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Endemic grasshopper species distribution in an agro-natural landscape of the Cape Floristic Region, South Africa

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ABSTRACT

Conservation biologists and ecologists often make use of models to identify important biotic and abiotic factors that constrain species distributions for conservation decisions to be taken. In line with such practices, we developed species distribution models for four localized, Cape Floristic Region (CFR) endemic, flightless, congeneric *Euloryma* grasshopper species. We chose this group as use of these models has been little explored for narrow range endemics with specific traits. *Euloryma larsenorum* and *E. lapollai* are associated with fynbos only, while *E. umoja* and *E. ottei* are both associated with fynbos and vineyards. We used the Maximum Entropy algorithm, which showed that vegetation type and soil characteristics were the most important environmental factors affecting local distribution of *Euloryma* species in the CFR. The models also showed that *Euloryma* species have a very narrow habitat suitability range in the CFR. We also showed that there are no significant differences in the distribution of species associated with fynbos only as well as those associated with both fynbos and vineyards. *E. larsenorum* and *E lapollai* are likely to be the most affected species in the event of further habitat transformation from fynbos to agricultural production. This is not likely to be the case for *E. umoja* and *E. ottei* which can tolerate agriculture environment, although they might survive both sets of environments in accordance with their life history traits.

1. Introduction

Conservation biologists and ecologists are often faced with the challenging task of identifying important biotic and abiotic factors for explicit and accurate species distribution models to support biodiversity assessments and conservation strategies (Rangel and Loyola, 2012; Lin et al., 2016). Such models are often referred to as species distribution, habitat suitability or ecological niche models (Dormann, 2012; Porfirio et al., 2014). Species distribution models (SDM) often link species' known occurrences with certain environmental conditions peculiar to sites where they were recorded to predict possible locations where populations could be maintained within the landscape (Pearson, 2010; Peterson et al., 2011). This is in accordance with the ecological niche theory where species' tolerance to certain environmental factors limit their persistence on a landscape (Soberón, 2007; Colwell and Rangel, 2009).

Most ecological correspondence analyses and species distribution models are aimed at describing mathematical or statistical patterns underlining species occurrences with fitted models (Peterson et al., 2011). In view of this, species distribution models can be described as the quest to simplify complex realities involving observed biological phenomena within a modelling environment. Consequently, species distribution models have become important instruments for generating simplified expected responses to potential future impacts of environmental change on biodiversity (Howard et al., 2014). This is particularly important in a biodiversity

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hotspot which is also heavily utilized for agricultural production, such as the Cape Floristic Region (CFR) with its high conservation priorities (Allsopp, 2014). For instance, application of SDM will help design ecological survey guidelines that have the potential to increase sampling precision through enhanced efficiency of data capture. Guided and precise data captures and their visualizations can have many applications in conservation biology especially for rare and threatened species (Elith and Leathwick, 2009; Pearson, 2010; Silva et al., 2016). It can also be used to identify important ecological factors that affect species persistence within a landscape (Lin et al., 2016) and predict the geographic range expansion of species, especially invasive ones (Calatayud et al., 2016). This is even more important for under-studied groups such as insects (Ballesteros-Mejia et al., 2016) many of which are threatened by anthropogenic change. Such threatened species can be used as surrogates for determining and/or designing conservation strategies for other such species that occupy the same geographic space. This is because such species often display similar physiological responses to environmental constraints similar to conditions which affect the focal surrogate species (Mace et al., 2008). Surrogate species are usually referred to as indicator species (Rodrigues and Brooks, 2007; Caro, 2010) because they play a vital role in monitoring the organisational structures of ecological communities (Menon et al., 2012).

An ideal group of insects as proxy subjects for assessing land-use change or land transformation are grasshoppers (Orthoptera: Acridoidea), as they have a fairly well understood biology, are highly responsive to environmental changes (changes in vegetation and land-use), and there is explicit and fairly widespread information on their geographical distributions. In spite of the available information, grasshopper studies are few in southern Africa. However, there are some studies in South Africa on grasshopper behaviour and ecology (Matenaar et al., 2014), their geographical distributions (Spearman, 2013), and in regard to conservation in natural systems (Gebeyehu and Samways, 2002) and agro-ecological landscapes (Kuppler et al., 2015 in Tanzania; Adu-Acheampong et al., 2016). In addition, there are a few studies on ecology and diversity of grasshoppers with regard to grazing and fire (Gebeyehu and Samways, 2003), and land management and design (Gebeyehu and Samways, 2003). Notably absent from this list of studies is ecological niche or species distribution models e.g. models that can predict their potential distribution based on known environmental factors and predict suitable areas where they could occur.

A potential surrogate grasshopper group of species, endemic to the CFR, are the flightless, narrow range Hemiacridinae of the genus *Euloryma*. Their value lies in their high sensitivity to environmental changes and their tight coupling to the dominant natural fynbos (a scrubland which is high in endemic plant species mostly proteas restiods, and ericoids, Rutherford et al., 2014) vegetation in the CFR. Most importantly, their biodynamics on this landscape can be translated into changes in habitat or land-uses. The majority of these flightless endemic *Euloryma* species are associated with only the dominant native vegetation (fynbos) in the CFR (Spearman, 2013). Nevertheless, a few species in this group are also associated with agricultural production e.g. vineyards (Adu-Acheampong et al., 2016). It is therefore important to develop a model that describes the environmental conditions that are necessary to support the persistence of a viable population for bioindication in the CFR.

In this study we use SDM techniques to identify the most important variables that could explain the occurrence of *Euloryma* species in the CFR. Such a study is yet to be conducted although a related one reported that vegetation type affected the abundance of grasshoppers in general including *Euloryma* in the CFR (Adu-Acheampong et al., 2016). These factors, usually referred to as explanatory variables could either be constraining e.g. temperature, rainfall, relative humidity, or conducive e.g. good soil conditions for egg laying and the type and structure of vegetation to provide sufficient food and shelter. Studies involving modelling of an organism's response to environmental factors (both conducive and constrains) mostly highlight the contributions of abiotic components only while often neglecting biotic interactions. However, in real life situations, species distribution focuses on the interaction between the two (biotic and abiotic interactions) (Soberón, 2007). This has generated much debate over the appropriateness of projecting species range in space using SDM techniques only (Russo et al., 2014). Despite these practical difficulties, SDM are still relevant in filling the knowledge gaps in species distribution, especially with regards to groups with limited spatially coherent available information (Silva et al., 2014). This is even more important in an agro-ecological landscape like the CFR which is dominated by highly endemic vegetation, and subsequently classified as a biodiversity hotspot with many undescribed insect groups (Allsopp, 2014; Rutherford et al., 2014). Essentially, we hypothesised that there are important environmental variables that influence the distribution of *Euloryma* in the CFR. We also suggest that species that occur in fynbos only (and not in agricultural fields) are more sensitive to future land-use change than species which occur in both fynbos and agricultural areas.

2. Methods

2.1. Study area

The study area is located in the Western Cape in south-western part of South Africa between 34° 09' 08" S, 19° 00' 13" E and 34° 27' 00" S, 19° 36' 00" E. The area has many folded mountains with valleys, rivers and rural clusters (settlements). The study area has cold, wet winters and warm, dry summers with daily temperatures ranging from 15 to 27 °C during summer and 7 to 18 °C in winter. The average annual precipitation in this region is 464 mm with the highest monthly rainfall of 96 mm and the lowest being 10 mm. Thirty-two sampling sites were selected, comprising of 16 in vineyards and 16 in fynbos. The specific areas were Stellenbosch (33° 55' 56" S, 18° 51' 37" E), Somerset West (34° 04' 33" S, 18° 50' 36" E) and Grabouw (34° 09' 08" S, 19° 00' 13" E); all located approximately between 50 to 70 km away from Cape Town towards north-eastern to the eastern part of Western Cape. As well as Paardeberg (34° 27' 00" S, 19° 36' 00" E) which is 70 kilometres away from Cape Town and towards the north western part of the Western Cape province (Fig. 1). All these areas are dominated by fynbos biome. This area was selected because a previous study on *Euloryma* reported that they are endemic here in the CFR, with different species within this group confined to certain specific geographic locations within the fynbos biome (Spearman, 2013).

2.2. Description and sampling of Euloryma species

Euloryma is an endemic, flightless South African grasshopper genus (Acrididae, Hemiacridinae). The genus consists of highly sensitive, narrow-range grasshoppers, small (about 12.5 mm long males) to medium in size (37.9 mm long females). There are two proposed species-groups of *Euloryma*. The Karoo group is mostly found in the Succulent Karoo biome and the Fynbos group is often associated with fynbos biome. Currently, there are 11 known species inhabiting the Karoo and ten known species in the Fynbos group (Spearman, 2013). Only the fynbos-species group was used here as it was the only group present in our focal area (Spearman, 2013). Diet requirements of the *Euloryma* genus can only be likened to that of their close relatives in the Hemiacridinae subfamily (e.g.