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Will tropical mountaintop plant species survive climate change? Identifying key knowledge gaps using species distribution modelling in Australia

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ABSTRACT

Species inhabiting tropical mountaintops may be most at risk from the detrimental effects of climate change. Yet few regional assessments have critically assessed the degree of threat to species in these habitats. Here we model under three climate scenarios the current and future suitable climate niche of 19 plant species endemic to tropical mountaintops in northeast Queensland, Australia. The suitable climate niche for each of the 19 species is predicted to decline by a minimum of 17% and maximum of 100% by 2040 (mean for all species of 81%) and minimum of 46% (mean for all species of 95%) by 2080. Seven species are predicted to have some suitable climate niche space reductions (ranging from 1 to 54% of their current suitable area) by 2080 under all three climate scenarios. Three additional species are projected to retain between 0.1 and 9% of their current distribution under one or two of the climate scenarios. In addition to these declines, which are predicted to occur over the next 30 years in northeast Queensland, we discuss and outline pressing research priorities that may be relevant for the conservation of biodiversity on tropical mountaintop environments across the globe. Specifically, further research is needed on thermal tolerances, acclimation potentials, and physiological constraints of tropical mountaintop taxa as current species distributions are primarily determined by climatic factors.

1. Introduction

Large-scale changes in the distributions of species and complete turnover of future ecosystems across the world have been predicted as responses to climate change (Parmesan and Yohe, 2003; Williams et al., 2007). In particular, the montane tropics, although little studied in comparison to documented cases in the temperate zone (Thomas, 2010), are considered highly threatened by even marginal increases in temperature due to steep environmental gradients (Corlett, 2011), narrow thermal tolerances of tropical species (Cunningham and Read, 2003b; Laurance et al., 2011), and by the secondary effects of rising ocean surface temperatures that are expected to increase the average altitude of cloud base formation (Foster, 2001; Still et al., 1999). Evidence for direct impacts of recent climate change on tropical mountaintops includes widespread amphibian extinctions and altering of community structure in Costa Rica (Pounds et al., 1999, 2006), and upslope displacement and range shifts of montane species in Madagascar (Raxworthy et al., 2008), Borneo (Chen et al., 2009) and Costa Rica (Pounds et al., 1999). A recent study examined data on the browning and greening of vegetation in response to recent climate changes in tropical montane zones in five continental regions and found that the rates of vegetation change were dependent on elevation with warming rates more pronounced at higher elevations (Krishnaswamy et al., 2014).

Here we investigate the impacts of climate change on a tropical montane flora in northeastern Australia's Wet Tropics bioregion (Fig. 1). A rise in the cloud base has already been projected to affect the availability of high and consistent moisture in Queensland's coastal mountain habitats (McJannet et al., 2007). In particular, the mountaintop regions of northeast Queensland were identified as "disappearing environments" in a global assessment of projected impacts of climate change on specific vegetation types (Williams et al., 2007). A subsequent study extended this assessment using species composition dissimilarity data and found similar results (Williams et al., 2012). The analysis suggested that the current tropical montane environment which harbors a unique assemblage of plants and animals will simply disappear and is unlikely to occur or be replicated anywhere else in

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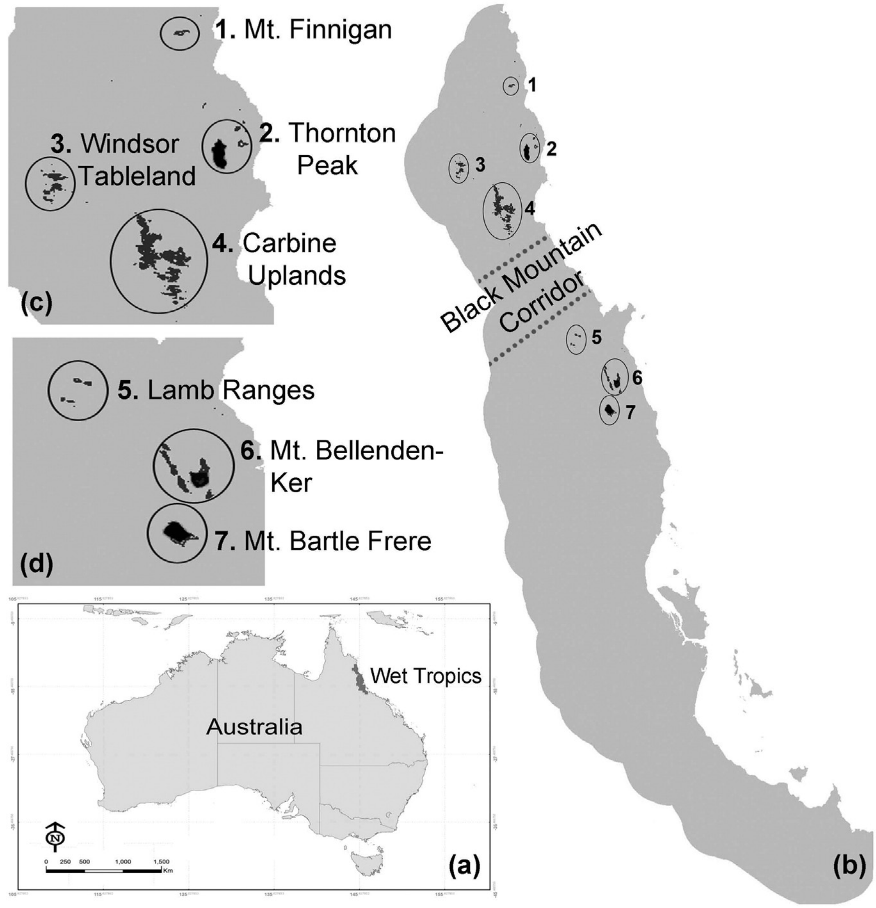

Fig. 1. The Wet Tropics bioregion of northeast Queensland, Australia (a); region overview (b); and centres of species diversity for the mountaintop endemic flora zoomed in for regions north (c) and south (d) of the Black Mountain Corridor.

Australia by 2070. Prior to this alarming prediction, Williams et al. (2003) investigated how climate change projections will affect the bioregion's vertebrate species and reported that increasing temperature is predicted to result in a significant reduction or complete loss of the core habitat of all regionally endemic vertebrates, the majority of which are restricted to upland habitats.

The Wet Tropics bioregion of northeastern Queensland in Australia is a World Heritage Area and is renowned for its antiquity and relictual Gondwanan taxa. It is home to 65 regionally endemic vertebrates, 674 endemic vascular plants, including 62 monotypic genera and one monotypic family (Metcalfe and Ford, 2008), and includes rain forest areas that are believed to have served as dynamic refugia for over 40 million years. A total of 5% of this bioregion occurs above 1000 m elevation and 96% of this area occurs within well functioning protected areas. An investigation of this bioregion provides an ideal opportunity for a first approximation of climate change threats to a well-protected environment of high conservation value.

Historical climate change has been a primary force shaping biodiversity patterns of this region. Pleistocene contractions of rainforest during glacial periods and subsequent expansions during global warming events left their mark on the extant vertebrate species assemblages (Williams and Pearson, 1997; Winter, 1997). The same process facilitated the migration of Asian plant lineages into tropical Australia (Crayn et al., 2015) creating novel Asian–Gondwanan mixed species assemblages in rain forest re-expansion areas (Costion et al., 2015). Historical climate changes have been a primary driver of extinctions and speciation in the region (Schneider et al., 1998; Williams and Pearson, 1997), and tropical mountaintop environments are widely accepted as highly vulnerable to climate change (Brooks et al., 2006; La Sorte and Jetz, 2010), possibly more so than temperate mountain environments (Sheldon et al., 2011). For these reasons we tested the prediction that climate change will have direct and significant impacts on the distribution of the endemic montane flora of northeast Queensland. Using environmental niche modelling methods we assessed the change in the geographical extent of the climate niche of 19 endemic plant species under three climate scenarios (a1b, a2, b1) over three time periods (2040, 2060, and 2080).

2. Methods

We used herbarium specimen records to identify plant species that are endemic to the Wet Tropics Bioregion and restricted to areas above 1000 m in elevation. Our use of the term “mountaintops” includes some local geographical areas that are more correctly defined as elevated plateaus or tablelands ≥1000 m. Initially, records from the Australian Tropical Herbarium (CNS) were searched to identify species for which all records occurred at ≥1000 m within the Wet Tropics bioregion (Metcalfe and Ford, 2008). These records were then refined to current taxonomy using the Australian Plant Name Index (APNI: http://www.cpbr.gov.au/apni/index.html accessed August 2013). A final search was performed using Australia's Virtual Herbarium (AVH: http://avh.ala.org.au accessed August 2013) to obtain all digitised collection records in Australian herbaria for each taxon. Many of the records were collected prior to GPS technology; however, in most cases these collections were made with precise elevation data. All GPS location records for each specimen were manually checked for accuracy using available data on each corresponding herbarium label and validated or corrected using Google Earth where necessary for maximum accuracy of locality data. This process necessitated further filtering of taxa from the final list