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Extent to which an agricultural mosaic supports endemic species-rich grasshopper assemblages in the Cape Floristic Region biodiversity hotspot

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ABSTRACT

The impact of expansion and intensification of agriculture on biodiversity requires quantification, especially in areas of exceptionally high biodiversity like the Cape Floristic Region (CFR). In the CFR, landscape mosaics consist of agriculture alongside Mediterranean-type fynbos scrubland natural vegetation rich in endemic insect species. However, little is known about how ground-dwelling insect herbivores utilize the various elements of the mosaic. We compared species richness, abundance, species composition, diversity and evenness of grasshoppers among 46 sites in four geographical areas in the CFR. We investigated three land-use types: fynbos (the historic condition as reference), vineyards and deciduous fruit orchards, the main production types in the region. Grasshopper abundance was significantly higher in vineyards than in fynbos or orchards. Species richness, diversity, and evenness were highest in fynbos followed by vineyards and then orchards. Orchards had no unique species, vineyards two, and fynbos 14 unique species. Nevertheless, there was overall high species similarity among all three land-use types, with high species assemblage similarities between vineyards and orchards. Species that preferred fynbos were mostly flightless and endemic to the CFR. We show that agricultural areas do not support the entire species assemblage of natural vegetation, although vineyards are more diverse than orchards, probably because of the presence of often grassy ground cover and an open canopy. Vineyards provide the greatest opportunity for improved harmony between production and biodiversity conservation through continuing to improve the ground cover quality and other farming practices. Fewer opportunities are provided by orchards in view of their closed canopy and absence of grassy ground cover (for generalist species) and fynbos plants (for endemic species). However, protected areas still remain vital for maintaining the full complement of species, especially flightless endemics.

1. Introduction

Biodiversity is threatened by increasing human stressors (Crains and Lackey, 1992; Corker, 2011; de Baan et al., 2013). The threats come from increasing demands for food, fibre and fuel, necessitating the expansion of agricultural lands at the expense of natural vegetation (Norris, 2008; Pagiola et al., 1998). Agricultural production is considered to be one of the strongest drivers of this biodiversity loss (Lindenmayer et al., 2013).

The Cape Floristic Region (CFR) is a world biodiversity hotspot, with high diversity of endemic plants and other organisms which face high levels of threat (Mittermeier et al., 2004; Myers et al., 2000). The CFR is also known for intensive agricultural production (Esler et al., 2014). Over 30% of the land mass of the CFR has been transformed by agriculture, urbanisation and alien invasive plants, with only 17% of the original extent of the primary natural vegetation (fynbos) still remaining (Cowling et al., 2003; Rouget et al., 2003). Furthermore, 47.7% and 78.6% of South Africa's vineyards and apple orchards, respectively, are located in the CFR (Greef and Kotze, 2007). These production types, together with potato and melon production, are responsible for the loss of the majority of the original extent of fynbos vegetation, mostly lowland fynbos (Esler et al., 2014) and there is still potential for expansion of agricultural holdings and further pressure on biodiversity within the CFR (Rouget et al., 2003).

While agriculture is known to adversely affect biodiversity, if good management practices are observed, they may be able to benefit biodiversity through mitigating the effects of transformation. This can be done by land sparing, such as conserving remnant

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patches (as has been done in the CFR; Gaigher et al., 2015) or provision of large scale ecological networks (Pryke and Samways, 2012; Samways et al., 2010), or it can be done by land sharing such as the instigation of biodiversity-friendly farming methods such as organic farming (e.g. in the CFR; Gaigher and Samways, 2010; Kehinde and Samways, 2014), or a combination of both land sparing and land sharing into an agroecological matrix. Interestingly, it is estimated that half of all species in Europe are dependent on agricultural habitats (Kristensen, 2003).

Previous research conducted in vineyards in the CFR recorded high arthropod diversities with minimal declines in relation to neighbouring natural vegetation (Gaigher and Samways, 2010; Kehinde and Samways, 2012; Magoba and Samways, 2011; Vrdoljak and Samways, 2014). Other studies conducted by Bailey et al. (2010) in Switzerland, Brown (2012) in the U.S.A. and Horak et al. (2013) in the Czech Republic, on the impact of deciduous orchard production on biodiversity produced mixed results. These mixed results support the notion that the impact of agriculture on biodiversity depends mostly on the type of agricultural production, production practices, surrounding landscape features and in particular the taxon under consideration (Badenhausser and Cordeau, 2012; Bailey et al., 2010; Bruggisser et al., 2010; Horak et al., 2013; Liu et al., 2015; Norris, 2008). Some taxa (e.g. snails and lichen) prefer a cold, wet and closed canopy with tall trees and dense vegetation (e.g. forests) (Bailey et al., 2010; Horak et al., 2013), while others (e.g. grasshoppers) prefer open, dry and warm relatively short vegetation (e.g. grasslands) (Uvarov, 1966).

Grasshoppers are good indicators of changes in environmental quality. For instance, grasshopper species assemblages showed strong responses to changes in semi-natural grasslands within the exotic timber plantation matrix in South Africa (Bazelet and Samways, 2011b, 2011c) and community succession in steppe grasslands and alluvial pine woodland in Germany (Fartmann et al., 2012; Helbing et al., 2014). Grasshopper diversity in grasslands of South Africa (Gebeyehu and Samways, 2002), grassland remnants within a timber plantation matrix (Bazelet and Samways, 2011a, 2011b, 2011c) and rocky afromontane grasslands (Crous et al., 2013) has been shown to be high. However, grasshopper ecology or diversity has been little studied in fynbos or agricultural areas of the CFR biodiversity hotspot (but see Matenaar et al., 2014). In neighbouring xeric succulent thicket (Fabricius et al., 2003) and sugarcane plantations (Bam et al., 2013) in South Africa, natural and cultivated lands in Eurasia (Sergeev, 1998), small scale farms adjacent to savannah vegetation in Tanzania (Kuppler et al., 2015) and lac plantations in China (Chen et al., 2011), high grasshopper diversities were reported, especially on agricultural lands but without focus on narrow-range endemics such as those which occur in the CFR.

Here, we aim to assess the extent to which the main agricultural land-use types in the CFR (grape vineyards and fruit orchards) are able to support indigenous grasshopper assemblages, including the CFR's characteristic high levels of endemic species, relative to historic fynbos in protected areas. We tested two hypotheses: (1) that agricultural production in the CFR has no impact on grasshopper diversity; and (2) that different agricultural production types (vineyards vs. orchards) have similar impacts on grasshopper diversity. We compare grasshopper species richness, composition, diversity and evenness among the three land-use types in four geographical areas in the CFR.

2. Methods

2.1. Geographical areas and sites

Forty six sites were selected belonging to three land-use types: historic Fynbos (F) in formally protected areas, Vineyards (V) and Orchards (O). The elevation of sites ranged from 90 m to 592 m asl. All sites were located in one of four geographical areas within the CFR: Grabouw, Somerset West, Stellenbosch and Paardeberg (Supplementary material: Table 1). The four areas constituted four independent landscape mosaics because they were either distant from each other (the farthest inter-site distance within an area was 23 km, while the closest inter-site distance between areas was 35 km), or separated by mountain ranges which probably acted as movement barriers to grasshoppers. Such distances, while seemingly short for northern-hemisphere temperate regions, are biogeographically highly significant for the CFR (Vrdoljak and Samways, 2014).

All selected vineyards were conventional vineyards that followed pesticide and irrigation management regimes based on IPW guidelines (Tromp, 2006). All vineyard sites were interspersed with one or more cover crops, mostly legumes (*Vicia* spp.), *Raphanus raphanistrum*, rye grasses (*Lolium* spp.), oats (*Avena fatula*), *Hypochoeris radicata*, *Bidens pilosa* and *Erodium moschatum*. Deciduous fruit orchards were mostly closed-canopy apple trees. All selected apple orchard sites practiced conventional production that involved mostly the use of broad spectrum pesticides, although they were based on market standards and requirements (see Hortgro, 2015). Most of the selected orchards had little to no cover crops. The few interspersed cover crops in orchards were mostly rye grasses, alfafa (*Medicago sativa*) and legumes. Irrigation application for our selected apple orchard sites were mostly based on soil moisture and plant requirements, with irrigation being much more frequently used in orchards than in vineyards. Fynbos sites were all located in protected areas (PAs): Hottentots Holland, Jonkershoek, Helderberg and Limietberg provincial nature reserves and were adjacent to vineyards and orchards (Fig. 1). Fynbos is a scrubland, high in endemic plant species and dominated by Proteaceae, Restionaceae, and Ericaceae (Esler et al., 2014; Mittermeier et al., 2004).

2.2. Grasshopper sampling

Grasshoppers were sampled on four different occasions between November 2013 to April 2014 between 09:00 and 17:00 on sunny days with low wind speed and cloud cover. A 50×50 m quadrat was delineated in the centre of each site >30 m from the edges, to avoid edge effects (Bieringer et al., 2013; Pryke and Samways, 2011). The choice of quadrat size was based on successful use elsewhere in South Africa (Bazelet and Samways, 2011a, 2011b). Each site was sampled for 30 min on four occasions by two collectors (i.e. four person hours per site). Sites were sampled repeatedly at different times of day and across seasons in order to eliminate bias and ensure that samples collected were an adequate representation of total grasshopper diversity at a site. All four samples were pooled per site.

Grasshoppers were initially flushed out of their swards and individuals seen hopping, walking or flying were caught with an insect net (Bazelet and Samways, 2011a, 2011b; Larson et al., 1999). The timed quadrat count method was appropriate for scrubland vegetation (fynbos), vineyards and orchards (see Bazelet and Samways, 2011a, 2011b; Gardiner et al., 2005). Captured grasshoppers were killed and identified in the laboratory using keys of Dirsh (1965), Eades et al. (2015), Jago (1994), Johnsen (1984), Johnsen (1991) and Spearman (2013).

2.3. Statistical analyses

Sample-based and individual-based rarefaction curves were plotted for each land-use type separately and for all sites together to verify the completeness of sampling using EstimateS (Colwell, 2005; Gotelli and Colwell, 2011; Moreno and Halffter, 2000).