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Will future climate change threaten a range restricted endemic species, the quokka (*Setonix brachyurus*), in south west Australia?

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ABSTRACT

Range-restricted species, such as regional endemics, possess traits that may make them particularly vulnerable to environmental change. The quokka, *Setonix brachyurus*, is a small macropod, endemic to south-western Australia and two adjacent islands. Climatic factors appear to play a role in defining the distribution of this species. Mainland populations are historically restricted to areas with an annual average rainfall in excess of 700 mm and their current distribution is almost completely confined within the 1000 mm rainfall isohyet. As such, the predicted increasing aridity of south-western Australia due to climate change is likely to threaten the continued persistence of the quokka on the mainland. To examine this possibility, we modelled the distribution of the quokka with Maxent using records of occurrence and a combination of historical climate (1961–1990) and habitat variables. Future projections of this distribution were then examined assuming two simple dispersal scenarios (zero and full migration) and three climate-change scenarios of increasing severity for 2030, 2050 and 2070. The predictive performance of the distribution model generated under historical climate conditions was high (AUC > 0.8), with annual precipitation contributing the most information to the model. Except for the low-severity climate-change scenario under the full dispersal assumption, the future projected distribution of quokka was shown to contract over time. The extent of range contraction tended to increase with the severity of the climate-change scenario, with the species predicted to lose almost all range by the year 2070 under the most extreme climate-change scenario. The results indicate the importance of identifying potential refuges for the quokka (i.e. areas where the species is predicted to persist) and defining management strategies to protect these areas from threatening processes.

1. Introduction

Understanding how species are likely to respond to climate change is imperative if we are to identify appropriate management strategies for assisting species to adapt. Climate change can effect a species' population and range dynamics in three primary ways: (1) a species can move in response to changing climate conditions, tracking appropriate conditions spatially (range shifts, expansions or contractions); or (2) a species can adapt *in situ*, either physiologically, behaviorally or genetically; or (3) failing either of these, as the living conditions are no longer suitable, the species goes extinct (Holt, 1990; Martínez-Meyer et al., 2004; Peterson et al., 2005). Evidence of contractions or shifts in geographic ranges due to recent climate change have been well-documented (e.g. Hickling et al., 2006; Thomas et al., 2006; Moritz et al., 2008; Rosenzweig et al., 2008; Thomas, 2010). Models of future distributions under projected climate-change scenarios, predict dramatic changes for many species (e.g. Williams et al., 2003; Thomas et al., 2004; Beaumont et al., 2005).

The ability of a species to withstand and/or recover from an environmental change (i.e. its resilience) depends on a number of key life history traits (Isaac et al., 2009). Traits that render a species particularly vulnerable to environmental perturbations include a narrow geographic range, limited dispersal capacity, low reproductive output and a high degree of habitat specialization (Isaac et al., 2009). Range-restricted species, such as regional endemics, tend to display most of these traits, and therefore their sensitivity to environmental change is likely to be pronounced (Thuiller et al., 2005). Moreover, contractions in range size of species with already restricted distributions are expected to result in small, highly fragmented and isolated populations that are susceptible to losses in genetic diversity, thereby reducing their capacity to adapt to environmental change (Isaac, 2009; Williams et al., 2008).

As a first step in assessing a species' vulnerability to climate change, predictions of change in geographic distribution in response to alternative scenarios of future climate can be informative in terms of the range of likely consequences (Araújo et al., 2005;

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Heikkinen et al., 2006; Lawler et al., 2006; Yates et al., 2010a). Species distribution models that statistically relate species geographic records to historical climate variables, when projected on changed climate scenarios can provide such predictions, and are now widely used (reviewed in Elith and Leathwick, 2009).

Here, we use this approach to examine the potential impact of climate change on the geographical distribution of the quokka (*Setonix brachyurus*), a small macropodid marsupial that is endemic to the south-west of Western Australia (SWWA), including two offshore islands (Rottnest and Bald Island) (Fig. 1). This region has a Mediterranean type climate and supports a large number of endemic species (Hopper et al., 1996; Hopper and Gioia, 2004). Mean annual temperatures in the SWWA have increased during the twentieth century and since the 1970's there has been a significant decline in autumn and early winter rainfall. The consensus among Global Climate Models (GCMs) is that temperature will continue to increase and rainfall will continue to decline in this region (CSIRO, 2007; Bates et al., 2008). Being at the cool, wet end of a hot dry continent, species occurring in SWWA may be particularly sensitive to climate change, especially because movements to the south and west are restricted by the coastline, and with the exception of the Stirling Range which is just 1109 m above sea level, the region is flat and there is little scope for contraction into cool montane refuges (Fitzpatrick et al., 2008; Yates et al., 2010a,b).

Climate, particularly rainfall, appears to play a role in defining the geographic range of the quokka. Historically, mainland quokka populations were restricted to areas with an annual average rainfall of >700 mm (de Tores et al., 2007). Since the 1930s, the species has declined in its distribution and abundance, and is now almost completely confined to areas receiving >1000 mm annual rainfall. Predation by the introduced European red fox (*Vulpes vulpes*) and loss of preferred habitat are likely to be the primary causes of this decline, but the role recent climate change has played is unknown (de Tores et al., 2007). The quokka is currently listed as vulnerable in accordance with IUCN Red List Criteria (http://www.iucnredlist.org/).

In the current study, we examine predicted changes in geographic range size of the quokka on the mainland in response to a range of future climate scenarios at 2030, 2050 and 2070. Future projections are made under the extreme assumptions of no dispersal and full dispersal (i.e. colonise all locations that are predicted to become suitable), and taking current land transformation into account.

2. Method

2.1. Distribution data

The study area was based on the inferred distribution of the quokka at pre-European settlement in 1829 (i.e. inferred from current and historically known location records, as well as subfossil records – from de Tores et al., 2007) ("study area" in Fig. 1). We ob-

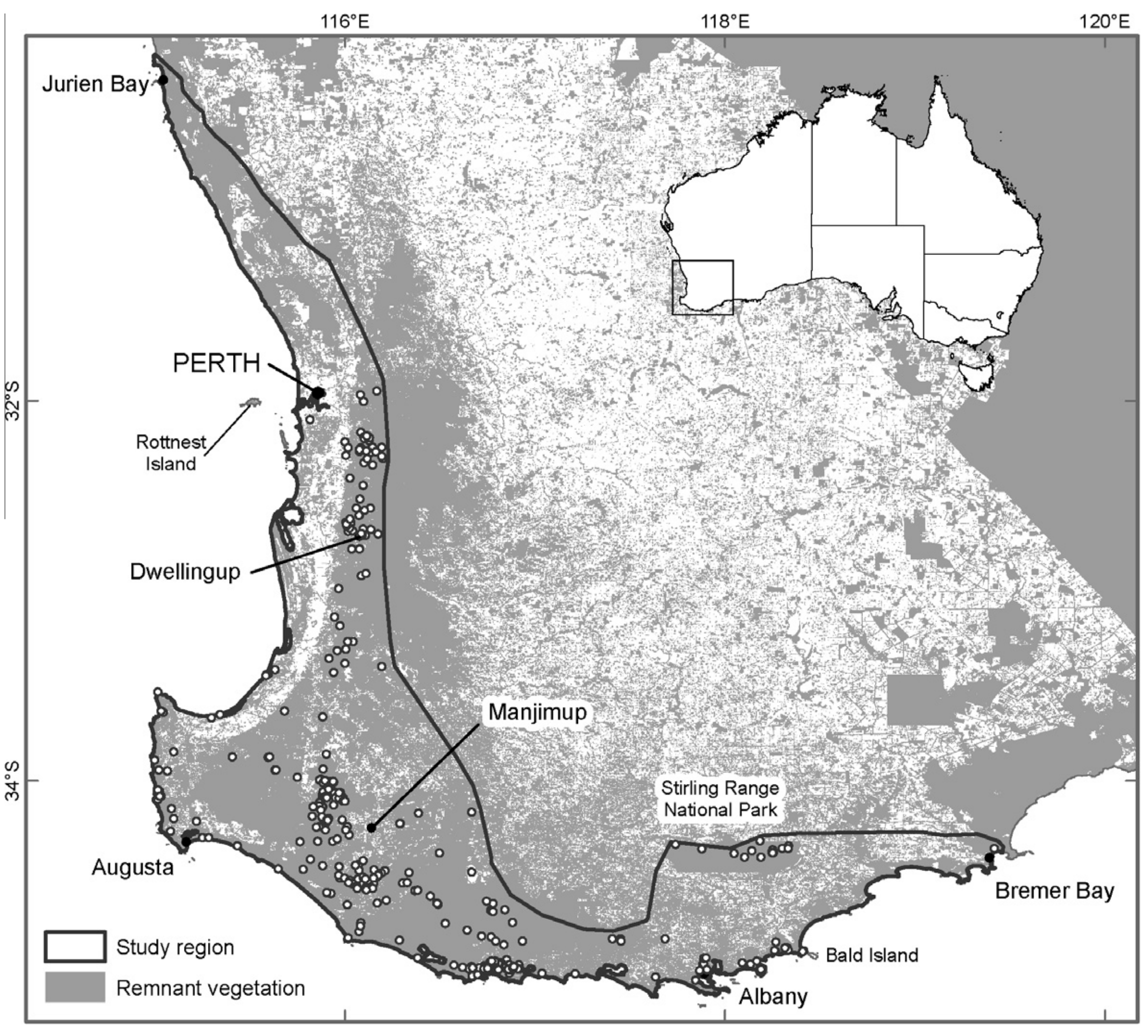

Fig. 1. Location of study region in south west Western Australia, showing the extent of remnant vegetation, the distribution of quokka occurrence records (represented as circles) and inferred distribution pre-European settlement (within the bold line).