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Effect of land use on anuran species composition in north-eastern KwaZulu-Natal, South Africa

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A B S T R A C T

Human induced landscape change is a major driver of biodiversity of loss and landscape homogeneity. North-eastern KwaZulu-Natal, South Africa, is an area of high biodiversity as well as increased human urban development and changing land use. We assessed the effects of various agricultural land uses on anuran species composition within this area. Anuran species composition was examined over three strata namely: land use, season and habitat. Land use types surveyed were eucalyptus (*Eucalyptus* sp.) plantations ($n = 4$), sugar cane (*Saccharum officinarum*) farms ($n = 4$) and conservation areas ($n = 5$). Sampling was split into three sampling periods: early (Oct–Nov), mid (Dec–Jan) and late (Feb–Apr). Each property was sampled once during each of these periods, and three habitat types were sampled: open water bodies, wetland areas and grassland/woodland complexes. Pit-fall traps with drift-net fences and vocalizations were used to identify anuran species. Mean number of anuran species found on conservation, sugar and eucalyptus sites were 13 ± 6.6; 4 ± 1.3; and 3 ± 1.4 respectively. Correspondence Analysis (CA) produced eigen values of 0.526, 0.485, 0.435 and 0.363 for the first four axes respectively. These axes accounted for 41.5% of the total inertia. Sites within the CA were classified according to land use, season and habitat. Sugar and eucalyptus plantations had lower variation between sites, and low variation in habitat type. Low anuran species richness in the eucalyptus and sugar cane areas is most likely lack of suitable habitat for species that are either totally dependent or totally not dependent on water bodies. Absence of *Hyperolius marmoratus* and *Amietophrynus gutturalis* was the factor defining the first division (eigen value 0.498) produced by the TWINSPAN analysis. The two groups produced were significantly different in terms of land use, habitat and season. Land use, particularly sugar cane and agroforestry plantations, had an impact on anuran species presence and composition, and needs to be considered in management for their conservation.

Introduction

Among the major drivers of biodiversity loss and landscape homogeneity worldwide are human induced landscape change, in particular agricultural reform and infrastructural development (Curado, Hartel, & Arntzen, 2011). This will continue with the high rates of human population growth in many parts of the world and associated development, particularly near protected or conservation areas in the developing world (Estes, Kuemmerle, Kushnir, Radeloff, & Shugart, 2012).

Life history and biological traits of amphibians make them sensitive to their environment, and many are habitat selective and dependent (Indermaur & Schmidt, 2011). This selectivity and sensitivity enables them to be used as indicators of environmental stress, and effects of changing land use (Beebee, 1977; Channing, 1997; Davis & Roberts, 2011; du Preez & Carruthers, 2009). Globally declines in population numbers of amphibians is of concern as it may be indicative of the current global ecological status (Blaustein & Wake, 1990; Murray, Rosauer, McCallum, & Skerratt, 2011; Richards, McDonald, & Alford, 1993; Wake, 1991). Numerous factors including climate change, increase in ultraviolet light, use of pesticides, water pollution, introduction of alien species, habitat loss or modification particularly as a result of land use, development and urbanisation, and emerging diseases, have been considered possible causes of these global amphibian declines (Alford & Richards, 1999; Anzalone, Kats, & Gordon, 1998; Blaustein & Kiesecker, 2002; Channing, 2001; Cushman, 2006; Hamer & Parris, 2011; Johnson et al., 2011; Lips, 1998; Murray et al., 2011; Muths, Corn, Pessier, & Green, 2003; Weldon & du Preez, 2004).

In South Africa, amphibian species distribution has been well documented (Carruthers, 2001; Channing, 2001; du Preez &

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Carruthers, 2009; Measey, 2011; Minter et al., 2004; Poynton, 1964). Despite this there has been a paucity of research on changes in anuran populations. The first Frog Atlas with population and distribution data of South African frogs was published in 2004 with previous population data scarce for most species (Measey, 2011; Minter et al., 2004). Despite this, there are local populations and species under threat of extinction (Carruthers, 2001; Channing, 2001; du Preez & Carruthers, 2009; Measey, 2011). Since then more species have been identified as threatened or near threatened (Branch & Harrison, 2004; du Preez & Carruthers, 2009; IUCN, 2011; Measey, 2011; Minter et al., 2004). A large majority of species have limited ranges and inhabit unique environments (Carruthers, 2001; Channing, 2001; du Preez & Carruthers, 2009; Measey, 2011; Passmore & Carruthers, 1979). These species are most affected by changing land use with habitat modification and loss (Angulo, Hoffmann, & Measey, 2011; Branch & Harrison, 2004; IUCN, 2011). Change in land use including afforestation, wetland drainage and urban sprawl have resulted in a loss of habitat for many amphibian species, and is the major cause of local amphibian population declines in South Africa (Angulo et al., 2011; Channing, 2001; du Preez & Carruthers, 2009; IUCN, 2011; Weldon & du Preez, 2004). *Microbatrachella capensis*, *Pyxicephalus adspersus*, *Hemisus guttatus* and *Hyperolius pickersgilli* are examples of South African amphibian species that occupy specific habitats and are sensitive to changes in their environments (Branch & Harrison, 2004; Measey, 2011).

Land use practices such as forestry and sugar cane (*Saccharum officinarum*) production change the vegetation structure within an area (Kotze, 2004) and the matrix of suitable habitat available to amphibians (Freidenfelds, Purrenhage, & Babbit, 2011; Johnson et al., 2011; Semlitsch et al., 2009). Generally the landscape is changed from a diverse matrix to one of monoculture (Ash, 1988). Regulations governing cultivation of these monocultures in South Africa usually stipulate that wetlands remain unplanted (Conservation of Agricultural Resources Act No. 43 of 1983). This may protect functioning of wetlands, but does not necessarily facilitate habitation of the area by certain animal species, which require a larger habitat comprising the wetland and surrounding area (Semlitsch & Bodie, 2003). There are many species of amphibians that occupy other regions besides large permanent wetlands (Carruthers, 2001; Dupuis & Steventon, 1999; IUCN, 2011; Measey, 2011; Minter et al., 2004; Zug, 1993). Some South African amphibians require permanent water sources, like the fully aquatic frog *Xenopus laevis* (Measey, 2004, 2011), or prefer shallow running rivers or streams (e.g. *Amietia anglolensis*) (Channing, 2004; Measey, 2011). Others only breed in small shallow temporary pools that are not recognised as wetlands or protected as such (e.g. *P. adspersus*) (du Preez & Cook, 2004; Measey, 2011). There are some amphibian species that do not rely on any water feature but live and breed amongst the leaf litter, in trees, or in burrows (e.g. *Breviceps mossambicus*) (Measey, 2011; Minter, 2004). Consequently protection of wetlands, e.g. within sugar cane and forestry regions, may not protect all species of amphibians (Semlitsch & Bodie, 2003). Furthermore, these land use practices may still place certain species at risk (Branch & Harrison, 2004).

In north-eastern KwaZulu-Natal land use varies. It was noted as far back as the 1960s by Bass (1966) that: "The influence of man on the vegetation of the area… has been most noticeable in the region from St. Lucia southwards. Sugar cane, pine and eucalyptus plantations have almost completely taken over the place of the natural vegetation except for the dune forest and occasional large pans such as at Richards Bay (Bass, 1966: p. 6)."

Bass (1966) studied anurans in a similar region to the present study. Since then human population, development and infrastructure have increased greatly here, and land use types that cover most of the region are classified as residential, eucalyptus (*Eucalyptus* sp.) plantations and sugar cane (aerial photographs and spatial information from the Department of Agriculture).

The aim of the present study was to examine the effects of land use on the species composition of anurans within the northern coastal region of KwaZulu-Natal in South Africa, by comparing species composition on nearby properties under (1) sugar cane cultivation, (2) forestry production, and those under (3) conservation. Based on distribution records for amphibians in this area, further objectives were to identify any possible factors that may be responsible for the difference in species composition, and highlight any anuran species that may be used as indicators of environmental stress. It was hypothesised that anuran species composition differs with land use if all habitat types where anurans occur were sampled in each land use type (see below). It was predicted that high species numbers would be found in conservation areas compared with the other land use types in close proximity.

Materials and methods

Study area

The broad study area in north-eastern KwaZulu-Natal on the north-eastern coast of South Africa (Fig. 1) ranged from approximately 32.00°S 27.75°E to 32.00°S 28.50°E and 32.45°S 27.75°E to 32.45°S 28.50°E. It incorporated the towns of Matubatuba, Hluhluwe and Mkhuze and was in the vicinity of the iSimangaliso Wetlands Park, a World Heritage Site; and the iMfolozi Game Reserve. Properties in relatively close proximity selected for the present study ranged fairly evenly from the north to the south of the study area, and represented sugar cane cultivation, eucalyptus plantation and conservation sites (Fig. 1, Table 1). Five were used as conservation sites. Iqina, the most northerly property, was a private game reserve (PGR) on the Mkhuze River with a range of vegetation including riverine forest, some grassland and thornveld, savanna, and sand forest. Phinda Resources Reserve, a PGR, bordering on Mkhuze Game Reserve, comprised of savanna, sand forest, riverine vegetation, and some grassland areas. Falaza Game Reserve, a PGR, consisted mainly of sand forest. Bonamanzi Game Reserve, a PGR noted for its bird biodiversity, had a range from sand forest, savanna, grassland to Lala palm veld. Lake Mavuya is a large wetland and lake region that falls under the management of the forestry company Sappi. Part of the area is under conservation, the southern section is under eucalyptus plantation and directly opposite, the northern bank is under sugar cane cultivation. This property had four study sites within it, two plantation sites, a sugar cane site, and a conservation site. Silver Sands farm (sugar cane site) had mainly sugar cane cultivation with a large dam and a stream on the property. Palm Ridge, an organic sugar farm, was used as a sugar cane site. Mvubu dam and Lake Futululu were eucalyptus plantation sites owned by Sappi. Bordering on Lake Futululu are also private sugar cane farms, with the site referred to as Umfolozi in this region and used as a sugar cane site.

Stratification and site selection

Anurans of this region inhabit a range of habitat types (Bass, 1966; Carruthers, 2001; Channing, 2001; du Preez & Carruthers, 2009; Frost, 2011; Passmore & Carruthers, 1979). A species/habitat matrix was compiled using available literature, for selection of habitat types to be sampled (Russell, 2009). To ensure that all possible species were encountered, the following habitat types were sampled: perimeter of open water bodies (dams, ponds, pools); wetlands; grassland or woodland complexes. Sampling occurred in each of the habitat types at each site. Within plantation