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Predation by small mammalian carnivores in rural agro-ecosystems: An undervalued ecosystem service?

Samual T. Williams [a,b,*], Naudene Maree [a], Peter Taylor [c,d], Steven R. Belmain [e], Mark Keith [f], Lourens H. Swanepoel [a]

[a] Department of Zoology, School of Mathematical & Natural Sciences, University of Venda, Thohoyandou, South Africa
[b] Department of Anthropology, Durham University, Durham, United Kingdom
[c] South African Research Chair on Biodiversity Value & Change, University of Venda, Thohoyandou, South Africa
[d] School of Life Sciences, University of KwaZulu-Natal, Private Bag X54001, Durban 4000, South Africa
[e] Natural Resources Institute, University of Greenwich, Chatham Maritime, Kent, United Kingdom
[f] Eugène Marais Chair of Wildlife Management, Mammal Research Institute, University of Pretoria, 0002, South Africa

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ABSTRACT

Africa is endowed with a diverse guild of small carnivores, which could benefit stakeholders by providing ecosystem services while fostering conservation tolerance for carnivores. To investigate the potential of small carnivores for the biological control of rodents within agro-ecosystems, we assessed both the ecological and social landscapes within two rural villages in the Vhembe Biosphere Reserve, South Africa. We employed a camera trapping survey underpinned by an occupancy modelling framework to distinguish between ecological and observation processes affecting small carnivore occupancy. We also used questionnaires to investigate perceptions of small carnivores and their role in pest control. We found the greatest diversity of small carnivores in land used for cropping in comparison to grazing or settlements. Probability of use by small carnivores was influenced negatively by the relative abundance of domestic dogs and positively by the relative abundance of livestock. Greater carnivore diversity and probability of use could be mediated through habitat heterogeneity, food abundance, or reduced competition from domestic carnivores. Village residents failed to appreciate the role of small carnivores in rodent control. Our results suggest that there is significant, although undervalued, potential for small carnivores to provide ecosystem services in agro-ecosystems.

1. Introduction

Rodents cause significant damage to crops in small-holder farms in Africa (Granjon and Duplantier, 2009; Monadjem et al., 2015; Singleton, 2010; Swanepoel et al., 2017). Existing rodent control is highly reactive and almost exclusively based on the use of rodenticides. This heavy reliance on poisons has led to increasing problems with the development of behavioural and physiological resistance, environmental contamination, and non-target poisoning (Buckle and Smith, 2015). Ecologically-based rodent management (EBRM) is a term popularised more than 20 years ago (Singleton et al., 1999) with an aim to re-emphasize the importance of understanding rodent biology and behaviour of different species as well as agro-ecological and socio-economic contexts. While traditional rodent pest solutions emphasized over-reliance on poisons, EBRM advocates less harmful and sustainable solutions such as biological control through increasing ecosystem services of natural predation for pest control. Several studies have shown that the adoption of EBRM strategies for rodent pest management can be highly effective in reducing rodent damage whilst reducing farmer reliance on rodenticides (Brown et al., 2006; Jacob et al., 2010). EBRM has recently gained traction in small-holder agro-ecosystems in Africa (Massawe et al., 2011; Monadjem et al., 2015; Taylor et al., 2012).

In smallholder agro-ecosystems, and many other modified landscapes, the removal of apex carnivore species from most human inhabited areas of Africa may have facilitated increased mesocarnivore abundance (Caro and Stoner, 2003; Prugh et al., 2009; Ritchie and Johnson, 2009). Such increases might cause several ecological services or disservices to human communities. For example, small carnivores such as the red fox (*Vulpes vulpes*) provide valuable ecosystem services such as seed dispersal and potentially controlling populations of small mammals, regulating their impacts on keystone plant species and threatened habitats in Europe (Cancio

* Corresponding author at: Department of Zoology, School of Mathematical & Natural Sciences, University of Venda, Thohoyandou, South Africa.
E-mail address: s.t.williams@durham.ac.uk (S.T. Williams).

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et al., 2017). In contrast, in Africa the importance of small carnivores around small-holder farming systems is well-recognised in terms of human-wildlife conflict and ecosystem disservices (Blaum et al., 2009; Gusset et al., 2009; Woodroffe et al., 2005), but is less understood in terms of potential ecosystem services (Roemer et al., 2009). This is unfortunate as Africa has a rich small carnivore assemblage, which could provide key ecosystem services to surrounding communities (Schuette et al., 2013). Furthermore, the relatively large number of small-sized farms and small settlement areas in sub-Saharan Africa (Lowder et al., 2016) are interspersed within a mosaic of semi-natural habitat that can increase human-wildlife conflict (Crooks, 2002; Lamarque et al., 2009). As farm sizes in Africa are likely to continue to decline and further fragment the landscape (Masters et al., 2013), there is a real risk of further natural habitat loss, trophic collapse and loss of potential ecosystem services provided by small carnivores (Dobson et al., 2006).

Although the use of biological control is well established for many insect pests in agricultural production (Vincent et al., 2007), it is not yet commonplace for rodent pests. The potential of avian predators to provide ecosystem services for the control of pest rodents has been recently reviewed (Labuschagne et al., 2016), highlighting that some species, such as barn owls (*Tyto alba*), are able to control rodent pests in some in agricultural contexts. Recent research suggests that domestic cats and dogs may increase the landscape of fear around rural homesteads, resulting in lower rates of rodent activity and food intake (Mahlaba et al., 2017). This indirect mechanism, affecting rodent behaviour, could work synergistically with direct control mechanisms such as predation of rodents by domestic carnivores, which could reduce rodent density (Krijger et al., 2017). Little attention, however, has been given to the potential services or disservices of wild terrestrial carnivores in terms of rodent pest control.

Thus, the first objective of our study was to understand which small- and medium-sized mammalian carnivores (<15 kg, hereafter referred to as small carnivores) were present in and around rural farming communities in the study area. Secondly, we set out to determine the influence of the abundance of domestic animals (livestock and pets) on the probability of use of an area by small carnivores; and also assess how the species richness of the small carnivore community was influenced by land use. Thirdly, we wanted to capture the knowledge and opinions of smallholder farming communities with respect to small carnivores. This will provide an initial yet essential step towards understanding the potential ecosystem services provided by small carnivores in rural agro-ecosystems, to help inform the development of EBRM strategies with a strengthened biological control component.

2. Methods

2.1. Study area

We conducted the study at two rural sites (Ka-Ndengeza: S23.31003° E30.40981° and Vyeboom: S23.15174° E30.39278°) in the Vhembe Biosphere Reserve, South Africa (Appendix S1). Both sites receive an annual rainfall of 700–800 mm per year, with a hot wet season from October to March and a cool dry season from May to August (Hijmans et al., 2005). Natural vegetation is classified as Granite Lowveld and Gravelotte rocky bushveld (Mucina and Rutherford, 2006). Vegetation is characterised by tall shrubs with few trees to moderately dense low woodland on the deep sandy uplands dominated by *Combretum zeyheri* and *C. apiculatum*. Low lying areas are characterised by dense thicket to open Savanna with *Senegalia (Acacia) nigrescens*, *Dichrostachys cinerea*, and *Grewia bicolor* dominating the woody layer, particularly the Granite Lowveld (Mucina and Rutherford, 2006).

Three major land-use types were identified in each of the villages. First, the settlement areas were used for residential purposes (hereafter settlements) (Odhiambo and Magandini, 2008). The majority of households had large gardens (50–80 m $\times$ 40–80 m) which were used to grow crops (maize (*Zea mays*), peanuts, beans (*Phaseolus vulgaris*), ground nuts (*Arachis hypogaea*), avocados mangoes, bananas, litchis, and oranges), and to overnight livestock (cattle, donkeys, sheep, goats, and poultry). The second land-use type identified was cropping areas (hereafter crops). Residents of both villages practiced either rotational cropping (maize, ground nuts, and beans) or intercropping (maize, beans, and pumpkins (*Cucurbita* spp.)). Land preparation was usually by manual labour, and preparation typically began in October or November, while planting commenced in early December. Harvesting of crops occurs in February until late April (crop dependant). Farmers reported yields varying between 5 to 20 bags (each bag weighing 50 kg) of maize and 3 to 10 bags of ground nuts (Swanepoel, unpublished data). Crop residues were typically used for livestock fodder. The third land-use type was the grazing areas, which comprised of short grass, shrubs and tall trees (hereafter grazing). In addition to communal grazing of livestock, these areas served for firewood collection and informal hunting. Due to poor land management practices, however, the grazing areas were typically severely overgrazed, with woody plants (mainly *Dichrostachys cinerea*) decreasing herbaceous production and replacing the grass and shrub layer, typically in low lying areas.

2.2. Potential small carnivore diversity and ecosystem services

We define predation of rodent pests and consumption of carrion as potential ecosystem services (Ćirović et al., 2016) that could be provided by small carnivores. We estimated theoretical small carnivore diversity for our study sites by compiling a list of all small carnivore species potentially present at the study sites from the IUCN Red List of Threatened Species (IUCN, 2016) and from published literature (Apps, 2012; Cillié, 2013; Kingdon and Hoffman, 2012; Skinner and Chimimba, 2005; Stuart and Stuart, 2007). For each species we then extracted from the literature, data on the amount of rodents in their diets, and whether the species consumed carrion (Admasu et al., 2004a,b; Apps, 2012; Camps, 2008; Cillié, 2013; Kingdon and Hoffman, 2012; Skinner and Chimimba, 2005). We regarded species with diets that included a minimum of 20% rodents as potential ecosystem service providers (Ćirović et al., 2016). The home range size of the species potentially present, were used to determine the average distance between camera traps.

2.3. Camera trapping and data preparation

We used camera trapping to determine both species richness and habitat use (occupancy) of small carnivores. Our surveys were underpinned by an occupancy based modelling framework, which guided the layout of camera traps (MacKenzie and Bailey, 2004). Each study area was divided into a settlement area, cropping area and grazing area, based on recent satellite imagery (Google, 2014), which was then overlaid with a regular spaced grid with a cell size of 300 $\times$ 300 m (9 ha). The size choice of the grid cells was guided by the median home range size of small carnivores expected to inhabit the study areas (Table 1), to adhere to the independent assumptions of occupancy models (Mackenzie and Royle, 2005). We deployed one camera trap in each grid, which resulted in an average spacing between camera traps of 193 m (standard deviation 65 m), and camera traps were operated for 10–12 days. Camera traps were set to record 24 h per day, with a 30 s delay between