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Linking changes in small mammal communities to ecosystem functions in an agricultural landscape

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ABSTRACT

Global increases in agricultural production have significant implications for biodiversity and ecosystem processes. In southern Africa, sugarcane production has converted native vegetation into agricultural monocultures. We examined functional group abundance along a conservation-agriculture gradient in the Lowveld of Swaziland. We captured small mammals representing 4 functional groups: omnivores, insectivores, granivores, and herbivores and found evidence of distinct changes in small mammal functional groups across the conservation-agriculture boundary. Granivores declined with increasing distance into the sugarcane and were completely absent at 375 m from the boundary while omnivores increased in the sugarcane. Insectivores and herbivores showed no differences between the two land uses; however, during the dry season, there were significantly more insectivores at the conservation-agriculture interface than in the conservation lands. Shifts in small mammal communities have clear implications for ecosystem processes as the removal of granivores from savannah systems can drastically alter vegetative structure and potentially lead to shrub encroachment via reduced levels of seed predation, while abundant omnivorous small mammals can cause significant crop damage and increase the prevalence of vector borne diseases in the environment.

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Introduction

The global landscape is dominated by agriculture, covering more than 40% of the earth's land surface (Foley et al., 2005; Ramankutty et al., 2008; Ramankutty and Foley, 1999). In developed countries, agricultural lands often utilize intensive agricultural practices which clear native vegetation, leaving negligible amounts of natural habitats for wildlife (Krebs et al., 1999; Sotherton, 1998). As intensive agriculture practices spread throughout southern Africa and the rest of the developing world there is a growing concern that these practices will decrease wildlife diversity and subsequent ecosystem functions (Donald, 2004; Tscharrntke et al., 2005). Nonetheless, the linkages among intensive agriculture, diversity

and ecosystem functioning are poorly understood (Matson et al., 1997; Tilman et al., 2002; Rands et al., 2010). Some wildlife populations appear to benefit from intensive agriculture while others may be reduced or eliminated (Matson et al., 1997; Tilman et al., 2001). Thus, there is a need to understand how differing population responses shape wildlife communities and ultimately the integrity of the ecosystem in landscapes dominated by high intensity agriculture.

One way to understand the link between communities changed by intensive agriculture and ecological processes is to measure a community's functional group structure, based on the ecological roles that species play (Clarke, 1954; Korner, 1994). Functional group structure and abundance also can be used as indicators of disturbance response and land-use impacts (Andersen, 1997a,b; Andersen et al., 2002; Jansen, 1997; Peterson et al., 1998). Furthermore, because functional groups provide a criterion that can be evaluated across taxa, their use has the added benefit of broadening the inferential space, generalizability, and comparative value of a study (Andersen, 1997a).

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During the last 40 years, large expanses (~8%) of the low-lying savanna (Lowveld) of Swaziland and southern Africa have been converted from native vegetation into areas of intensive sugarcane (*Saccharum* spp.) production (Hackel, 1993; Lankford, 2001). Sugarcane plantations combine with overgrazed communal lands and small-scale subsistence agriculture to create a matrix surrounding patches of intact vegetation that serve as *de facto* conservation areas (Monadjem and Garcelon 2005). Sugarcane production in the Swazi Lowveld has become so prolific, that the few *de facto* and designated conservation areas in the region are all adjoined by sugarcane plantations (Monadjem and Garcelon, 2005). Furthermore, from 2000–2013 the extent of sugarcane production in Swaziland increased by 28%, this trend is expected to continue (USDA, 2013).

Small mammals play an integral role within African Lowveld savanna ecosystems as herbivores, seed predators, prey items and disease vectors; changes in their community structure are likely to have consequences for the integrity and stability of the system (Goheen et al., 2004; Keesing, 2000). Nonetheless, there is only limited information on the basic ecology of small mammals in African savanna systems, few data on how small mammal communities respond to land-use alterations such as intensive agriculture, and practically no information on how small mammal community changes from intensive agriculture relate to ecosystem processes (Avenant and Cavallini, 2007; Hurst, 2010). As such, the goal of our study was to describe the changes in abundance and structure of small mammal functional groups across a spatial gradient between intensive agriculture plantations and conservation lands, and to understand how these changes might influence ecosystem functions.

Material and methods

Study area

We conducted our research in the Lowveld of Swaziland, the low-lying region between the northern Drakensburg Escarpment and the Lubombo Mountains (Fig. 1). The Lowveld lies in the eastern half of Swaziland and is its lowest, warmest, and driest region. Vegetation is characterized into 3 distinct broad-scale types: *Acacia* savanna, broadleaved woodland, and riverine forest (Mucina and Rutherford, 2006; Roques et al., 2001). Swaziland has a subtropical climate, and exhibits distinct wet (October–March) and dry (April–September) seasons; 75% and 25% of rains fall during these respective seasons (Matondo et al., 2004). Annual precipitation ranges between 550–725 mm decreasing on a north–south gradient (Matondo et al., 2005). The Lowveld is drought-prone due to the combination of erratic rain events and high summer temperatures (Matondo et al., 2004).

We conducted our research at 3 sites (Hlane-Mbuluzi, Crookes, and Nisela) where conservation lands adjoined large-scale sugarcane plantations. Conservation lands were identified as lands with an explicit goal of wildlife conservation as a component of their management. These lands included private cattle ranches, private game reserves, and national parks. Hlane-Mbuluzi included lands administered by Hlane Royal National Park, Mbuluzi Game Reserve, Tongaat-Hulett Sugar (Tabankulu Estate), and Royal Swazi Sugar Corporation (Simunye and Mhlume Estates). Conservation lands (Hlane Royal National Park and Mbuluzi Game Reserve) at Hlane-Mbuluzi were managed for wildlife conservation and tourism. Dirt and graveled access roads and a 3 m high fence separated conservation lands and sugarcane, restricting movements of medium- to large-sized mammals. Our second site (Crookes) included lands managed by Crookes Brothers Plantation and Bar J Cattle Ranch. Conservation lands were included in the Big Bend Conservancy, a consortium of land-users who managed their lands for wildlife conservation. Bar J managed their conservation lands using sustainable

stocking rates, rotational grazing, and prescribed burning. Agriculture and conservation lands were separated by dirt access roads, 1.5 m barbed wire fence and 1 m wide irrigation canals. Our third site (Nisela), was overseen by Nisela Farms where conservation lands were managed for wildlife viewing, conservation, and cattle grazing. Prescribed burning and free-range grazing were practiced here. At Nisela, agricultural and conservation lands were separated by dirt access roads, railroad tracks, and an electrified 3 m fence. Nisela used center pivot irrigation and had two structurally different varieties of sugarcane.

Sampling design

We used a gradient study design to elucidate changes in small mammal communities from conservation areas to plantation agriculture. Using ground-truthed aerial photographs and Landsat images in a GIS (ArcGIS 9.3, ESRI, Redlands, California), we digitized the linear extent of the conservation-agriculture interface at each site with the fence line between land-types representing the interface. We then placed 4 transects at random linear distances perpendicular to the interface at each site. We spaced transects >300 m apart to ensure independence of sampling units based upon estimates of small mammal (<300 g) ranges in Swaziland (Monadjem and Perrin, 1998a). Along each transect, we placed small mammal traplines at 0 (interface), 75, 150, 225, and 375 m into each land-use type, parallel to the interface (Fig. 2). We used the farthest trapline, (375 m) as a reference of the interior small mammal communities in interior of both land-uses because research suggests that the influence of the edge should be <250 m for most taxa (Ries et al., 2004). We sampled each transect once per season, and alternated sampling among the 3 sites. We duplicated our transect sampling order between the 2 seasons so that sampling events were spaced approximately 4 months apart.

Each trapline consisted of 20 Sherman live traps (size large) spaced 10 m apart ($n = 180$ traps per transect) and baited with a combination of oats and peanut butter. Our design was developed to yield high levels of area surveyed per trap. The relatively close spacing of traps and sampling for 4 consecutive nights ensured adequate sampling for small mammal species richness (Jones et al., 1996; Pearson and Ruggiero, 2003).

We placed pitfall arrays to sample for shrews at each trapline (Jones et al., 1996). Pitfall arrays consisted of 7 pitfall buckets and were offset 50 m from the Sherman live traps. They had a central pitfall with 3 10-m long, radiating drift fences set at every 120°. Additional pitfalls were placed along each drift fence at 5 m and at each terminus. Drift fences consisted of 30 cm tall plastic sheeting, staked vertically with the bottom buried; pitfalls were at least 40 cm deep to eliminate the chance of escape and were flush with the ground (Jones et al., 1996). We used 63 pitfalls (9 arrays) on each transect. We restricted pitfall trapping to one site (Hlane-Mbuluzi) during the dry season due to logistical constraints, but during the wet season all three sites were surveyed using pitfalls.

Upon capture we recorded species, age, sex, and mass of each small mammal (Kunz et al., 1996; Skinner and Chimimba, 2005). We gave each individual weighing >15 g a unique ear tag identifier (1005-1, National Band Co., Newport, Kentucky, USA), smaller individuals and African pygmy mice (*Mus minutoides*) were given ear punches (INS500075-5, Kent Scientific, Torrington, Connecticut, USA). Individuals that received ear punches were uniquely identified using a combination of measurements, including: mass, tail length, body length, and hind foot length. All captured shrews (*Crocidura* spp. and *Suncus* spp.) were collected and deposited in the Durban Natural Science Museum (South Africa) for identification. Our capture protocols and data collection followed guidelines outlined by the American Society of Mammalogists (Gannon and Sikes,

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