Biological Conservation 217 (2018) 207–212

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Applying the niche reduction hypothesis to modelling distributions: A case study of a critically endangered rodent

Peter J. McDonald[a,b,*], Alistair Stewart[b], Chris R. Dickman[a]

[a] Desert Ecology Research Group, School of Life and Environmental Sciences, University of Sydney, New South Wales 2006, Australia
[b] Flora and Fauna Division, Department of Environment and Natural Resources, Alice Springs, Northern Territory 0870, Australia

ABSTRACT

The 'niche reduction hypothesis' (NRH) is based on the idea that the realized niche of a declining species is reduced by threats that are mediated by environmental, biotic and evolutionary processes. The hypothesis was promoted to identify locations and interventions most likely to benefit declining species. We used a niche reduction approach to species distribution modelling by predicting the historic and current distributions of a critically endangered Australian rodent, the central rock-rat (CRR). Our habitat suitability maps confirm a dramatic range contraction for this species over the last 100 years. The current association of CRRs with extreme landscape ruggedness supports the hypothesis that the impact of a key threat to the species—cat predation—is mediated by habitat complexity. We detected no CRRs in five new locations predicted to be highly suitable in the current distribution model. This highlights the need for in-situ threat management at the three known sub-populations, one of which may already have been extirpated. Our map of the CRR's historic distribution identifies potential areas for translocation, including the site of a current translocation proposal into a predator-proof fence. We conclude that the NRH provides a useful framework for modelling the change in distributions of declining species in order to prioritise locations and interventions for management.

1. Introduction

Species distribution models (SDMs) relate species occurrences to environmental data in order to predict distributions (Elith and Leathwick, 2009). The use of SDMs has increased dramatically over the last decade, and they are now the primary means of predicting environmental suitability for species (Guisan et al., 2013). Proponents of SDMs claim they have broad utility to help solve a range of environmental problems (Guisan and Thuiller, 2005; Elith and Leathwick, 2009). However, much of the SDM research has been directed at refining and assessing modelling methods (e.g. Bean et al., 2012; Crase et al., 2012) or predicting future climate-driven shifts in distributions (e.g. Kearney et al., 2010; Franklin et al., 2013). Examples of SDMs applied to conservation management are rare in peer reviewed papers and are mostly restricted to the grey literature (Cayuela et al., 2009; Guisan et al., 2013).

Two key concepts in SDM theory are the 'fundamental niche' – defined as the area of potentially suitable habitat for a species, and the 'realized niche' – defined as the portion of the fundamental niche occupied by the species due to biotic interactions (Guisan and Thuiller, 2005). Although firmly entrenched in ecological theory following Hutchinson's seminal work (Hutchinson, 1957), Scheele et al. (2017) advanced these concepts into conservation biology by proposing the 'niche reduction hypothesis'; this is based on the idea that the current realized niche of a declining species is reduced from the historic realized niche by threats that are mediated by environmental, biotic, geographic and evolutionary processes. The authors argue that by focusing on how threats shape the current realized niche, management of declining species can be improved by identifying where to prioritise conservation actions (Scheele et al., 2017).

One declining species that will benefit from an improved understanding of changes in the realized niche is the critically endangered central rock-rat (*Zyzomys pedunculatus*; referred to hereafter as 'CRR'). Historically, CRRs occurred over a vast area of dryland Australia, but are currently known from only three small sub-populations in the rugged MacDonnell Ranges of the Northern Territory (McDonald et al., 2015a). Predation by feral cats (*Felis catus*; referred to hereafter as 'cats') is regarded as the main threat to the CRR, and rugged terrain is predicted to provide an environmental refuge by reducing the impact of feral cat predation (McDonald et al., 2015a; McDonald et al., 2017). The largest remaining sub-population of CRRs is currently being managed through in situ activities to reduce the threat from cats, and is also

* Corresponding author at: c/o Flora and Fauna Division, PO Box 1120, Alice Springs, NT 0871, Australia.
E-mail address: peterj.mcdonald@nt.gov.au (P.J. McDonald).

https://doi.org/10.1016/j.biocon.2017.10.002
Received 17 July 2017; Received in revised form 21 September 2017; Accepted 2 October 2017

the subject of a translocation proposal (Australian Wildlife Conservancy, 2017).

Here, we modelled the change in distribution of the CRR based on a framework of the niche reduction hypothesis. While it has been suggested that only mechanistic models – based on physiological or behavioural data – can predict the fundamental niche (Kearney and Porter, 2004), correlative SDMs may also predict the fundamental niche when the environmental data in the models correspond to the underlying processes constraining distribution (Dormann, 2007). Using measures of landscape-scale ruggedness and other environmental variables, we modelled the CRR's current distribution to identify potentially suitable areas and we surveyed five locations predicted to be highly suitable. We also modelled the CRR's historic distribution to identify suitable sites for translocation and we compared the two models to gain insights into the processes driving the dramatic range contraction in this species.

2. Methods

2.1. Focal species and study area

The CRR is a rock-dwelling, granivorous rodent endemic to the Northern Territory, Australia, listed as critically endangered by the IUCN (Woinarski and Burbidge, 2016). Once widespread in rocky ranges and mountainous areas across the Northern Territory's drylands, the species is known currently from three sub-populations in the rugged MacDonnell Ranges (Fig. 1). There are also sub-fossil records from Western Australia's drylands, although it is unknown whether the CRR was extant there at the time of European colonisation (Baynes and McDowell, 2010). Predation by feral cats (*Felis catus*) is regarded as the main driver of range decline, and experimental feral cat control is currently being trialled at the largest known sub-population. There are also plans to translocate CRRs into a predator-proof fence on Newhaven Reserve, in the southern Tanami Desert, Northern Territory, where there are areas of potentially suitable rocky habitat. Our study area of ~365,000 km^2 covers the historic known distribution of the CRR in the drylands of the Northern Territory (Fig. 1).

2.2. Distribution modelling

We used the software package MaxEnt to estimate the historic and current distribution of the CRR. MaxEnt is a presence-only model that minimises the relative entropy of estimated probability densities between species presences and the background landscape (Elith et al., 2011). MaxEnt frequently outperforms other modelling techniques and is typically robust to small samples sizes (Hernandez et al., 2006; Wisz et al., 2008).

For the historic distribution, we compiled the 32 CRR records spanning the period from first collection in 1894 to its recent temporary disappearance in 2002 (Nano, 2008). The species has not been detected at any of these locations since 2002, despite considerable search effort (McDonald et al., 2013). For the current distribution we compiled the 36 records made from 2010 to 2016. We selected six environmental raster layers predicted to influence CRR distribution and represent the environmental variables restricting the fundamental niche. These included two ruggedness layers based on the prediction that ruggedness and habitat complexity mediates predation by feral cats and red foxes: ruggedness_coarse, the standard deviation of mean elevation within a 1 km radius of

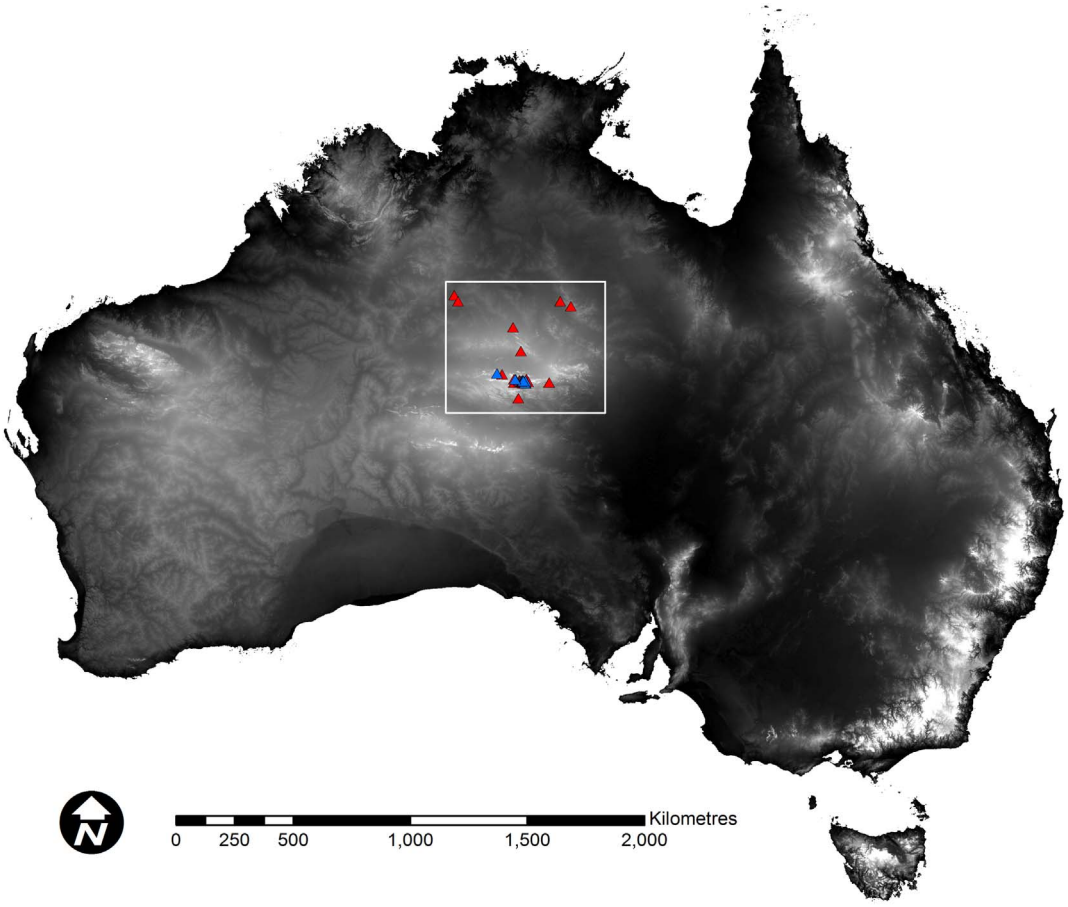

Fig. 1. Location of the study area in dryland Australia. Red triangles are historic (1884–2002) records and blue triangles are current (2010–2016) records for the central rock-rat. Background 9-second digital elevation model courtesy of Geoscience Australia. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)