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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 most 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.

Keywords: extinction, habitat loss, brigalow forest, habitat clearance

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 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.

1.2 The brigalow forest and its decimation

Brigalow forest is dominated by *Acacia harpophylla* with greater than 50% canopy cover and stem densities typically greater than 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)* 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 56 291 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 on the list.

Regional ecosystem mapping for the state of Queensland (Queensland Herbarium, 2016) includes a pre-clearing coverage and a 2013 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 percentage of records from brigalow forest (based on the terms 'brigalow' or 'harpophylla' in the habitat notes) relative to records with any habitat information (Appendix 1) was determined as factor *A*, and the percentage of the geographic range within the Brigalow Belt was determined as factor *B*. Potential threat from the clearance of brigalow was quantified by a Threat Exposure Index ($A \times B/100$). An arbitrary Threat Exposure Index greater than ten was used to identify a list of species for presentation that are potentially the most threatened by the clearance of the brigalow forest.

The geographic range of the candidate species was intersected with the pre-clearing and remnant extent of brigalow forest and other vegetation types (Appendix 2). Dry rainforest (Fensham, 1996), grassland (Fensham, 1999), poplar box (*Eucalyptus populnea*) woodland (Fensham et al., 2017) and Alluvial woodland (Keith et al., 2009) have been extensively cleared and other eucalypt woodlands, eucalypt forests and open wetlands associated with streams are still relatively intact. The candidate species with more than half the specimen records from habitat types that have been extensively cleared were identified.

To address the possibility that there is a survey bias in relation to brigalow habitat an analysis was conducted (Appendix 3). This analysis demonstrated that brigalow forest originally represented 24.9% of the Brigalow Belt region in Queensland but had diminished to 5.6% of remnant vegetation in 2013. The percentage of specimen records from brigalow forest is between these values at 6.6%. The brigalow flora is only 9.7% of the total number of native plant species in the region. These statistics suggest that the collection effort in brigalow forest is not substantially biased relative to other habitats.

3. Results

Sandstone ranges through the middle of Brigalow Belt do not support extensive brigalow forest and other vegetation communities become more prevalent along the coastal and inland margins of the region (Fig. 1b). The clearing has been extensive throughout the region but is highest in eastern and southern areas (Fig. 1c). There are only very small areas of the brigalow forest that are protected within conservation reserves on public land (Fig. 1d).

The flora of the brigalow forest consists of 1229 native plant species, although most of these have a small proportion of their records associated with brigalow forest (Appendix 4). These species are represented by a total of 564,766 records within the Australian continent. Of these records 70.0% have habitat information that is used to determine factor *A*. Of the 1229 species, 56 have a Threat

Exposure Index greater than ten. Twenty of the 56 also occur in habitats that have not been extensively cleared (Table 1; Figure 2). Of the remaining 36, 25 do not occur exclusively in brigalow forest and these species have generally lost less habitat than the species closely associated with the brigalow forest (Figure 2). Of the eleven species with a close association with brigalow forest *Aneilema sclerocarpum*, *Eucalyptus argophloia*, *Melaleuca squamophloia*, *Solanum dissectum* and *S. johnsonianum* are probably the most imperilled because they all have relatively small geographic ranges and have less than or equal to 5% of brigalow forest remaining within those areas (Appendix 4; Figure 2).

Fourteen of the 56 species identified by the current process are listed under Queensland State legislation (*Nature Conservation Act 1992*, Queensland) (Appendix 4). Of these species the habitat of the only known recent population of *Corchorus thozetii* has been cleared in recent decades and the species may be extinct. Of the currently unlisted species, *Denhamia* sp. (Mt Coolon D. Corr PA409), *D.* sp. (Junee Tableland T.J.McDonald 553), *Lagenophora fimbriata* and *Melaleuca squamophloia* have less than 20% of their habitat remaining (Figure 2).

4. Discussion

This study presents a systematic approach to identifying plant species that may be threatened by habitat clearance using herbarium records and vegetation mapping. The brigalow forest of north-eastern Australia has been decimated by habitat clearance in 60 years and the populations of most associated plant species drastically reduced. Some of the plant species identified are already recognised as being of conservation concern and are listed under government legislation (Appendix 4). Current understanding of most species in Table 1 is inadequate to accurately determine conservation status. There is published information on the status of *Xerothamnella herbacea* (Shapcott et al., 2017), but this study lacks an accurate population assessment based on systematic assessment of population density (Keith, 2000) and conservative extrapolations to available habitat (see Silcock et al., 2014). Population assessments founded on the assumption that species density in surveyed habitat is indicative of unsurveyed habitat will often generate population estimates orders of magnitude higher than those derived from actual surveyed plants. Such systematic surveys have not been conducted for any of the 56 species identified in the current study and are required to further refine the prioritisation of plant species threatened by the clearance of brigalow forest.

Some native species persist in pasture after clearing. However perennial species are particularly prone to decline after the clearing of brigalow forest (Fairfax and Fensham, 2000), and there is only one ephemeral species, *Solanum adenophorum*, amongst the 26 potentially threatened species. The tree species (Table 1) and particularly the epiphytic parasite *Viscum bancroftii* will generally decline with habitat clearance. An exception is brigalow (*Acacia harpophylla*) itself which generally proliferates by root suckering after clearing. For short-lived plants, it cannot be assumed that clearing necessarily results in the loss of habitat for non-woody species and habitats modified by tree removal and exotic pasture establishment will need to be included in future plant survey. Even the possibly extinct *Corchorus thozetii* may persist in the cleared landscape as other species in this genus often respond to disturbance.

Most brigalow forest can be converted to highly productive pasture but there are restricted habitats including *Acacia harpophylla* as a tree but occupy relatively unproductive soils. *Denhamia* sp. (Junee Tableland T.J. McDonald 553) and *Olearia cuneifolia* occur where *Eucalyptus thozetiana* occurs with brigalow on acidic soils that are relatively unproductive and are often reprieved from clearing. *Macropteranthes leichhardtii* can be abundant in rocky habitats that are not subject to clearance. Despite undergoing substantial habitat declines, some of the candidate plant species identified here occur at high density within remaining habitat (authors pers. obs.). *Alectryon diversifolius*, *Eleocharis blakeana*, *Enteropogon paucispiceus* and *Sclerolaena tetracuspis* are examples. Information on habitat and population densities can be guided by the advice of botanical experts and ensure that field surveys target genuine data deficiencies and the plant species most likely threatened by extinction.

There are some remnants of brigalow forest in conservation reserves (Fig. 1b) and there is current legislation in place that protects remnant forests. However, the effectiveness of the current laws are subject to the vacillations of government (Maron et al., 2015) and remnant brigalow forest continues to be cleared (Reside et al., 2017; Rhodes et al., 2017). There are few prospects for the recovery of brigalow forest. Cleared brigalow trees do recover as regrowth but is typically re-cleared in order to maintain pasture production and ease of stock management. Blade-ploughing is an alternative to re-clearing and is a widespread practice that eradicates tree regrowth, favouring exotic perennial grasses probably at the expense of native species in cleared pasture. The recovery of brigalow forest through incentives directed towards carbon sequestration has been proposed (Dwyer et al., 2009; Fensham and Guymer, 2009), but is not eligible under compliant trading schemes because of arguments relating to definitions under the protocols inherited from the Kyoto accord (Van Oosterzee et al., 2010).

Remnant brigalow forest faces ongoing threats within a matrix of mostly cleared land. The vigorous exotic buffel grass and other similar high biomass grasses invade remnant brigalow forest, especially in regions that have been heavily cleared (Butler et al., 2014). In high rainfall seasons these grasses provide sufficient fuel for fires, which penetrate the forest and open up the canopy, thereby allowing for even more vigorous growth of buffel grass. This negative feed-back results in ongoing diminution of brigalow forest even in conservation reserves (Butler and Fairfax, 2003). Narrow roadside strips that provide important remnants in heavily cleared areas are especially vulnerable to this grass fire cycle. Thus broadscale clearing is not the only threatening process for the brigalow forest and populations of threatened species will continue to decline as the quality of remnant habitat degrades in the future.

Criteria A within the IUCN categories is: 'An observed, estimated, inferred or suspected population size reduction of (*Critically endangered: ≥80%, Endangered: ≥70%, Vulnerable: ≥50%*) over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of the following *which includes* a decline in area of occupancy, extent of occurrence and/or quality of habitat'. This criteria is satisfied for plant species specialised to the brigalow forest providing their generation time is greater than 20 years (given that the clearing of the brigalow occurred over about 60 years) depending on the extent to which species survive in cleared areas. An understanding of the lifespan of perennial plant species is the major limitation for assessing the candidate species (Table 1) according to IUCN criteria A.

Despite the vast former extent of brigalow and the scale of its destruction there are only 36 plant species identified as potentially highly threatened by the clearance of the brigalow forest, and no confirmed extinctions with the possible exception of *Corchorus thozetii*. This is because few species are endemic to this vegetation type, and only a small proportion of these have narrow geographic ranges. The tree *Denhamia* sp. (Mt Coolon D.Corr PA409) is an exception and raises the possibility of unrecorded extinctions with the clearance of the brigalow forest. Other heavily-cleared ecosystems such as the Western Australian Wheatbelt with high levels of narrow-range endemism have a much higher risk of extinction (Hopper and Gioia, 2004). Many of the brigalow species identified as potentially threatened also occur in other vegetation types (Table 1) and the extent of clearing in these habitats is a critical determinant of threat status of individual species (Figure 2). In the Brigalow Belt, poplar box woodland, dry rainforest and alluvial woodland have all been extensively cleared, although dry rainforest occurs on both rocky and non-rocky landscapes and the former habitats are not likely to be cleared (Fensham, 1996). It is possible that some species have relatively small areas of occupancy within their geographic ranges because of microhabitat preferences but this requires further ecological survey.

We present and discuss the plant species with a Threat Exposure Index greater than ten. This is an arbitrary threshold and there will be plant species with lower values that may also be threatened. Species with a marginal association with brigalow forest may be threatened by clearance in other habitats. The nature of threatening processes in the areas beyond the geographic range of the Brigalow Belt is partially accounted for in the method provided here because we were able to assess the extent of habitat loss, at least within the state of Queensland, using time-series vegetation mapping (Table 2).

In general the habitat of species whose ranges extend to the north and the west will be more intact than species extending to the east and south, because of the limitations of climate and soils on land development in eastern Australia.

5. Conclusion

This study has demonstrated how existing data, in this case herbarium collection records and vegetation mapping, can be used to identify species threatened by rapid habitat loss. The study highlights the threatened status of plant species exposed to steep population declines with rapid habitat clearance, and particularly for species with a clearance association with habitat targeted for clearance and with small geographic ranges. Many of the species identified by the process were not previously recognised as threatened and highlights the probability that rapid habitat loss is threatening plant species before their plight has been realised.

Acknowledgments

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Table 1. The lifeform and habitat association of plant species with a Threat Exposure Index of >10 ordered from highest Threat Exposure Index. Species nomenclature follows Bostock and Holland (2010) as do designated 'hispid' names where a species is yet to be formally described. The 26 species in bold are those with a strong association with heavily cleared habitats.

Species	Lifeform	Habitat; and microhabitat
***Denhamia* sp. (Mt Coolon D.Corr PA409)**	Tree	Brigalow forest only
Solanum johnsonianum	Perennial herb	Brigalow forest only
Solanum dissectum	Perennial herb	Brigalow forest only
Xerothamnella herbacea	Perennial herb	Brigalow forest, alluvial woodland
Aneilema sclerocarpum	Ephemeral graminoid	Brigalow forest only
Solanum adenophorum	Ephemeral herb	Brigalow forest predominantly
Olearia cuneifolia	Tree	Brigalow forest; *Eucalyptus thozetiana* footslope microhabitats
Viscum bancroftii	Parasitic epiphyte	Brigalow forest, poplar box woodland
Solanum elachophyllum	Shrub	Brigalow forest predominantly
Corchorus thozetii	Perennial forb	Brigalow forest only
Eucalyptus argophloia	Tree	Brigalow forest predominantly
Macropteranthes leichhardtii	Tree	Dry rainforest, brigalow forest

Teucrium micranthum	Perennial forb	Brigalow forest, dry rainforest
Leptochloa ligulata	Perennial grass	Brigalow forest, poplar box woodland; gilgai microhabitat
Enteropogon paucispiceus	Perennial grass	Brigalow forest, dry rainforest
Cyperus isabellinus	Perennial graminoid	Brigalow forest, alluvial woodland
Solanum latens	Perennial forb	Brigalow forest, dry rainforest, lancewood forest, eucalypt forest
Homopholis belsonii	Perennial grass	Brigalow forest, poplar box woodland
Kelita uncinella	Ephemeral forb	Lancewood forest, brigalow forest
Solanum innoxium	Perennial forb	Lancewood forest, brigalow forest
Sclerolaena tetracuspis	Perennial forb	Brigalow forest, poplar box woodland
Leptochloa southwoodii	Perennial grass	Brigalow forest, alluvial woodland; gilgai microhabitat
Uniola sp. (Palm Grove P.I.Forster PIF23666)	Perennial grass	Brigalow forest, dry rainforest, lancewood forest, eucalypt forest, eucalypt woodland
Synostemon spinosus	Perennial forb	Brigalow forest, lancewood forest

Melaleuca squamophloia	Tree	Brigalow forest; low lying areas
Lagenophora fimbriata	Perennial forb	Brigalow forest, alluvial woodland
Solanum mitchellianum	Perennial forb	Eucalypt forest predominantly
Brachychiton rupestris	Tree	Brigalow forest, dry rainforest
Solanum coracinum	Perennial forb	Lancewood forest predominantly
Rutidosis lanata	Perennial forb	Brigalow forest, eucalypt forest
Sporobolus disjunctus	Perennial grass	Alluvial woodland, poplar box woodland predominantly
Cadellia pentastylis	Tree	Brigalow forest, dry rainforest predominantly
Eleocharis blakeana	Perennial graminoid	Brigalow forest, poplar box woodland, alluvial woodland
Nyssanthes erecta	Perennial forb	Eucalypt woodland, dry rainforest predominantly
***Teucrium* sp. (Pittsworth A.R.Bean 18338)**	Perennial forb	Grassland, brigalow forest, alluvial woodland
Alectryon diversifolius	Tree	Dry rainforest, eucalypt woodland
Denhamia parvifolia	Tree	Dry rainforest predominantly

Solanum tetrathecum	Perennial forb	Dry rainforest, eucalypt forest
Myriophyllum jacobsii	Perennial forb	Open wetland
Acacia harpophylla	Tree	Brigalow forest, grassland, poplar box woodland, dry rainforest
Rhodanthe polyphylla	Perennial forb	Brigalow forest, alluvial woodland, dry rainforest
Brachyscome dalbyensis	Perennial forb	Grassland, poplar box woodland, brigalow forest
***Denhamia* sp. (Junee Tableland T.J.McDonald 553)**	Tree	Brigalow; *Eucalyptus thozetiana* footslope microhabitat
Corchorus tomentellus	Perennial forb	Poplar box woodland, eucalypt woodland
Lindernia sp. (Tingoora A.R.Bean 10311)	Perennial forb	Open wetland predominantly
Samadera sp. (Dam Creek T.S.Ryan 1006)	Shrub	Eucalypt forest
Capparis shanesiana	Tree	Poplar box woodland, dry rainforest
Zieria verrucosa	Tree	Dry rainforest, eucalypt forest
Solanum furfuraceum	Perennial forb	Dry rainforest, eucalypt forest
Sida pleiantha	Perennial forb	Brigalow forest, grassland
Triflorensia ixoroides	Tree	Dry rainforest

Lysiphyllum carronii	Tree	Poplar box woodland, brigalow forest
Paspalidium caespitosum	Perennial grass	Brigalow forest, poplar box woodland
Harnieria sp. (Lornesleigh E.J.Thompson+ CHA75)	Shrub	Lancewood forest, eucalypt forest
Calandrinia pickeringii	Perennial forb	Eucalypt forest; rock outcrops
Capparis humistrata	Shrub	Poplar box woodland, eucalypt woodland

Figure captions

Figure 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 proportion of brigalow forest in each 0.5 degree cell throughout the Brigalow Belt region in Queensland. The proportion is determined from the area of the cell in the region. c) The proportion of brigalow forest cleared by 2013 for each 0.5 degree cell, d) The proportion of the 2013 area of remnant brigalow forest that is within conservation reserve (including State Forest) for each 0.5 degree cell.

Figure 2. The percentage habitat remaining for ten species with the highest threat exposure score (Appendix 4) in three groups: species confined to brigalow habitat (left-hand column), species also associated with other heavily cleared habitats (middle column); species also associated with less heavily cleared habitats (right-hand column). These three categories are indicated by the colours: brigalow (brown); other heavily cleared habitats (mustard); less heavily cleared habitats (blue), and the letter codes: B, brigalow,; A, alluvial woodland; P, poplar box woodland; D, dry rainforest; F, eucalypt forest; W, eucalypt woodland; L, lancewood forest. The threat exposure score is indicated next to the name of the species.

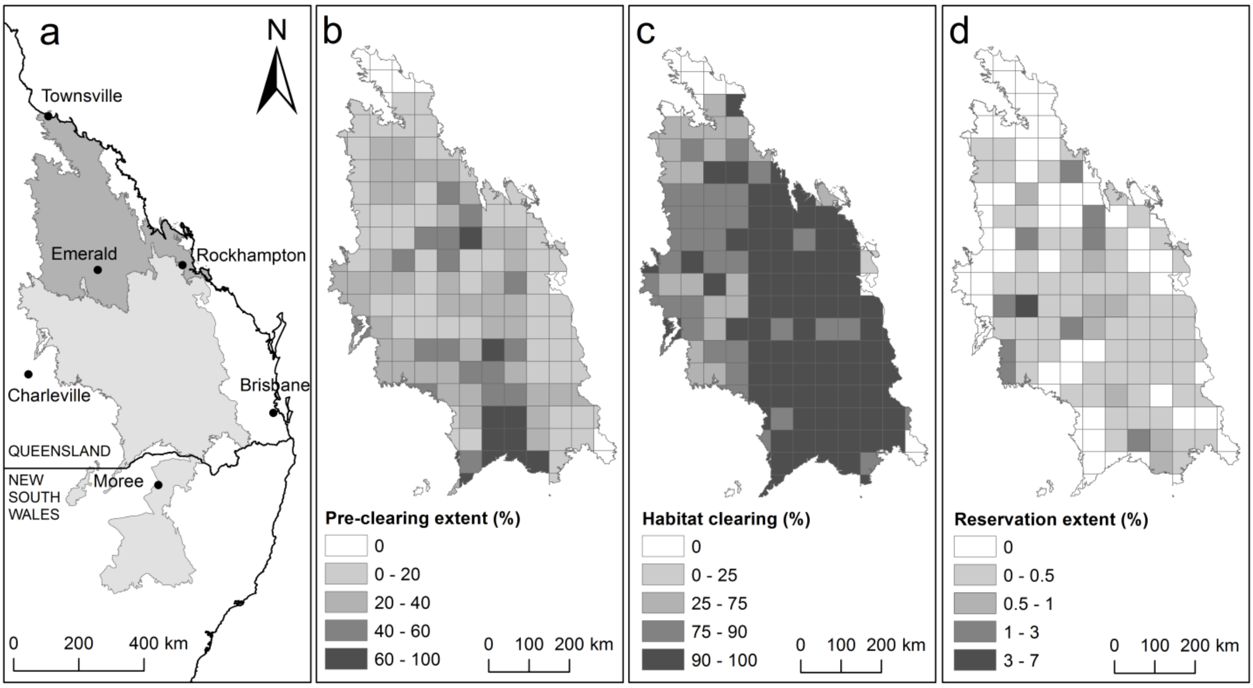
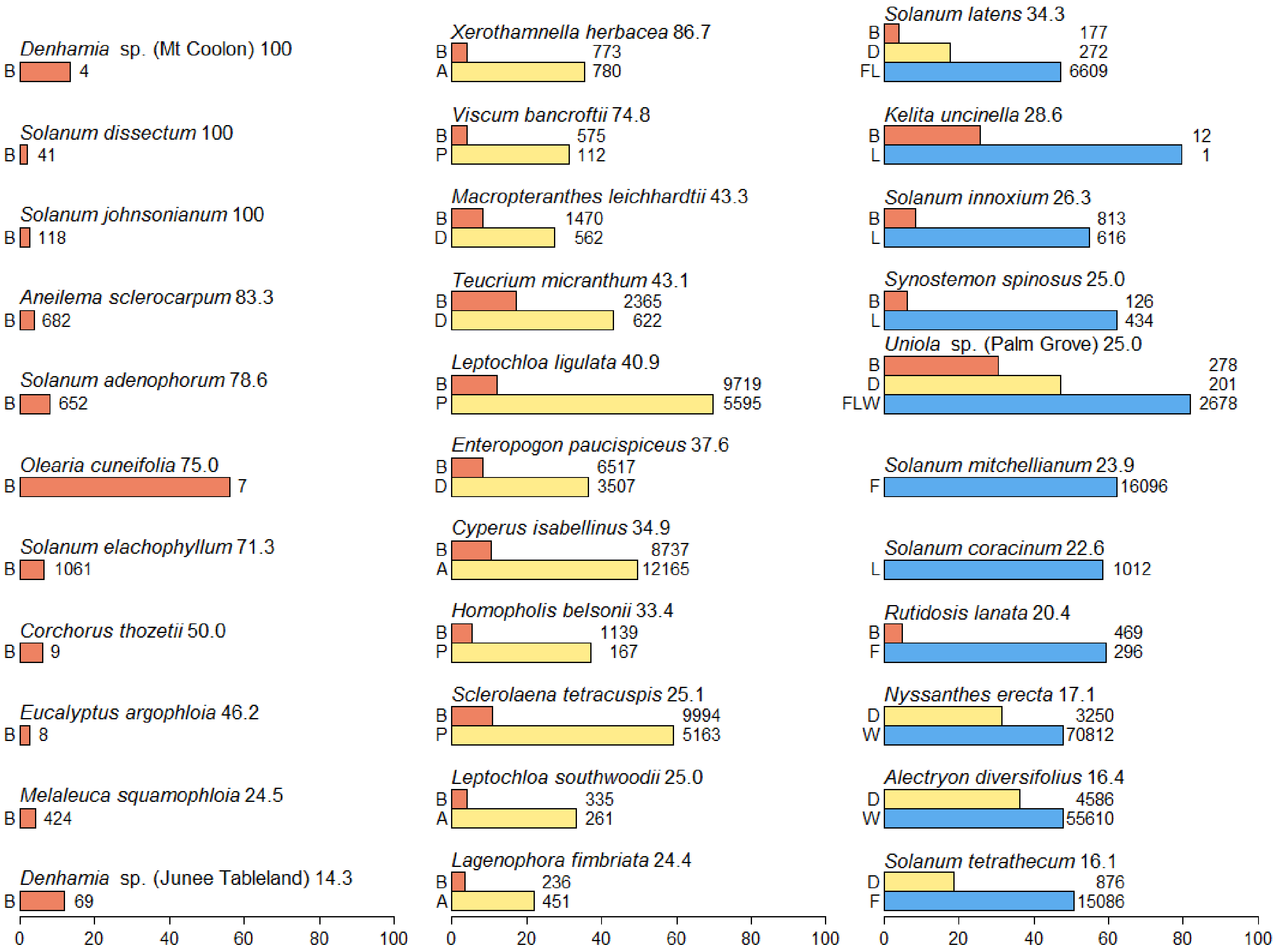

a
N
Townsville
Emerald
Rockhampton
Charleville
Brisbane
QUEENSLAND
NEW SOUTH WALES
Moree
0 200 400 km
b
Pre-clearing extent (%)
0
0 - 20
20 - 40
40 - 60
60 - 100
0 100 200 km
c
Habitat clearing (%)
0
0 - 25
25 - 75
75 - 90
90 - 100
0 100 200 km
d
Reservation extent (%)
0
0 - 0.5
0.5 - 1
1 - 3
3 - 7
0 100 200 km

Figure 1



Denhamia sp. (Mt Coolon) 100
B 4
Solanum dissectum 100
B 41
Solanum johnsonianum 100
B 118
Aneilema sclerocarpum 83.3
B 682
Solanum adenophorum 78.6
B 652
Olearia cuneifolia 75.0
B 7
Solanum elachophyllum 71.3
B 1061
Corchorus thozetii 50.0
B 9
Eucalyptus argophloia 46.2
B 8
Melaleuca squamophloia 24.5
B 424
Denhamia sp. (Junee Tableland) 14.3
B 69
Xerothamnella herbacea 86.7
B 773
A 780
Viscum bancroftii 74.8
B 575
P 112
Macropteranthes leichhardtii 43.3
B 1470
D 562
Teucrium micranthum 43.1
B 2365
D 622
Leptochloa ligulata 40.9
B 9719
P 5595
Enteropogon paucispiceus 37.6
B 6517
D 3507
Cyperus isabellinus 34.9
B 8737
A 12165
Homopholis belsonii 33.4
B 1139
P 167
Sclerolaena tetracuspis 25.1
B 9994
P 5163
Leptochloa southwoodii 25.0
B 335
A 261
Lagenophora fimbriata 24.4
B 236
A 451
Solanum latens 34.3
B 177
D 272
FL 6609
Kelita uncinella 28.6
B 12
L 1
Solanum innoxium 26.3
B 813
L 616
Synostemon spinosus 25.0
B 126
L 434
Uniola sp. (Palm Grove) 25.0
B 278
D 201
FLW 2678
Solanum mitchellianum 23.9
F 16096
Solanum coracinum 22.6
L 1012
Rutidosis lanata 20.4
B 469
F 296
Nyssanthes erecta 17.1
D 3250
W 70812
Alectryon diversifolius 16.4
D 4586
W 55610
Solanum tetrathecum 16.1
D 876
F 15086
0 20 40 60 80 100
0 20 40 60 80 100
0 20 40 60 80 100

Figure 2

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