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Multi-species occupancy modelling of mammal and ground bird communities in rangeland in the Karoo: A case for dryland systems globally

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ABSTRACT

The transition from natural habitat to agricultural land use is widely regarded as one of the leading drivers of biodiversity loss. Despite this, most wildlife still lives outside protected areas on private agricultural land, particularly on rangeland used for livestock grazing. Understanding which species persist and which decline in agricultural landscapes is important for global biodiversity monitoring, management and conservation. In this study, we used hierarchical multi-species occupancy modelling to estimate terrestrial vertebrate (body mass > 0.5 kg) richness in the Karoo, a semi-arid region of South Africa. We evaluated species-specific responses to different anthropogenic and environmental variables in rangeland and a nearby protected area of similar size. We grouped mammal species according to trophic guild and body size and compared their occurrence between areas. In total we detected 42 species over 4035 6-day pooled trap nights across 322 sites. Community species richness was not significantly different between the two types of land use and decreased with increasing elevation in the protected area. Human disturbance did not affect individual species occupancy in either area. Carnivores, omnivores and medium-sized species occupancy probabilities were similar between the two areas but were higher for herbivores and large species in the protected area and for insectivores and small species in rangeland. Our results reveal that drylands in the South African Karoo region, including rangeland used for small-livestock farming, support a diverse community of terrestrial vertebrates. Private landowners are thus important custodians of key components of indigenous biodiversity outside of protected areas, especially in low-lying areas.

1. Introduction

Habitat loss through anthropogenic activities is a major driver of the observed decrease in global biodiversity (Pimm and Raven, 2000). The drive for agricultural productivity explains why most protected areas (PAs) are located in the least productive portions of the landscape or in areas with a high disease risk for humans and/or livestock (Norton, 2000; Pressey, 1994; Rouget et al., 2003) and often at higher elevations (Joppa and Pfaff, 2009; Scott et al., 2001). Yet, the distribution of extant terrestrial plants and animals suggests that the greatest numbers of species are found at lower elevations, on more productive soils, often on privately owned land (Scott et al., 2001). Consequently, significant elements of biodiversity are underrepresented in PAs. As a consequence, species preferring such environments have to persist in highly fragmented or marginal habitats where their ability to respond to environmental change may be limited (Scott et al., 2001). Africa is no different from the global pattern, with only 8.5% of the land designated as PAs (Bonkoungou, 2009). In Namibia, unprotected rangelands comprise 86% of the land surface and contain up to 90% of the populations of some large mammal species (Richardson, 1998) while in Kenya, 65% of wild animals live outside national parks and reserves (Western et al., 2009), and in the United States, > 90% of threatened and endangered species occur on private lands, with 66% having > 60% of their total existing area on private lands (Scott et al., 2001). In South Africa, PAs are mostly situated in less productive mountainous or arid regions of the country (Gallo et al., 2009; Hoffman et al., 1999) and many of them are too small to be sufficient for the survival of larger and more wide-ranging species (Baeza and Estades, 2010; Woodroffe and Ginsberg, 1998).

The limited extent and growing threats to existing PAs worldwide demands that we include the unprotected surrounding private lands in the biodiversity conservation process if we are to protect the full range

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of species and conserve different – and sometimes more endangered – habitats than those found in PAs (Gallo et al., 2009; Groves et al., 2000; Knight, 1999). Yet without information on what species are found on private lands compared to PAs and how wildlife communities respond to livestock presence, it is difficult to develop stewardship programmes and other management strategies that incentivise landowners to contribute to global and local biodiversity conservation goals.

Although the literature has shown that areas outside of PAs can hold significant populations of various wildlife species (Kiffner et al., 2015; Msuha et al., 2012; Rannestad et al., 2006), most studies have shown that increased intensity of land use reduces habitat diversity, resulting in a decrease in species diversity (Du Toit and Cumming, 1999; Maitima et al., 2009; Wretenberg et al., 2010). In particular, compared to pristine lands, rangelands used for livestock farming have shifted from wild herbivore multi-species guilds differentiating their foraging in space and time (McNaughton and Georgiadis, 1986), to few-species guilds (commonly sheep, goats and cattle), which can have adverse impacts on vegetation diversity and plant palatability (Todd, 2006). Intensification of land use has also been shown to negatively impact large-bodied mammal diversity (Kinnaird and O'Brien, 2012; Stephens et al., 2001), including carnivores (Kauffman et al., 2007; Zimmermann et al., 2010) that occur at lower densities and have larger home ranges and greater food requirements (Duncan et al., 2015; Jetz et al., 2004) than other species.

Drylands cover around 41% of the Earth's surface (Davies, 2017) and 65% of the African continent (Darkoh, 2003). They harbour half of the world's population (UNCCD, 2014), support 50% of the world's livestock and provide forage and habitat for many wildlife species (Niemeijer et al., 2005). However, low productivity and low biomass have resulted in ecologists and conservationists overlooking the biodiversity present in drylands (Davies et al., 2012), to the point that "the status of species in the drylands remains unknown, as no assessment exists to date" (UNCCD, 2012). Our study is an attempt to contribute to global understandings of drylands and to provide cost-effective tools that can be applied to study terrestrial vertebrate diversity across dryland systems worldwide.

Compared to the more mesic areas, in drylands most terrestrial mammals are active at night, occur at low densities and are thus difficult to detect (Van der Weyde et al., 2018). In addition, many wildlife species in drylands are actively hunted to reduce grazing competition with livestock (Gordon et al., 2004) and livestock predation by carnivores (Zimmermann et al., 2010). Together, these factors make it difficult to obtain baseline information on important state variables such as species richness, which are needed to inform conservation and management decisions linked to anthropogenic change (Yoccoz et al., 2001). Camera traps have emerged as a useful tool for providing data on multiple species (even in surveys dedicated at a single species) across diverse habitats and are particularly useful for detecting elusive species (Tobler et al., 2015). The recent proliferation of large-scale camera trapping studies that aim to make inferences at the community level, have generally focused on a particular guild, such as carnivores (e.g. Schuette et al., 2013) or ungulates (Stoner et al., 2007). Few studies have attempted community-level research (e.g. Tobler et al., 2015 and Rich et al., 2016). In this study, we aim to investigate the effects of land use on wildlife species richness and occupancy by including a comparison of drylands used for extensive small-livestock farming and a similar sized protected area (PA). We also aim to address the paucity of foundational biodiversity knowledge in the largest semi-arid region of southern Africa – the Karoo, which is under development pressure and is the core of an ancient conflict between farmers and livestock predators (Nattrass et al., 2017). To do so, we carried out an extensive camera trap array of all terrestrial vertebrates with a body mass > 0.5 kg, using a multi-species hierarchical modelling approach (Dorazio et al., 2006). This technique has the potential to be adopted across dryland systems globally and here, we present an example of its application in the South African Karoo.

We tested the hypothesis that (H1) species richness and community occupancy would be different between the two types of land use, (H2) environmental and anthropogenic variables related to occupancy would be unique to each species and would vary between the two areas, and (H3) life-history traits such as body size and trophic guild would influence mammals occupancy in the two areas.

We made the following predictions:

(i) Rangeland would display lower species richness and community occupancy than the PA (Kinnaird and O'Brien, 2012; Rich et al., 2016);
(ii) Human disturbance would reduce wildlife occupancy in rangeland (Kinnaird and O'Brien, 2012) more than in the PA;
(iii) As carnivores are often persecuted, usually occur at lower densities and have larger home ranges and food requirements than other species (Duncan et al., 2015), we predicted that small-livestock farming would reduce the occupancy of carnivores, particularly of livestock predators, more than of other guilds (Kinnaird and O'Brien, 2012; Krausman et al., 2011; Rich et al., 2016);
(iv) Large mammals would show higher occupancy probability in the PA than in rangeland (Rich et al., 2016).

Our research was motivated by the need to provide robust baseline data and cost-effective tools for vertebrate monitoring programmes in semi-arid zones, both inside and outside PAs, particularly in the face of changing environments and human-wildlife conflict.

2. Materials and methods

2.1. Study area

We conducted our research in the Western Cape Province of South Africa, in the Karoo ecosystem, an arid region covering one quarter of the area of South Africa and the southern part of Namibia, where droughts are common and rainfall is both unpredictable and patchy in distribution (Desmet and Cowling, 1999). Our study area covers *c.* 160,000 ha and includes two equally-sized contrasting types of land use: a group of 22 neighbouring sheep farms in the Laingsburg Municipality District and a PA, Anysberg Nature Reserve, located *c.* 40 km southwest of the rangeland in the Klein Karoo sub-region (Appendix A, supporting information).

The farmland study site falls within the second-largest biome in the country, the Nama Karoo, which is characterized by sparse vegetation and dominated by xeric shrubland and grasses (Palmer and Hoffman, 1997). Rainfall represented 125.2 mm (13.4% CV) in the town of Laingsburg (closest town, 40 km west of the farmland site) over the period 2012–2015. The topography is mainly flat ground interspersed with dry riverbeds, rolling hills and bordered by mountains (average elevation: 676 ± 148 m.a.s.l.). Domestic sheep dominate livestock production and the two main breeds are Dorper and Merino, with < 4% of stock comprised of Boer and Angora goats. The approximate stocking rate for the area is 144 breeding ewes/1000 ha (Drouilly et al. unpublished data). The Laingsburg local municipality has a human population density of 0.94 inhabitants/km^2 and 0.49 households/km^2 (Statistics South Africa, 2011).

Anysberg Nature Reserve falls mainly within the Succulent Karoo and the Fynbos biomes, both characterized by exceptional plant diversity and endemism and slightly denser vegetation than on farmland. Rainfall represented an average of 247.6 mm (11.7% CV) in the centre of the reserve over the period 2012–2015. The reserve includes a large valley bordered by two mountain ranges (average elevation: 823 ± 191 m.a.s.l.) extending east to west to form natural boundaries with neighbouring farms. Further study area description can be found in Drouilly et al. (2018).