1. Introduction

Globally, expanding agricultural practices are creating increasingly fragmented landscapes, with patches of habitat that can support high biodiversity becoming interspersed with a matrix of crops and pastures (Alexandratos and Bruinsma, 2012). The persistence of biodiversity in these fragments depends crucially on an individual''s capacity to move through the agricultural matrix (Ricketts, 2001; Zollner and Lima, 2005). The degree to which the matrix genuinely represents a barrier to movement has therefore been the focus of intense research effort in recent years (e.g. Anderson et al., 2015; Cooney et al., 2015; Driscoll et al., 2014; Malekian et al., 2015; Rodríguez-San Pedro and Simonetti, 2015; Smith et al., 2013; Sozio et al., 2013). Landscape-scale occupancy studies, as well as expert opinion, have dominated assessments of species movements (Driscoll et al., 2014). More recently, mark-recapture and molecular studies have also shown that certain matrix environments represent a barrier to movement for many species (e.g. Anderson et al., 2015; Prevedello and Vieira, 2010a). Despite increasing evidence for the impact of the matrix on some elements of biodiversity, previous studies have tended to remain correlative, focused on broad (>1 km) movements and have rarely identified the specific mechanisms that influence fine-scale movement (Lechner et al., 2015). Understanding specific mechanisms explaining why movement might be poorer in some matrix

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environments at fine-scales would allow us to implement effective management strategies to improve biodiversity conservation (Hawkes, 2009).

The type and structure of the matrix represents a key factor influencing the fine-scale movements of terrestrial animals through agricultural landscapes (Driscoll et al., 2013). The composition and height of vegetation can greatly influence the distance at which individuals may perceive neighboring habitat – its perceptual range (Peer and Kramer-Schadt, 2008Pe'er and Kramer-Schadt, 2008; Prevedello et al., 2010). For example, lower vegetation obstruction associated with certain land-use types (i.e. grazed pastures) support greater perceptual range in some Brazilian marsupials (Prevedello et al., 2011). Despite the important role of the matrix on perceptual range, empirical data quantifying this impact is lacking for most taxa. Additionally, the type and structure of the matrix can directly influence a species' ability to orientate and move, even when within the perceived range of habitat. For example, the fine-scale movements of some small mammals are strongly guided by the linear structure of cereal crops despite proximity to habitat (Prevedello and Vieira, 2010b; Sozio et al., 2013) but this important effect has not been examined for any other terrestrial fauna in cropping landscapes. Comprehensive examinations of the effects of matrix type and structure on the fine-scale movements of small, ground-dwelling organisms would be useful but are rare (but see Haynes and Cronin, 2006; Sozio et al., 2013). Additionally, how the fine-scale movements of non-mammalian organisms are affected by a broad suite of different agricultural environments has yet to be explored.

Understanding fine-scale movements within different matrix environments could be particularly useful for enhancing connectivity for reptiles (Southwood and Avens, 2010) and amphibians (Pittman et al., 2014b), both of which are undergoing major declines in agricultural landscapes globally (Böhm et al., 2013; Gibbon et al., 2000). These groups are consistently under-studied in connectivity science (Driscoll et al., 2013), yet are likely to show strong movement patterns between different matrix environments due to their direct associations with management-specific groundcover habitats (Moore et al., 2008; Schutz and Driscoll, 2008). For example, cultivated pasture and crop matrices generally support fewer micro-habitat features critical for many reptiles (Kay et al., 2016) and may illicit more "directed" movements than required in native pastures where these micro-habitat features are more common. Our understanding of reptile navigation has mostly focused on long-range movements of marine turtles (Rivas et al., 2015; Southwood and Avens, 2010) and a crocodilians (Read et al., 2007), while our knowledge of the specific cues terrestrial reptiles use for guiding fine-scale movements is comparatively limited. For example, extensive review of the literature reveals evidence only for the role of sun position in orienting movements in some terrestrial turtles (DeRosa and Taylor, 1978) and lizards (Beltrami et al., 2010; Freake, 2001), as well as homing ("map and compass") senses in some pythons (Pittman et al., 2014a) and geckos (Marek et al., 2010). A further examination of the influence of matrix and non-matrix cues on the perceptual range and movement of small terrestrial reptiles within agricultural landscapes is needed.

Here, we provide a novel examination of the influence of a range of matrix environments on the fine-scale movements of small terrestrial reptiles to better understand mechanisms guiding habitat perception and orientation within the matrix. First, we examined the impact of a range of matrix types (native pasture, improved pasture, and cropped landscapes) and structures (tall or short) on habitat detection and orientation. Visual cues are thought to be most important for guiding fine-scale movements for small terrestrial reptiles (e.g. Freake, 2001; Gruber and Henle, 2004), and so we expect the structure (specifically short pastures) would have strongest influence on habitat perception and movement. Second, we examined the influence of crop sowing direction on fine-scale movements. Based on strong effects observed for small mammals (Prevedello and Vieira, 2010b; Sozio et al., 2013), we hypothesized crop sowing direction would also strongly influence reptile orientation.

We selected a nocturnal arboreal gecko (*Christinus marmoratus*) as a model species to test the influence of the matrix because it is arboreal with limited dispersal capability. Translocation experiments are an ideal approach to test orientation ability (Betts et al., 2015; Wiltschko and Wiltschko, 1999), and so we used field experiments to address the following two questions:

i) How does the type (improved pasture, native pasture or crop) and structure (pasture height) of different agricultural matrix environments influence the fine-scale habitat detection and movement of reptiles?
ii) How does crop sowing direction influence fine-scale movement of reptiles?

2. Methods

2.1. Study area and design

Our study was conducted in the highly fragmented mixed cropping/grazing agricultural landscape near Boorowa −34.437°S, 148.717°E), south-eastern Australia (Fig. 1a). The predominant form of agriculture in this area is pasture dominated by native groundcovers with no or infrequent fertilization (native pasture), pasture dominated by exotic groundcovers and a regular history of fertilization (exotic pastures), and cereal cropping of either wheat (*Triticum vulgare*) or canola (*Brassica napus*) (see Appendix A for details).

We undertook movement experiments during October–November 2014 within fields comprising six different matrix environments: short native pasture, short exotic pasture, long native pasture, and long exotic pastures plus two cereal crops: wheat and canola (Fig. A1 in Supplementary material). We replicated these treatments three times in separate fields (spaced >2 km to ensure spatial independence) giving a total of 18 sites. We measured pasture height at each site using a rising-plate pasture meter (Correll et al., 2003) and defined short pastures where the site mean height was <10 cm and long pastures where the mean height was >20 cm (Appendix A). Both crops (canola and wheat) were cultivated along rows spaced approximately 20 cm apart, with plants closer within lines creating semi-permeable guides without acting as a barrier for movement. We examined two crops with contrasting growth-form to provide a wider test of the general influence of crops on species movement that was not possible in previous studies that examine only a single crop type (Prevedello and Vieira, 2010b; Sozio et al., 2013). At ground-level, both crops formed visible lines of planted stems although wheat crops were more closely planted (1–2 cm apart) than canola crops (5–10 cm apart) and allowed greater ground-level visibility than within the leafy multi-stem branching canola crops. For both native and exotic pastures, the distribution of plants did not follow any regular pattern.

2.2. Movement experimental protocol

Our experiment involved releasing individuals of a nocturnal arboreal gecko (*Christinus marmoratus*) into fields comprising an isolated tree surrounded by different matrix environments and recording the direction of movement (or orientation). Trees are key habitat structures for this species (Michael et al., 2015; Taylor et al., 2015; Wilson and Swan, 2013) and we therefore expected animals