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Using predictive modelling to guide the conservation of a critically endangered coastal wetland amphibian

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ABSTRACT

Amphibians are the most threatened Class of vertebrate, with wetland-associated anurans in particular suffering high levels of habitat loss. We used predictive modelling to better understand the distribution of a critically endangered South African endemic (*Hyperolius pickersgilli*) and to guide conservation action. MaxEnt distribution models were produced based on limited occurrence data. Predicted localities with probability of occurrence ≥60% were surveyed. Ten new sub-populations were discovered. The mean probability of occurrence for the species at wetlands where it was detected was greater than that at wetlands where it was not detected or absent. In addition, 17 known historical localities were re-visited and the species deemed absent at 8 of these. The total number of localities at which the species is now known to occur is 18, which is an increase in the known extant sub-populations of six. We recalculate the area of occupancy and extent of occurrence for the species as 108 km^2 and 2081.5 km^2, respectively; both increases on previous estimates. Implications of these changes on the IUCN Red List status of *H. pickersgilli* are discussed. A friction map was created to identify possible linkages between sub-populations, which can be used to guide habitat restoration and population repatriation. Given the degree of isolation of subpopulations and the potentially severe threats to most of these, urgent conservation action for *H. pickersgilli* remains crucial. This study provides a method for use in conservation planning for wetland-breeding amphibians in eastern coastal regions of Africa and elsewhere.

Introduction

The eastern coast of Africa hosts high amphibian species richness and endemism but is also subject to large-scale land transformation and habitat destruction (Driver et al., 2012; Wilson, 2011), the most significant threats to amphibians worldwide (Cushman, 2006; Gascon et al., 2007; Stuart et al., 2008). Two biodiversity hotspots occur in this region: the Coastal Forests of Eastern Africa and the Maputaland–Pondoland–Albany hotspot (Mittermeier et al., 2005). The coastal region of southern Mozambique and of the KwaZulu-Natal Province of South Africa falls within the latter, much of which is experiencing high levels of habitat transformation (Bass, 1966; Russell & Downs, 2012), with some of the coastal terrestrial and wetland ecosystems being classified as Critically Endangered (Driver et al., 2012). The region has few herpetologists and little funding to support the conservation of its amphibian fauna, such that conservation action often has to proceed without detailed information on the ecology and population dynamics of the fauna (Andreone et al., 2008; Measey, 2011; Semlitsch, 2002). Therefore species prioritisation and efficient gathering of associated information is necessary (Fielding & Bell, 1997; Funk, Richardson, & Ferrier, 2005). This study makes use of GIS-based techniques for developing conservation solutions for a highly threatened South African endemic amphibian.

Pickersgill's reed frog, *Hyperolius pickersgilli* (Raw, 1982), is a small Hyperoliid endemic to the KwaZulu-Natal (KZN) coast of South Africa. It is a habitat specialist, favouring dense reed-beds in Coastal Bushveld-Grassveld (Mucina & Rutherford, 2006), and is found at altitudes below 340 m a.s.l. (Bishop, 2004). The species occurs in permanent wetlands and requires a combination of a dense understorey together with taller reed vegetation (Raw, 1982; pers. obs.). Its favoured habitat, cryptic behaviour, small size and inconspicuous call make this species difficult to locate. The use of ecological niche modelling (ENM) may provide an effective tool for directing field surveys and revealing unknown populations of threatened amphibians that inhabit the eastern coastal region of Africa (for other examples see Armstrong, 2009; Guisan et al., 2006; Jackson & Robertson, 2011; Lomba et al., 2010; Stillman & Brown, 1994; Tinoco, Astudillo, Latta, & Graham, 2009).

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As a result of the 2010 IUCN Red-List re-assessment of South African frogs, *H. pickersgilli* was up-listed from Endangered to Critically Endangered B2ab (ii, iii), based on its small Area of Occupancy (AOO), fragmented distribution and continuing decline in habitat (SA-FRoG and IUCN, 2010). Measey (2011) recognised the species as having the highest conservation priority for any frog species in South Africa and a high priority for monitoring and surveillance. Improved knowledge of its distribution, population size, phylogeography and threats were also highlighted as requirements for the successful conservation of the species (Measey, 2011). At the time of the assessment, *H. pickersgilli* was known only from 12 localities along the KZN coast (Bishop, 2004; Measey, 2011). This area has been, and continues to be, under high pressure from agriculture, silviculture and urban development (Armstrong et al., 1998; Armstrong, 2009; Johnson & Raw, 1987; Scott-Shaw, 1999). Only two sub-populations occur within formally protected areas (Bishop, 2004; Measey, 2011).

The aims of this study were to address conservation research priorities for *H. pickersgilli* outlined in Measey (2011) by (1) modelling its predicted distribution using MaxEnt and surveying predicted wetlands with high probability of occurrence; (2) resurveying historical localities to ascertain its presence and determine site status; (3) delimiting potential populations, to guide conservation measures and decisions, and; (4) recalculating its Extent of Occurrence (EOO) and Area of Occupancy (AOO) and re-examining its IUCN Red-List status in the light of these findings.

Methods

Modelling methods

Species occurrence records were obtained from the Frog Atlas (Minter et al., 2004) and the Biodiversity Database of Ezemvelo KZN Wildlife. Twenty-four occurrence records (pre-October 2010) with a spatial accuracy up to 250 m (WGS84 datum) were used in the modelling. Environmental predictors likely to influence the distribution of the species (Armstrong, 2001; Elith et al., 2011) were ascertained from the literature (Bishop, 2004; Du Preez & Carruthers, 2009; Franklin, Wejnert, Hathaway, Rochester, & Fisher, 2009; Poynton, 1964). For the purposes of this model, only continuous variables were used, with categorical variables overlayed at a later stage. The continuous variables used were the means of minimum and maximum daily temperatures and relative humidity for January and July (the hottest and coldest months, respectively), and mean annual temperature and precipitation for KwaZulu-Natal (Table 2). These coverages were developed at a scale of $1' \times 1'$ using the decimal degree Cape (1880) datum by Schulze (2007), and were re-projected to the WGS84 datum, Transverse Mercator lo31 central meridian, and then resampled to a $20\,\mathrm{m} \times 20\,\mathrm{m}$ ($400\,\mathrm{m}^2$) grid based on the Ezemvelo KZN Wildlife 2008 version 1 land-cover coverage (Ezemvelo KZN Wildlife, 2009, 2011). No increase in the resolution accuracy of the climatic variables was assumed. Resampling was performed to allow the incorporation of finer scale data in the form of the wetland and hard transformation (100% loss of native habitat) coverages. Many of the wetlands and associated land transformation would otherwise be lost from the analysis.

MaxEnt version 3.3.3e (Phillips, Dudík, & Schapire, 2004; Phillips, Anderson, & Schapire, 2006) was run to develop an ecological niche model for *H. pickersgilli*. Five replicates were run using the cross-validate setting. The maximum number of iterations was set at 1000 to ensure algorithm convergence; default settings were used for all other relevant parameters. A mask was used to ensure that the background samples were selected from the general region in which the species occurs. This was taken to be the Indian Ocean Coastal Belt of KZN, which spans altitudes between 0 and 450 m a.s.l. (Mucina & Rutherford, 2006). Areas above 450 m altitude were therefore masked out of the background selection. The coverage of the coastal and sub-coastal areas of KZN historically and recently has been relatively good in terms of amphibian distribution records (Minter et al., 2004), so it is not expected that the species will be found currently outside this region. The performance of the model was evaluated by jack-knife tests and the area under the curve (AUC) statistic of the receiver operating characteristic plots (Phillips et al., 2006). MaxEnt has a regularisation method that enables ecologically relevant but correlated variables to be included in the modelling process (Elith et al., 2011).

The probability map and the land transformation and wetlands coverages were overlaid in the Idrisi Geographic Information System (Eastman, 1999). Wetland types suitable for *H. pickersgilli* were determined from an overlay of distribution records on the wetlands coverage, and the probability of occurrence of *H. pickersgilli* in the suitable wetlands obtained from the MaxEnt probability map. Hard-transformed land was subtracted from the MaxEnt probability map to eliminate as many transformed wetlands from the resultant map as possible.

From a previous version of the probability occurrence map, created without the use of a mask and the cross-validate parameter, wetlands with probability of occurrence of ≥60% for *H. pickersgilli* were selected and overlaid with 1:50,000 topographical maps (Chief Directorate: National Geo-spatial Information, Mowbray, Cape Town, South Africa) for the purpose of directing surveys.

Potential populations of *H. pickersgilli* were delimited using RAMAS GIS (Akçakaya, 2005). The scale and size of the final probability of occurrence wetland map was adjusted through pixel thinning to a pixel size of 40 m. The resized map was then reclassed to boolean, with wetlands having a probability of occurrence for *H. pickersgilli* of more than zero being assigned the value of one. Although this may be an overestimate of the extent of occurrence of *H. pickersgilli*, we considered any other cut-off arbitrary. The maximum dispersal distance was estimated to be 2 km, based on observations of *H. pickersgilli* up to 1.6 km from the nearest probable breeding wetland (J. Harvey, pers. comm.). The potential dispersal distance of 2 km that was used in the analysis is less than the maximum dispersal distances for other species reported in Marsh and Trenham (2001), but the adult snout-vent lengths of those frogs are all greater than that of *H. pickersgilli* (Du Preez & Carruthers, 2009). Smith and Green (2005) recorded an average maximum dispersal distance of 2.92 km for 53 species of anuran.

A friction map for the movement of *H. pickersgilli* was developed from the KZN 2008 land-cover coverage, with five arbitrary ease-of-movement classes (1–4 and a barrier class). Class 1 represents habitats that present or are likely to present the lowest friction to movement by *H. pickersgilli*, class 2 represents habitats that are assumed to present somewhat greater friction to movement of the species (landcover classes adjacent to records of the species), class 3 represents habitats that are degraded class 2 habitats and therefore are not likely to be as amenable for *H. pickersgilli* as class 2 habitats, whereas class 4 represents the highest friction to movement but through which the species could conceivably occasionally move (Table 1). Barriers for anurans can include major roads with high traffic volumes, major rivers and other large water-bodies, bare sand, relatively high altitudes for lowland frogs, railway lines with high traffic volumes (e.g. Fahrig, Pedlar, Pope, Tatlor, & Wegner, 1995; Garcia-Gonzalez, Campo, Pola, & Garcia-Vazquez, 2012; Joly, Morand, & Cohas, 2003). The friction map was used to illustrate potential linkages between wetlands for maintaining sub-population dynamics such as dispersal between sub-populations.