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Short communication

In the wake of bulldozers: Identifying threatened species in a habitat decimated by rapid clearance

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ABSTRACT

Where habitat loss is rapid, formerly common species may be at risk of extinction. We provide a method for using habitat mapping data and herbarium records to identify plant species that are threatened by the rapid conversion of brigalow forest, a widespread habitat type in eastern Australia that has been decimated over the last 60 years. The method weights species depending on the strength of their association with the brigalow forest habitat and their association with the Brigalow Belt region where the clearance of native vegetation has been extensive. The process identifies 56 out of a total of 1229 plant species that are at greatest potential risk. Twenty of the 56 species also occur in habitats that have not been extensively cleared. Of the remaining 36 species, 11 are closely associated with brigalow forest, which in general has been more extensively cleared than other habitats. The method revealed several species potentially imperilled by habitat loss that have not previously been identified by formal listing of threatened species. The rate of habitat loss for the target species can be clearly documented, although further survey is required to determine the potential persistence of species in habitat that has been modified by clearing and an estimate of generation length of the plant species is required in order to assess this decline against IUCN threat categories. The method has broad application in situations where there are records of species and documentation of habitat loss.

1. Introduction

Habitat loss is a fundamental threat to biodiversity and is driving many species towards extinction (Sala et al., 2000; Millennium Ecosystem Assessment, 2005; Maxwell et al., 2016). When habitat loss is rapid the threat of extinction may be underestimated due to the phenomenon of 'extinction debt', which takes into account future species extinctions as a result of past habitat loss (Kuussaari et al., 2009). Populations of species may persist but fall below a minimum viable population size and/or be restricted to tiny remnants which are inherently vulnerable to destruction and degradation. Populations restricted to small scattered remnants may also suffer the breakdown of key ecological processes, particularly those driving recruitment. The period over which extinction debt will be realised may span many generations, depending on the life histories of species involved and the outcome of stochastic processes (Vellend et al., 2006; Rogers et al., 2009; Kolf and Naaf, 2015).

The cost of the extinction debt for the preservation of biodiversity is recognised within the IUCN Red List of Threatened Species (IUCN, 2015) where estimates of the decline in population size are emphasised. The rates of decline for a species relate to its range of habitats and how rapidly those habitats have declined. A generalist species that occurs in a habitat that has been rapidly cleared but also in less cleared habitats will have a lower extinction risk than a species that is specialised to heavily cleared habitats.

Herbarium data provide a relatively accurate record of the distribution of plant species and have been used for assessing threat status (Lughadha et al., 2005; Brummitt et al., 2015). In Australia these data date back to the first days of European exploration and settlement in the 18th century, and have been compiled in Australia's Virtual Herbarium (CHAH, 2016). Australia has vast areas that have undergone rapid and relatively recent habitat destruction, including the heathlands and shrublands of south-western Australia (Hopper and Gioia, 2004), southern Australian temperate grasslands (Kirkpatrick et al., 1995) and the brigalow (*Acacia harpophylla*) forests of eastern Australia (Fensham et al., 2017).

The current study develops a method to use the database of Australia's Virtual Herbarium and habitat mapping to prioritise the threat status of the brigalow flora. A simple algorithm is presented to identify potentially threatened plant species by combining their

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association with the brigalow forest habitat and the overlap of their geographic range with the heavily cleared region that contains the brigalow forest. Further evaluation is based on the association of species with habitat clearance including non-brigalow habitats.

1.1. The brigalow forest and its decimation

Brigalow forest is dominated by *Acacia harpophylla* with > 50% canopy cover and stem densities typically > 500 per ha (Fensham et al., 2017). While brigalow itself is the defining tree, other species can be prominent including *Casuarina cristata*, *Eucalyptus cambageana*, *E. populnea* and *Terminalia oblongata*. Brigalow forest generally occurs on clay-rich soils formed on fine-grained sedimentary rocks or on extensive ancient alluvial plains. Large areas of brigalow forest have gilgai topography characterised by small-scale (< 0.1 ha) hummocks and hollows forming ephemeral wetlands. The relatively dense canopy of the forest prohibits a dense grass sward despite the relatively fertile soils. Once cleared the soils generally support pastures dominated by exotic grasses with buffel grass (*Cenchrus ciliaris*) being the most widespread and Rhodes grass (*Chloris gayana*) and guinea grass (*Megathyrsus maximus*) prominent in higher rainfall areas. The exotic pastures result in dramatic diminishment of species richness (Collard et al., 2011), with perennial herbs and grasses particularly susceptible to decline (Fairfax and Fensham, 2000; Fensham et al., 2015).

Brigalow forest typically occurs within a mosaic of other vegetation types. Poplar box (*Eucalyptus populnea*) woodland occurs on moderate fertility soils, dry rainforest with a diverse tree layer or open grassland on higher fertility soils and alluvial woodlands (*E. coolabah* and *E. camaldulensis*) woodlands and wetlands are associated with watercourses subject to flooding. Other vegetation types occupy low fertility sandy and rocky soils, including eucalypt woodlands (typically dominated by *E. crebra* and *E. melanophloia*) and eucalypt forest (typically dominated by *Eucalyptus citriodora*). Lancewood forest (*Acacia shirleyi* and *A. catenulata*) occur on rocky slopes and tablelands with shallow soils and have similar structure to the brigalow forest.

The brigalow forest is mostly contained within two biogeographic regions, the Brigalow Belt North (BBN) extending over 136,745 km^2 and the Brigalow Belt South (BBS) extending over 272,197 km^2 in eastern Australia (Fig. 1; Thackway and Cresswell, 1995). The former is exclusively in the state of Queensland and the latter extends into New South Wales (56,230 km^2) where specific mapping of this vegetation is unavailable. In the BBN the original area of the brigalow forest was 48,412 km^2 and in the Queensland section of the BBS 56291 km^2. For the remainder of this paper the two biogeographic regions will be referred to in combination as the Brigalow Belt.

The Brigalow Belt was settled by Europeans between 1840 and 1860 mostly for sheep and cattle production, although sheep have waned and cattle have endured. For nearly a century the savanna woodlands around the brigalow forest provided the pasture, while the dense brigalow forest remained uncleared, except in the south and east where higher-value production systems from dairy and cropping with good access to transport made labour-intensive clearing techniques feasible (Seabrook et al., 2006). It was not until the widespread availability of bulldozers from the 1950s that the clearing of the brigalow commenced in earnest. Subsidised by a government funded development program, the brigalow forest was torn out of the ground by bulldozers joined by giant chains, and during the 1960s–1970s the clearing rate was about 2% of the original area per annum. By the time legislative controls were implemented around 2005 only about 9% of the brigalow forest remained, much of which is on public land such as road corridors, state forests and conservation reserves (Seabrook et al., 2006; Fensham et al., 2017).

2. Methods

Australia's Virtual Herbarium (AVH) includes specimen records of native vascular plants from all major Australian herbaria (CHAH, 2016). Prior to this analysis records identified as 'cultivated' or 'planted' were removed from the AVH dataset. In order to identify the flora of the brigalow forest, native vascular plant species were selected where either the term 'brigalow' or 'harpophylla' occurred in the habitat notes of at least one collection. It is fortuitous that both these terms pertain only to *Acacia harpophylla*, but specimens without adequate habitat notes, including the vast majority of nineteenth century collections will not be included.

Regional ecosystem mapping for the state of Queensland (Queensland Herbarium, 2016) includes a pre-clearing coverage and a 2015 remnant coverage of the brigalow forest (selected using broad vegetation group 25; a unit in the Queensland Herbarium mapping database; Neldner et al., 2015). This allows for a spatial analysis to represent the original extent of the brigalow forest, the proportion remaining as remnant brigalow forest, and the extent of brigalow forest in conservation reserves.

The geographic range of each of the 'brigalow forest' species, excluding cultivated records, was circumscribed by a convex hull polygon intersected with the land surface of mainland Australia and Tasmania. For species with more than two records no buffer was applied but for those with only one or two records a 10 km buffer was applied. The

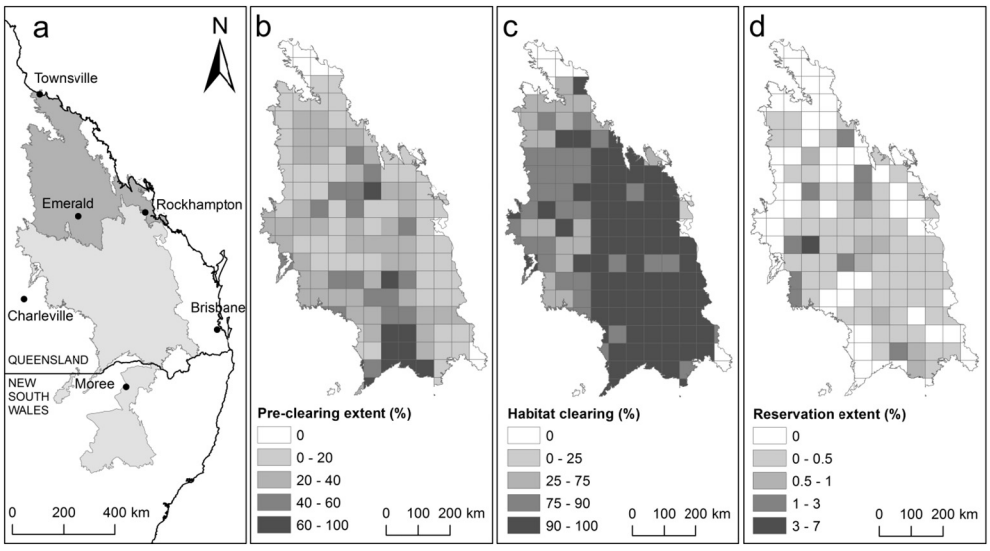

Fig. 1. a) The Brigalow Belt defined as the combined areas of the Brigalow Belt North (dark grey) and Brigalow Belt South (light grey) biogeographic regions. The state border is indicated. b) The percentage of brigalow forest in each 0.5 degree cell throughout the Brigalow Belt region in Queensland. The percentage is determined from the area of the cell in the region. c) The percentage of brigalow forest cleared by 2013 for each 0.5 degree cell, d) The percentage of the 2013 area of remnant brigalow forest that is within conservation reserve (including State Forest) for each 0.5 degree cell.