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Accounting for detectability when surveying for rare or declining reptiles: Turning rocks to find the Grassland Earless Dragon in Australia

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ABSTRACT

Reptiles are in global decline with nearly 20% of species currently threatened with extinction. Despite these alarming trends, data documenting detailed changes in reptile populations remain sparse and the methods for detecting those changes are largely unevaluated. Rock turning is one commonly used method for detecting the presence or absence of reptiles. Here, we use data from four years of rock turning surveys for the endangered *Tympanocryptis pinguicolla* to estimate the probability of species occurrence while accounting for detectability. Our data set was zero-inflated with only 36 detections despite some 69,146 detection attempts (rocks turned) across 60 sites. Our analysis revealed the species probability of detection per detection attempt is extremely low (0.00098 (95% CI: 0.00064–0.00142)) and suggested that the species remained undetected at some sampling sites where it was present. Indeed, our estimate of actual site occupancy was nearly double the naïve estimate obtained when not accounting for detectability, suggesting the species is more widespread than previously thought. Our results highlight some important considerations for landscape conservation planning for *T. pinguicolla* and rupicoline (rock inhabiting) reptiles more generally. In particular, the application of rock turning as a sampling technique must be questioned given the low confidence of detecting a presence in the study reported here and the likely destructive nature of the approach. We recommend that the effectiveness of detection surveys by rock turning be fully evaluated for any species before it is applied widely as a detection technique and suggest that other approaches such as camera traps may prove equally or more effective while being less destructive.

1. Introduction

Evaluating the conservation status of rare or declining fauna is a major conservation challenge, especially given that resources are limited and the rate of species decline continues to grow. This problem has become particularly stark in reptiles where nearly 20% of species are threatened with extinction yet knowledge of diversity in this group remains disparate and in need of innovative approaches to the analysis of changes in status (Gibbon et al., 2000; Sinervo et al., 2010; Böhm et al., 2013). Presence–absence surveys across a species distribution can provide meaningful insights into population dynamics and factors correlating with persistence (MacKenzie and Nichols, 2004; Pollock, 2006) and have been applied to determine the population status of reptile species with survey approaches including spotlight surveys (Sarre et al., 1995), diurnal searching (Kéry, 2002; Sewell et al., 2012; Manning et al., 2013), pitfall trapping (Moseby and Read, 2001; Garden et al., 2007), funnel traps (Thompson and Thompson, 2007), camera trapping (McGrath et al., 2012; Welbourne, 2013), use of artificial refuges (Dorrough et al., 1996; Dimond et al., 2012; Michael et al., 2012) and rock turning (Porter, 1998; Wong et al., 2011). Using data collected in such surveys to estimate the occupancy of a species (i.e. the proportion of area, patches or sample units that it occupies) can help guide important conservation and management decisions (MacKenzie et al., 2006).

Presence–absence data for rare species are usually characterised by a high frequency of zero observations (MacKenzie et al., 2002).

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While some zeros reflect true species absences, data sets are often 'zero inflated' in the sense that they contain 'false zero' observations where a species is not detected at a site even if it is present (Martin et al., 2005). A failure to account for species detectability can induce bias in the estimation of species occupancy (MacKenzie et al., 2002, 2006; Guillera-Arroita et al., 2014), its relationship with the environment (Tyre et al., 2003; Gu and Swihart, 2004; Kéry, 2011; Lahoz-Monfort et al., 2014), the parameters characterising the processes underlying its dynamics (MacKenzie et al., 2003; Kéry et al., 2013) and affect the validity of inferences made about the presence or absence of a species from a given site (Reed, 1996; Kéry, 2002; Pellet and Schmidt, 2005; Garrard et al., 2008; Wintle et al., 2012; Lahoz-Monfort et al., 2014). Hence, the importance of understanding and accounting for imperfect detection extends to major decision-making bodies (MacKenzie et al., 2006). Failure to do so risks inadequate conservation measures (Wintle et al., 2004).

Accounting for detectability while estimating species occupancy is best achieved by using statistical models that explicitly describe the detection process (MacKenzie et al., 2006; Royle and Dorazio, 2008). When data are collected based on repeated presence–absence surveys (or more correctly, detection/non-detection), the binomial mixture model (MacKenzie et al., 2002; Tyre et al., 2003) is a robust method for estimating species occupancy and detectability, enabling the user to model how these two quantities vary as a function of relevant environmental variables. Occupancy and detectability modelling has established itself strongly in the scientific literature for a wide variety of taxa. Howeverwith few exceptions (e.g. Kéry, 2002; Roughton and Seddon, 2006; Durso et al., 2011; Sewell et al., 2012) it has had limited application to rare or declining reptiles. Such models have been used for determining species distribution and range (Kéry et al., 2013), informing monitoring programs (Pellet and Schmidt, 2005; Guillera-Arroita et al., 2010; Wibisono et al., 2011; Neilson et al., 2013), identifying priority habitat for species and assisting with reserve design (Cabeza et al., 2004) and guiding the design of surveys for rare species in environmental impact assessments (Garrard et al., 2008).

Despite having a poor record of species extinctions (Kingsford et al., 2009) and being on the brink of a new wave of species extinctions (Flannery, 2013), no mainland reptile has become extinct in Australia. Keeping this record at zero however appears challenging when there is a general paucity of information on many reptiles in Australia (Cogger et al., 1993), reports of global decline and concerns about their status (Gibbon et al., 2000; Böhm et al., 2013) and little evidence about which conservation approaches are effective in arresting or reversing species declines in Australia (Taylor et al., 2011). This challenge is particularly daunting when dealing with reptiles in temperate grazing environments where there are declines reported in several reptile species (Fischer et al., 2004; Brown et al., 2008; Dimond et al., 2012).

The Grassland Earless Dragon *Tympanocryptis pinguicolla* is one such species. This small agamid lizard, which inhabits temperate grazing lands in south eastern Australia, has contracted severely in geographic range and undergone a significant recent decline leading to its listing as an endangered species under the Australia's *Environment Protection and Biodiversity Conservation Act* 1999 (Dimond et al., 2012). Urban expansion and agricultural practices have reduced this species habitat to only 5% of its former range (Kirkpatrick et al., 1995). The species currently occurs in only two isolated regions on the Southern Tablelands of NSW separated by some 100 km. These two populations show genetic distinctiveness from each other (Melville et al., 2007) and are threatened by habitat loss and fragmentation (Dimond et al., 2012; Hoehn et al., 2013).

T. pinguicolla is difficult to detect so it is likely that the species remains undetected at sites where it is present even after significant survey effort. Indeed, this species was thought extinct until accidentally rediscovered (Osborne et al., 1993a). Here, we use occupancy modelling to estimate site occupancy and detection probabilities with two aims: to provide a framework within which to test hypotheses about the drivers of occupancy for *T. pinguicolla* and as a means to investigate the effectiveness and application of rock turning, a frequently used survey technique for detecting rare or declining reptiles.

2. Methods

2.1. Study area

This study was conducted in the Monaro region of New South Wales in south eastern Australia, across the known and potential distribution of the southern population of *T. pinguicolla* (Fig. 1). The study area is characterised by naturally treeless native grassland communities; predominately dry tussock grasslands comprising snow grasses (*Poa* spp.), wallaby grasses (*Austrodanthonia* spp.) and kangaroo grass (*Themeda triandra*) (Benson, 1994; Rehwinkel, 2009). The underlying geology is dominated by basalt with heavy clay soils but in some areas comprises mixed sedimentary geology and skeletal soils (Costin, 1954). Elevation ranges from 758 m asl in the north and south with areas as high as 1234 asl in between. The major river systems in the study area are the Murrumbidgee River in the north, the Maclaughlin River and Bombala rivers in the south and the Snowy River in the southwest. Annual average rainfall varies across the study area from 540 mm in Cooma in the north to 644 mm in the south at Bombala, with Nimmitabel in the southeast receiving the greatest average annual rainfall of 686 mm (BOM, 2013). Summers in the Monaro region are characterised by hot days, temperate nights, prolonged periods of relatively high temperatures and strong winds. Winters are characterised by sub zero overnight lows, frequent frosts, cold days and occasional snowfall (Costin, 1954; Dovers, 1994).

Continuous grazing by livestock is the dominant form of land management in the study area (Dovers, 1994; Garden et al., 2000; Dorrough et al., 2004) with the majority of the area being privately owned and grazed by stock with some minor cropping taking place on the alluvial flats (Benson, 1994). Past and present land use has resulted in much of the native grasslands either being largely replaced with introduced pastures or crops, or highly modified by a combination of livestock grazing, application of fertilisers and introduction of exotic legumes (Eddy, 2007). Much of the study area comprises large paddocks (i.e. >1000 ha), which vary in composition, condition and topography, and small paddocks such as Travelling Stock Reserves (i.e. 11–100 ha), which are relatively uniform and fenced.

2.2. Study species

T. pinguicolla is a sit-and-wait predator known to forage predominately on ants and other invertebrates. It basks on tussocks and occupies home ranges of between 925 m^2 and 4768 m^2 (Stevens et al., 2010). The species seeks overwintering refuge in crevices or burrows excavated by wolf spiders beneath surface rocks (Osborne et al., 1993b). Fidelity to these burrows is known to increase with the onset of winter (Stevens et al., 2010) and the species is reported to be torpid in winter (Brereton and Backhouse, 2003). The species is short lived, surviving for only one to two years (Dimond et al., 2012).