



Early-season movement dynamics of phytophagous pest and natural enemies across a native vegetation-crop ecotone



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ABSTRACT

There is limited understanding about how insect movement patterns are influenced by landscape features, and how landscapes can be managed to suppress pest phytophage populations in crops. Theory suggests that the relative timing of pest and natural enemy arrival in crops may influence pest suppression. However, there is a lack of data to substantiate this claim. We investigate the movement patterns of insects from native vegetation (NV) and discuss the implications of these patterns for pest control services. Using bi-directional interception traps we quantified the number of insects crossing an NV/crop ecotone relative to a control crop/crop interface in two agricultural regions early in the growing season. We used these data to infer patterns of movement and net flux. At the community-level, insect movement patterns were influenced by ecotone in two out of three years by region combinations. At the functional-group level, pests and parasitoids showed similar movement patterns from NV very soon after crop emergence. However, movement across the control interface increased towards the end of the early-season sampling period. Predators consistently moved more often from NV into crops than vice versa, even after crop emergence. Not all species showed a significant response to ecotone, however when a response was detected, these species showed similar patterns between the two regions. Our results highlight the importance of NV for the recruitment of natural enemies for early season crop immigration that may be potentially important for pest suppression. However, NV was also associated with crop immigration by some pest species. Hence, NV offers both opportunities and risks for pest management. The development of targeted NV management may reduce the risk of crop immigration by pests, but not of natural enemies.

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1. Introduction

While there is increasing recognition that phytophagous pest management based on the activity of predatory arthropods and parasitic wasps requires a landscape approach (Cronin and Reeve, 2005; Chaplin-Kramer and Kremen, 2012), the development of landscape-scale pest management strategies is still in its infancy (Schellhorn et al., 2008). Studies examining the relationship between landscape-scale features on pest suppression are becoming more common (Bennett and Gratton, 2012; Caballero-López et al., 2012; Chaplin-Kramer and Kremen, 2012). However,

there is still limited understanding about which factors influence the spatial and temporal distribution of arthropod-mediated ecosystem services, and how these can be manipulated to suppress pests. The movement of pests and natural enemies is common (Rand et al., 2006; Thomson and Hoffmann, 2013), however we know little about the behavioural responses of arthropods to edges and ecotones. This movement is often described as the spillover of natural enemies from natural areas into cropping areas or vice versa (Rand et al., 2006). Understanding how landscape features may facilitate or impede movement can provide important information about immigration to crops and have implications for the management of arthropod-mediated ecosystem services (Kremen, 2005).

Agricultural landscapes can be considered as a collection of 'patches' with different land uses and disturbance levels. Crop

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habitats tend to be ephemeral, frequently disturbed, and recolonised throughout the growing season (Wissinger, 1997). In contrast, natural vegetation (NV) is more stable and can function as reservoirs of natural enemies (Bianchi et al., 2012; Letourneau et al., 2012), but potentially also of pests (Van Emden, 1965; Zhang et al., 2007; Al Hassan et al., 2013). Immigration from NV to crops involves the crossing of an ecotone, and species can have specific responses to different ecotones (Duelli et al., 1990; Duelli and Obrist, 2003). The contrast in vegetation types found on each side of an ecotone may be perceived differently by each species (Ries and Debinski, 2001). Therefore we cannot assume that all species will move easily from a remnant NV patch into a nearby crop. Quantifying the composition of the arthropod communities moving across a NV/crop ecotone can provide novel insights into the function of these habitats in supporting pests and their natural enemies, and suggest which species can easily access resources in both these habitats.

The relative timing of pest and natural enemy arrival in crops is considered a key factor for the effectiveness of natural enemies in suppressing pest populations (e.g. Settle et al., 1996). Theory suggests that the timing of natural enemy arrival in crops can be influenced by the distance between the crop and source habitat (Bianchi et al., 2009), and the dispersal ability of natural enemies relative to that of the pests (Sivakoff et al., 2012). This implies that pest populations in crops far from natural enemy source habitats have an increased time window for unchecked build-up compared to crops near source habitats (Ekbom et al., 1992; Bianchi et al., 2010). However, empirical evidence of how timing of arrival is influenced by landscape context is scant (Petersen 1999; Alomara et al., 2002). Here, we use bi-directional interception traps to measure the activity of flying insects across the NV/crop ecotone, relative to a control crop/crop interface. In the early part of the cropping season, in two distinct agricultural regions, traps were placed on these different interfaces. Our aims are three-fold. Firstly, we characterise the insect community at the NV/crop ecotone relative to a control interface. Secondly, we assess the direction of movement across the ecotone, and use this to indicate whether NV is a net exporter of pests, predators or parasitoids during the early stage of the growing season. Thirdly, we explore species-specific behaviour across the ecotone and between two regions which have a different cropping season phenology.

2. Methods

Our study was conducted in two regions in Australia: a temperate and a sub-tropical region with both autumn-sown cereals. In both regions the field dimensions, crop-types and NV patches were mapped in a 7 km radius circular area using aerial images and ground-truthing. The temperate region in New South Wales (NSW) was located near the town of Young (−34.422 S, 148.460 E, Appendix A) and 16% of the area consisted of NV dominated by *Eucalyptus melliodora*, *E. macrocarpa*, *E. blakelyi*, and *Acacia* spp. The crops included autumn-sown cereals and canola (25%) interspersed with managed pastures (51%). The sub-tropical region in Queensland (QLD) was located near the town of Pittsworth (−27.716 S, 151.635 E, Appendix A) and contained 15% NV dominated by *E. orgadophila*, *Acacia harpophylla* and *Casuarina cristata*. This region had year-round cropping (21%) that included autumn-sown cereals (wheat and barley) and, summer cropping (cotton and sorghum). Unmanaged pastures (19%) and fallow land (43%) were other important landscape elements.

2.1. Sampling design

Bi-directional flight interception traps (Southwood and Hendersen, 2000) were used to compare the direction and

intensity of insect flight activity at the NV/crop ecotone relative to the crop/crop interface (Appendix A). These traps were used to measure the number of insects intercepted on both sides of the trap while they were flying from one habitat patch to another over weekly periods. The data were used to make inferences about the movement patterns at the community, functional group and taxon level. Within each region there were six trapping sites: three ecotone sites and three control interfaces. The location of each trapping site was independent in terms of not sharing field boundaries with other sites. The straight-line distance between sites ranged from ~500 m to 8 km (Appendix B). In 2010, cereal fields consisted of wheat in NSW and either wheat (two sites) or barley (four sites) in QLD; in 2011 all fields were wheat.

There were six traps per region, and each trap had two collection bottles (on each side of the trap), therefore there were 24 samples per time period. At each time period the bottles were open for 5–8 days. Sampling commenced at cereal crop planting and continued over two winter cropping seasons; QLD July–November 2010 and July–August 2011, NSW May–November 2010 and May–August 2011. Samples were collected every two weeks for 5–8 sample periods (QLD 9 – 2010 and 5 – 2011, NSW 8 – 2010 and 8 – 2011), giving a total of 360 samples. Two samples (both in NSW) were discarded because the trap was damaged by cattle. Samples were labelled as “NV” (NV/crop ecotone, insects moving from NV into crops), “crop” (NV/crop ecotone, insects moving from the crop and entering NV), or “control” (crop/crop, insects moving from a crop field to another crop). The samples of the crop/crop interface consisted of insects moving between crops from both directions and received the same label. Therefore, there was double the number of samples at each time point for the control than for either the NV or crop treatments.

As there was large variation in crop growth development rates between the two regions it was necessary to standardise the sampling dates to ensure we were focussing only on the samples collected in the early-season growth period of the crop. Growth Degree Days (GDD) at each site was calculated using the equation:

$$\text{GDD} = \frac{(T_{\max} + T_{\min})}{2} - T_{\text{base}}$$

where T_{\max} is the daily maximum temperature, T_{\min} is the daily minimum temperature and T_{base} was set at 0 °C. When temperatures were below 0 °C, T_{\min} was converted as $T_{\min} = T_{\text{base}}$ (McMaster, 1997). Temperature data were collected from nearby weather stations to calculate GDD. Daily GDD value from the date of crop planting was summed to provide an accumulated GDD value (referred to as AGDD hereafter). When no information on the planting date was available, this date was estimated as 10 days prior to crop emergence. AGDD was used as a proxy for time and then to select samples to analyse that were within 0–900 AGDD (this reduced the total number of samples from 360–211). AGDD values between 0–900 were considered in the early stage of crop development as this roughly corresponds to the period up to stem elongation of cereal crops.

2.2. Insect sampling

The bi-directional interception traps (Sante Traps, Lexington, KY) were made out of fine mesh material and had a black mid-vane (165 cm length, 178 cm height at front, 104 cm height at back) that functioned as an interception trap. One end was supported with a tent pole and had two collection bottles half filled with 70% ethanol (~250 ml and ~5 ml of detergent). Insects flying from one direction hit the mid-vane and climbed upwards entering the collection bottle, while insects flying from the other direction were captured on the opposite side (Appendix A). Traps were positioned along the ecotone or control interface regardless of prevailing wind

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