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Fine-scale spatial and seasonal rangeland use by cattle in a foot-and-mouth disease control zones

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ABSTRACT

Overgrazing of ranglands and foot-and-mouth disease (FMD) are persistent problems in the communal lands bordering the Kruger National Park (KNP) and the adjacent private game reserves in South Africa. Improved livestock management is needed to address these problems, and detailed understanding of cattle ranging behaviour in the FMD control zones is central to improving livestock management. We used environmental data on seasonal variation in forage quality (nitrogen content) and quantity (biomass) derived from high resolution satellite imagery, coupled with cattle GPS locations, to develop a resource utilization function of cattle space use patterns and predicted spatial patterns of their probability of occurrence in the wet and dry seasons. We calculated cattle resource utilization distributions and delineated home ranges of cattle from six villages by applying utilization kernels using the plug-in method as a bandwidth estimator. The overlap between seasonal home ranges was 61% and between core areas 49%, indicating seasonal selectivity mainly within the home ranges. Cattle selected forage with higher quantity and quality during the dry season but behaved like bulk grazers in the wet season. Furthermore, we found that herds in the dry season usually have smaller home ranges and stay closer to water sources and villages than in the wet season. Our prediction maps highlight seasonal differences in probability of cattle occurrence, with implications for rangelands management strategies to minimalize overgrazing and FMD transmission.

1. Introduction

Kruger National Park (KNP) and its adjacent private game reserves are the only area in South Africa recognised as a foot-and mouth-disease (FMD) infected zone (Bastos et al., 2000). The neighbouring communal rangelands act as a protection zone (one of the FMD control zones) and occasionally experience FMD outbreaks (Jori et al., 2009; van Schalkwyk et al., 2014). FMD is one of the most contagious animal diseases and can cause serious economic hardships when trade embargoes are placed on agricultural products originating from countries where the disease is not adequately controlled (Thomson and Bastos, 2004; van Schalkwyk et al., 2014; Vosloo et al., 2006). In the South Africa the FMD virus is typically spread through direct contact between African buffalo (*Syncerus caffer*) that stray into communal areas and susceptible cattle grazing in those areas (Alexander et al., 2002; Brückner et al., 2002; Dawe et al., 1994; Jori et al., 2009; Miguel et al., 2013; Vosloo et al., 1996). For this reason, disease control and prevention in the protection zone focuses on cattle vaccination (compulsory bi- to tri-annual vaccination applied in the protection zone immediately adjacent to the infected zone), and the physical separation between protected and communal lands using fences (van Schalkwyk et al., 2014). However, the efficiency of these methods has recently been called into question (Jori et al., 2009; Scoones et al., 2010). Fences are difficult to maintain, and are frequently damaged by local people, animals (especially elephants) and floods. This allows buffaloes to stray into

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communal lands, with approximately 30–120 events per year and a up to 650 individual buffaloes escaping KNP annually (Jori et al., 2009; van Schalkwyk et al., 2014). Controlling FMD through vaccination is equally challenging as the three SAT serotypes of the FMD virus are prevalent in most southern African buffalo populations and there is considerable geographically-specific variation among these viruses (Bastos et al., 2003; Scoones et al., 2010; Vosloo et al., 2002). The costs arising from the administration of multivalent vaccines on a systematic basis have proven to be too high for the limited budgets of veterinary services (Bastos et al., 2003). As a result of these challenges, veterinary services record an outbreak of FMD in the protection zone nearly every year, which results in financial losses for local farmers. Other than KNP and adjacent control zones, where FMD is controlled through livestock inspection, vaccination and movement permits, South Africa is considered free of FMD by the World Organization for Animal Health (OIE). This status enables the country to export agricultural products. However, if the outbreaks in the control zones are not immediately contained, South Africa could potentially lose its FMD-free zone status (Scoones et al., 2010), which was the case between September 2000 and May 2002 (Brückner et al., 2002).

Another serious problem related to cattle production in South Africa is overgrazing (Moyo et al., 2013), which is caused by excessive use of rangelands throughout the year (e.g., due to large numbers of cattle and/or large overlap of herd seasonal home ranges/core areas), giving vegatation no opportunity for regrowth. This is particularly true for communal areas bordering fenced protected lands, where cattle owners have constrained space for ranging. Overgrazing in savanna ecosystems can lead to a reduction in the competition for water between grass and woody vegetation, resulting in bush encroachment and suppression of grass productivity (Roques et al., 2001). Several studies have indicated that savannas under pastoral land use are often threatened by severe degradation due to poor rangeland management and inappropriate grazing strategies (Fritz et al., 1996; Hassler et al., 2010; Moyo et al., 2013; Quaas et al., 2007). A comprehensive analysis of the mechanisms governing livestock distribution can help prevent FMD outbreaks, and can provide guidelines for local authorities to minimise overgrazing. Knowledge of fine scale space use and seasonal foraging strategies of cattle in the rangelands of South Africa's FMD control zones would be a critical component of developing optimized grazing strategies to reduce overgrazing and FMD transmission risk.

Home range measurement and habitat selection have been studied extensively in wildlife populations, while cattle habitat selection and home range patterns in heterogeneous agricultural landscapes remain poorly explored. There are few existing studies on cattle space use patterns in semi-arid savannas similar to the rangelands of South Africa's FMD control zones (Moyo et al., 2013; Scoones, 1995; Zengeya et al., 2014), and none of these explored fine-scale seasonal patterns of cattle fodder selection or produced results that were readily extrapolated to broader extents.

Herbivores in heterogeneous landscapes often adopt different seasonal foraging strategies as a response to temporal changes in resource availability. For example, home range size of various free ranging herbivores decreases with increasing availability of resources (Damuth, 1981; Hodder and Low, 1978). Temporal changes in the size, location and habitat composition of cattle home ranges have been reported by Zengeya et al. (2014) and Moyo et al. (2013). Zengeya et al. (2014) found that cattle home ranges varied greatly across months, but averaged seasonal home ranges did not differ between wet and dry periods. Moyo et al. (2013) found that home range patterns varied among different geographical areas, suggesting that cattle space use patterns might be unique to each rangeland management type and can be affected by grazing management practices. Yet these factors are often unaccounted for in cattle habitat use studies.

We expect cattle habitat selection to respond to forage quality and/or quantity, as is the case for wild African buffaloes in nearby protected areas (Kaszta et al., 2016a) and foraging strategies to vary with seasonal variations in fodder quality and quantity. Relationships between quality and quantity of forage and animal distribution have been studied in wildlife using faeces and vegetation surveys (Leite and Stuth, 1990; Leslie and Starkey, 1985; Ryan et al., 2006; Wofford et al., 1985). With the emergence of new remote sensing technologies, such as very high spatial and spectral resolution imagery, it is now possible to extract detailed information about biophysical and biochemical parameters of vegetation remotely and over broad spatial extents (Ramoelo et al., 2015, 2012). For example, vegetation biomass is a good proxy for forage quantity, and vegetation nitrogen (N) concentration, reflecting the photosynthetic capacity of plants is a good indicator of rangeland quality (Ramoelo et al., 2015). Furthermore, vegetation N concentration is also positively correlated to protein content (Clifton et al., 1994; Wang et al., 2004) – often a limiting factor for herbivore population density (Prins and Beekman, 1989; Prins and Van Langevelde, 2008). The only existing study exploring the relationships between forage quality and cattle distribution at a fine scale in a semi-arid savanna was conducted by Zengeya et al. (2013). The authors successfully validated a vegetation N content map derived from very high resolution (VHR) imagery with cattle telemetry data covering one month, showing that cattle locations tend to cluster in areas of higher forage quality. However, the study of Zengeya et al. (2013) did not investigate how representative this pattern is across villages or rangeland management types and whether it remains stable across seasons.

To date there are no extensive studies analysing cattle spatial and temporal behaviour in communal farming systems in South Africa's FMD control zones. The goal of this study was to produce a fine-scale mapping of cattle space use patterns across seasons in the FMD control zones to inform rangeland management and FMD control efforts. We developed seasonal models of cattle space use that incorporated fine-scale data on forage quality (biomass) and quantity (N content). Our objective was to understand cattle seasonal behaviour and to map the probability of cattle occurrence in an area of high FMD transmission risk from buffaloes. We hypothesized that cattle will utilize different areas in the wet and dry seasons due to forage and water availability, with smaller home ranges during the dry season, as semi-free range cattle would stay near water sources located closer to villages to minimalize energy losses. Furthermore, we expect that selection for forage of higher quality and quantity will be stronger in the dry season, when food resources become scarcer.

2. Materials and methods

2.1. Study area

The study area covered 460 km^2 of low-lying semi-arid savanna in the north-eastern South Africa (Fig. 1). It encompasses the communal lands of Bushbuckridge Local Municipality and the southern part of the fenced Kruger National Park and Sabi Sands Wildtuin/Game Reserve. The main villages in the study are Belfast, Calcutta, Ireagh, Justicia, Lillydale and Ronaldsay (Fig. 1).

Rains in the study area occur mainly between October and April (wet season). The rest of the year is relatively dry with frequent bush fires (Venter et al., 2003). The total annual average precipitation is 630 mm, and the mean annual temperature is 22 °C.

Topography varies from mostly flat in the basalt areas, to gently undulating in the granitic sites, with elevation ranging between