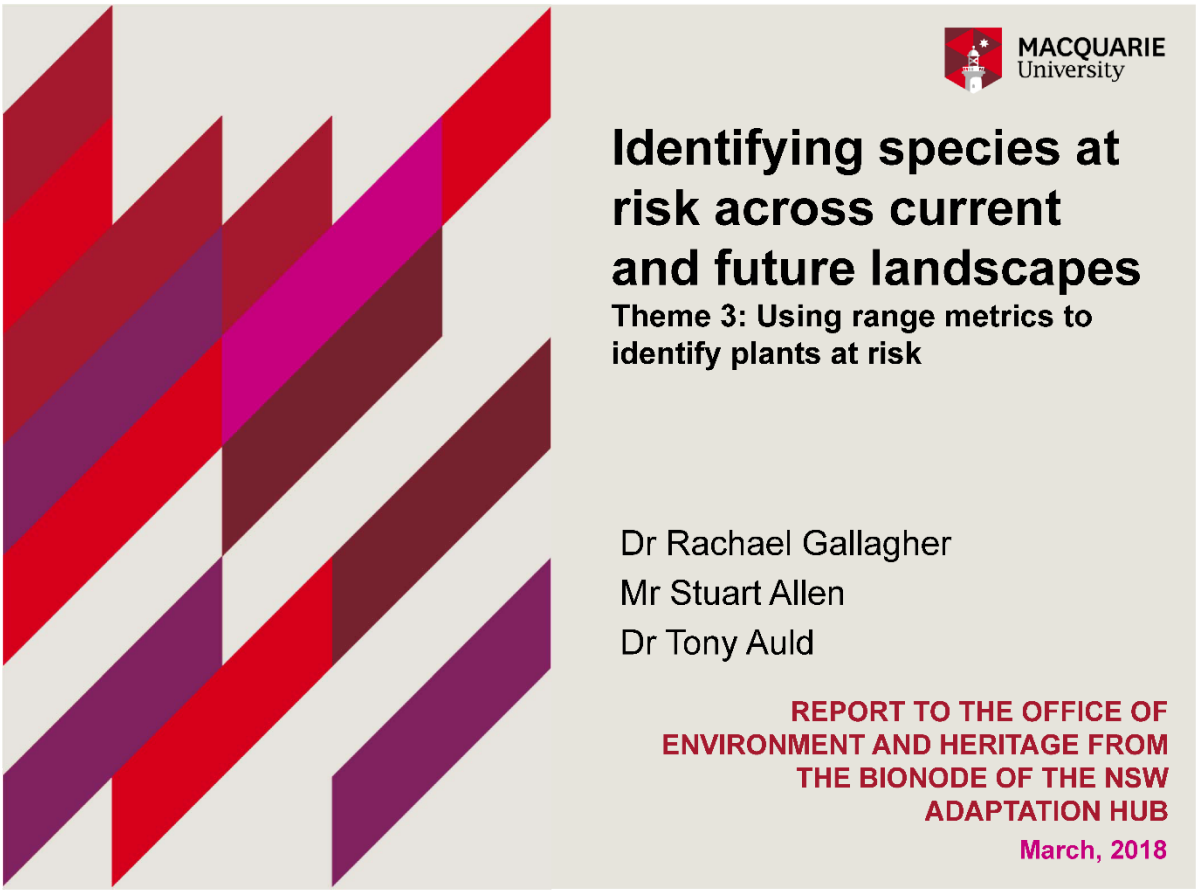


Project Overview

This NSW Adaptation Hub project provides baseline information about the potential extinction risk for a suite of ~5000 NSW plant species which are currently not listed as threatened under the NSW *Biodiversity Conservation Act* 2016.

The project objectives and outcomes are to:

1) Assess the relationship between extinction risk and range metrics (niche breadth for key climate variables) of NSW plants;

2) Undertake a species-level assessment of extinction risk for each NSW plant species;

3) Map clusters of small-ranged species across NSW and spatial analysis of the factors predicting small range size;

4) Communicate research findings and disseminate outputs via masterclasses and conferences.

Project rationale

Efforts to conserve biodiversity typically focus on actions which can minimise extinction risk in species already identified as threatened. Arresting the decline of listed threatened species through conservation programs like *Saving Our Species* is essential for preventing the decline of biodiversity. However, the process of nomination, assessment and listing of species in NSW – which requires substantial effort at each stage – means that only a subset of biodiversity is being examined for its potential extinction risk. This is problematic because the ability to prioritise conservation actions should be informed by the extinction risk across the broadest suite of species which may be affected by critical threats. This is particularly important for threats such as climate change, which operate at the landscape scale and require strategic planning to mitigate.

In this project, we have used the wealth of data embedded in digitised herbarium specimens of the NSW flora to assess 4,976 plant species against parts of the IUCN Red List criteria (IUCN Criterion B – geographic range; IUCN (2016)). Specifically, we have assessed the area of occupancy (AOO) and extent of occurrence (EOO) of each taxon (species, subspecies or variety) for which we could confidently clean occurrence records (see **Methods** below for details). AOO and EOO are essential elements in the IUCN assessment process; all species which are listed via IUCN Criterion B must have range sizes (AOO and/or EOO) below the following thresholds:

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

Figure 1. IUCN Criterion B thresholds for Area of Occupancy (AOO; Criterion B1) and Extent of Occurrence (EOO; Criterion B2) and condition for sub-criteria.

We provide quantitative assessment of how of the ranges of non-listed NSW plants meet these AOO and EOO thresholds. We also assess the vegetation condition (Drielsma & Ferrier 2006; Drielsma *et al*. 2012) across the range of all taxa as an indicator of potential habitat quality and decline (required sub-criteria to meet a classification of threatened under IUCN Criteria B). Maps of the landscape locations with the highest numbers of potentially threatened species (hotspot maps) are provided alongside species checklists for NPWS Regional Operations branches.

Project outputs

This project provides the following key resources for OEH:

- A dataset detailing the following for 4,976 non-listed NSW plant taxa ("**IUCN_CriteriaB_NSW_flora.xls**"):

    - Area of occupancy (AOO);
    - Extent of occurrence (EOO);
    - IUCN Criteria B1 and B2 classification (Critically Endangered, Endangered, Vulnerable) based on AOO and EOO metrics;
    - Vegetation condition across the range (categorical - poor, adequate, good; and continuous values i.e. minimum, maximum, mean, median, standard deviation);
    - % of the EOO/number of occurrences inside the extent of the vegetation condition layer;
    - Niche breadth for precipitation and temperature;
    - Flags for species occupation across each NPWS Regional Operations Branch.

  Each variable in the dataset is detailed in the METADATA tab in the Excel spreadsheet.

- Maps of the spatial patterns of potentially at-risk species across NSW (see below). These maps indicate where species which meet Critically Endangered, Endangered, Vulnerable thresholds are distributed across the landscape and identifies hotspots.

Methods

Taxon selection

A list of 16,051 plant taxa occurring in NSW was extracted from the Atlas of Living Australia using its web service API (https://api.ala.org.au/). Taxa were excluded if they met criteria for removal as shown below. (Note that taxa often met more than one of the listed criteria.) Using these criteria, a list of 4,991 taxa was derived.

Criteria for taxon removal	**% taxa affected**
Rank higher than species	12.64
Not in one of the subclasses *Cycadidae*, *Magnoliidae* or *Pinidae*, or the fern group [Major subclasses as defined in the Australian Plant Census (APC)[1]; fern group as defined in PlantNet[2]]	28.76

Not in the APC[1]	26.29
Not having status *ApcConcept* in the APC[1]	1.2
Not native to NSW according to APC distribution data[1]	60.24
Not in the PlantNet database[2]	49.04
Not having accepted name status in PlantNet[2]	2.93
Introduced species according to PlantNet[2]	10.04
Taxonomy is ambiguous or unresolved [manuscript name, hybrid name, etc]	15.11
Listed as threatened in NSW[3]	3.67

[1] Australian Plant Census (https://biodiversity.org.au/nsl/services/api/export/index; accessed 21/02/2017)

[2] PlantNet, derived from NSW Herbarium database; provided by Wayne Cherry, February 2017

[3] Office of Environment and Heritage website [http://www.environment.nsw.gov.au/threatenedspeciesapp/]

Occurrence cleaning

Occurrence data for 4,976 taxa were downloaded from the Atlas of Living Australia using its web service API (https://api.ala.org.au/). This initial dataset contained 7,590,662 occurrence records, which were then excluded if they met criteria for removal as shown below. (Note that occurrences often met more than one of the listed criteria.) Using these criteria, a dataset of 1,230,517 occurrence records for 4,976 taxa was derived.

Criteria for removal	**% occurrences affected**
Not a vouchered herbarium specimen (data provider not Australia's Virtual Herbarium (AVH))	77.39
Not preserved specimen in AVH	0.03
Missing longitude or latitude	2.3
Flagged as cultivated in AVH	0.16
Locality name suggests cultivation (e.g., botanic gardens)	0.22

Collected prior to 1950	5.89
Collection year unknown	2.35
Taxon identification issue flagged in AVH	0.23
Coordinate (lat/lon) issue flagged in AVH	0.53
Collection date suspicious (e.g., 01/01/1900)	0.12
Coordinates outside 0.05 degree buffer around Australian coastline [This is intended to retain a portion of occurrences which may appear to be located off the coast owing to rounding of coordinates to one decimal place]	3.22

Range size metrics

Range size metrics were computed according to the definitions provided by the IUCN Red List of Threatened Species (http://www.iucnredlist.org/static/categories_criteria_3_1#definitions; IUCN 2016). For the purposes of computing range size metrics, occurrence point coordinates were projected to Australian Albers (EPSG:3577).

We calculate AOO and EOO for all taxa. AOO and EOO offer two complementary measures of geographic range: AOO approximates the likely resistance of the species to stochastic and deterministic threats and approximates population size, whereas EOO captures the overall geographic spread of known species occurrences (Gaston and Fuller 2009).

EOO for a taxon was measured as the area in km^2 of the minimum convex polygon containing all the occurrence points for that taxon.

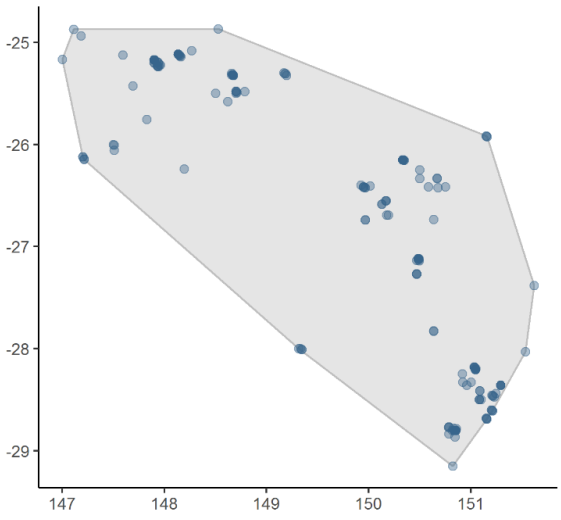


Figure 2. Construction of minimum convex polygon for Extent of Occurrence (*Eucalyptus panda*)

For species with fewer than three occurrence points a minimum convex polygon could not be computed, and so EOO could not be measured for these taxa.

AOO for a taxon was measured as the total area of 2 x 2 km grid cells occupied by the species. This scale is matched to the IUCN criterion B2 thresholds.

All calculations were made in R using the *ALA4R* package.

Threat category

Note that threat category is based solely on thresholds defined in IUCN Red List Criteria B1 (Extent of Occurrence) and B2 (Area of Occupancy) (see **Figure 1**). It is suggested to indicate those species which would warrant further investigation for their ability to meet essential subcriteria for listing under IUCN Guidelines. Criteria B2 (a), (b) and (c) are not evaluated here, although vegetation condition as a surrogate for habitat quality is examined.

Bioclimatic niche breadth

Climate niche breadths were calculated as the difference between the lowest and highest values of climate variables (mean annual temperature (MAT) and annual precipitation (AP)) encountered by species across its Australian range. Occurrence records were overlaid on gridded climate datasets and values were extracted using the *raster* package in R. The bioclimatic variable data was accessed from WORLDCLIM1.0 and the following bioclimatic variables were used (http://worldclim.org/version2):

- Annual mean temperature (BIO1)
- Annual precipitation (BIO12)

These variables are widely used to characterise the niche of species in comparative analyses. Whilst other variables, such as extremes like minimum and maximum temperatures, could also be used to assess the niche we have concentrated on two key variables.

Vegetation condition

An index of vegetation condition (Drielsma et al. 2012 (Fig. 3)) was used as a surrogate for habitat quality. Although these data do not cover the entirety of the Australian continent, 69.2% of cleaned herbarium occurrences had vegetation condition values extracted. Across all species, 29.8% had all of their occurrences within the vegetation condition area. For the purposes of our analyses we grouped values of vegetation condition into three equally-sized categories: Poor (<=33), Adequate (>33 and <= 66) and Good (>66). This data on vegetation condition can be used as a proxy of habitat

quality across the range and be useful for more detailed assessments of species threat risk.

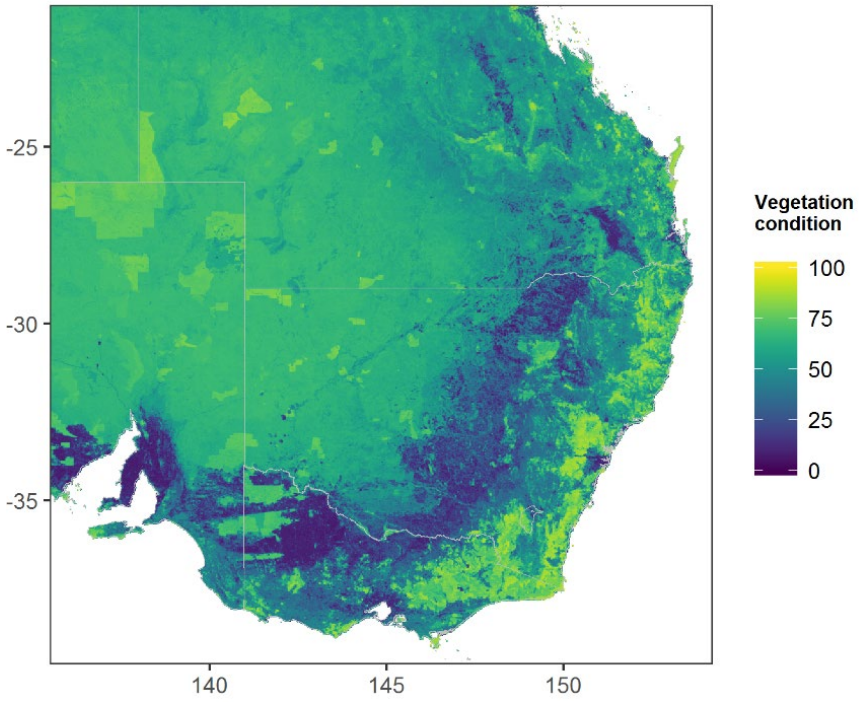


Figure 3. Vegetation condition index (0 – 100) at 0.0025 degree resolution, encompassing mainland Australia east of longitude 135.5° and south of latitude -21.0°.

Results

Below we provide graphs and maps detailing the potential extinction risk of non-listed plant species in NSW. Combined with the datasets provided as outputs of this project, the graphs and maps below highlight the potential risk of extinction to NSW flora and highlight those species which have not yet been formally assessed for threat status via the threatened species listing process. The maps provided identify areas across NSW which have high numbers of plant species at risk of extinction which may aid in the proactive management of NSW flora.

Across the 4,976 species assessed in this project (Fig. 4):

- 92 species meet thresholds for AOO or EOO (or both) for critically endangered (CE);
- 2,711 species meet thresholds for AOO or EOO (or both) for endangered (E);
- 1,756 species meet thresholds for AOO or EOO (or both) for vulnerable (V).
- 417 species did not meet any threshold (None).

None of these species are currently listed as threatened in NSW.

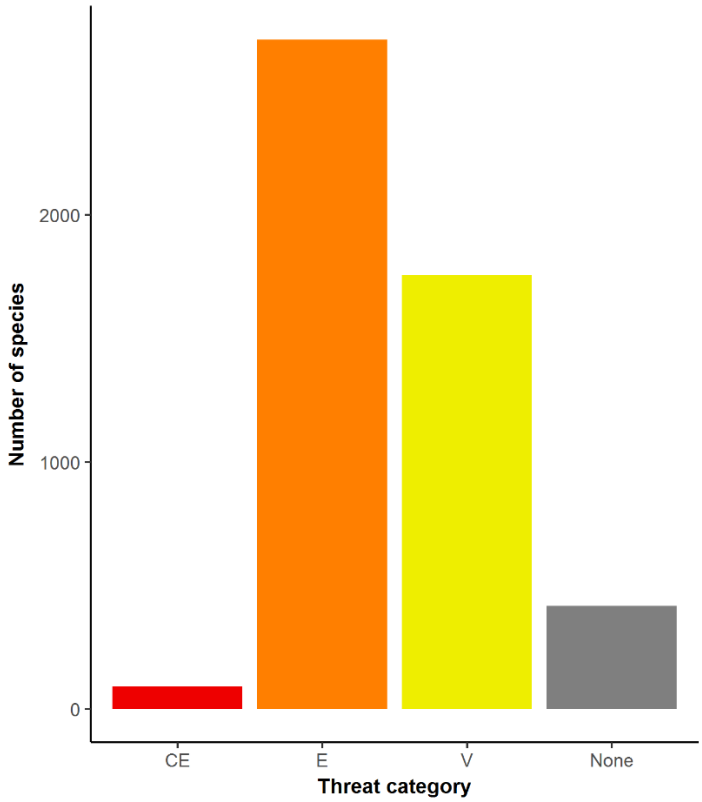
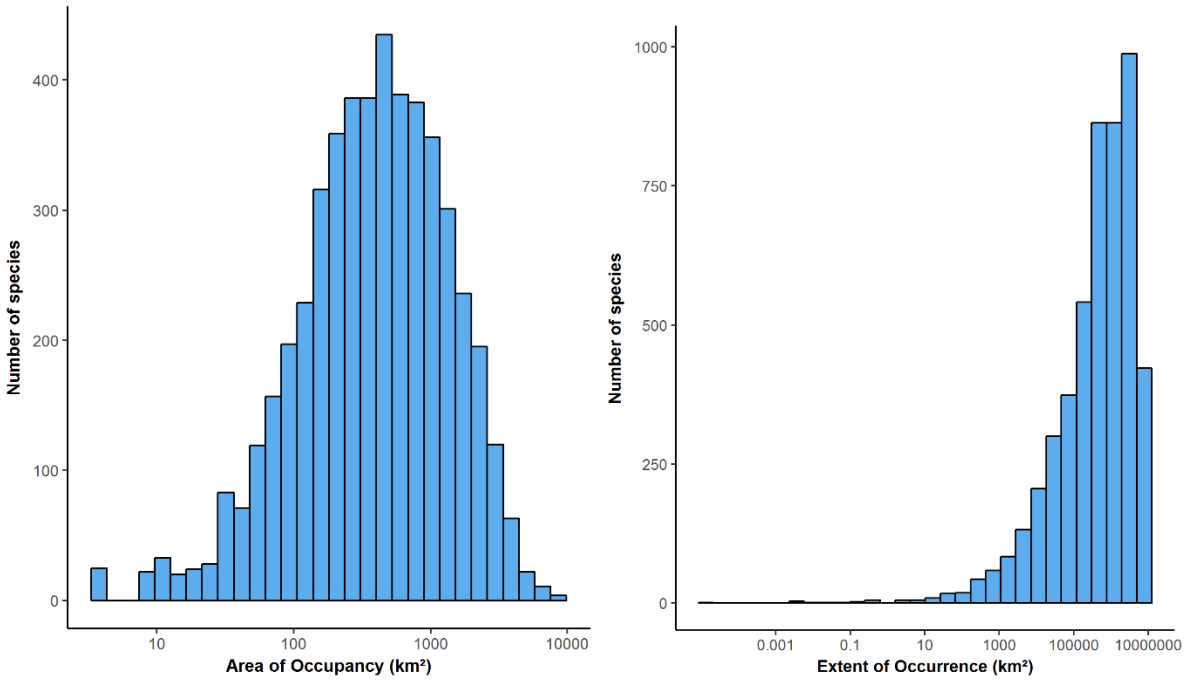
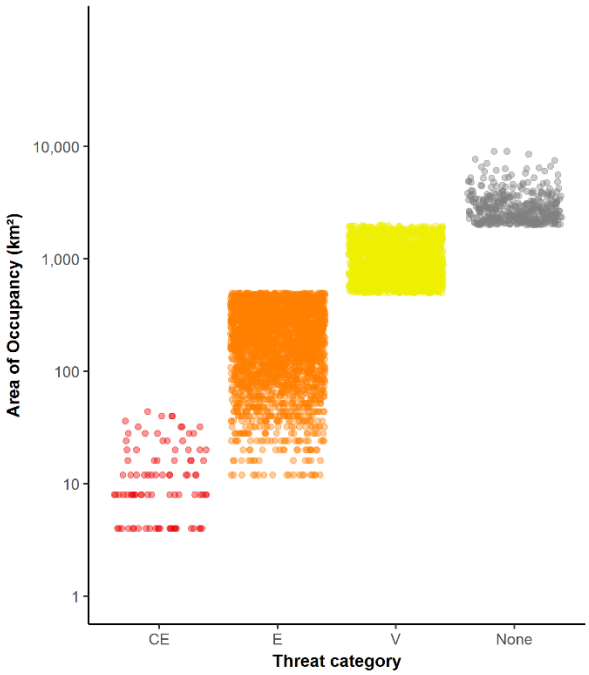
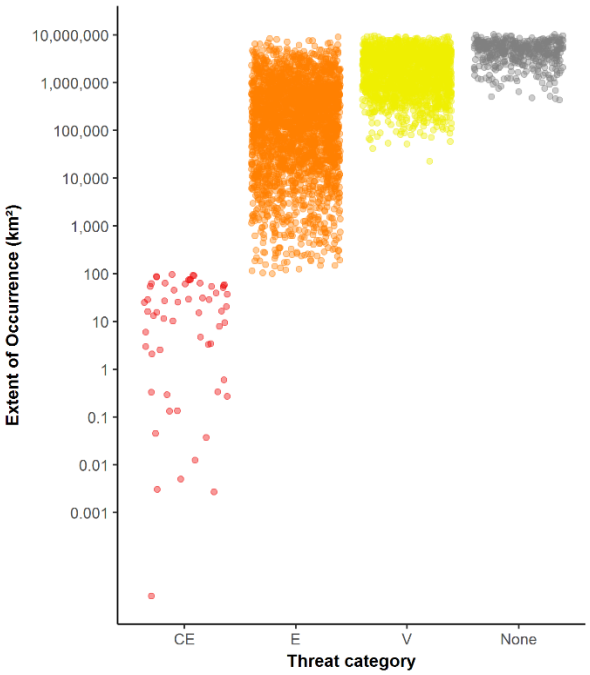


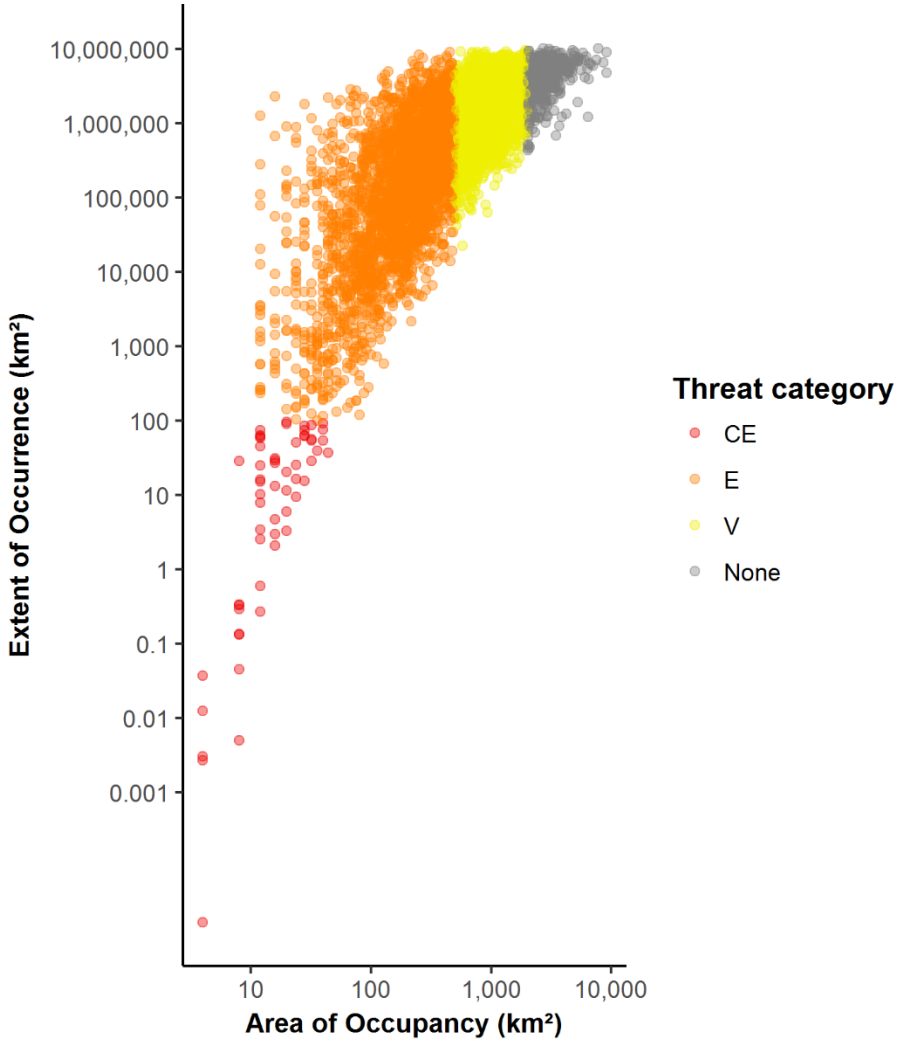
Figure 4. Provisional IUCN Red List threat category based on AOO or EOO (range size) for 4,976 NSW plant taxa. CE = critically endangered (92 spp.), E = endangered (2,711 spp.), V = vulnerable (1,756 spp.), None = species which do not meet any IUCN threshold (417 spp).

Range sizes (AOO and EOO) across all assessed species

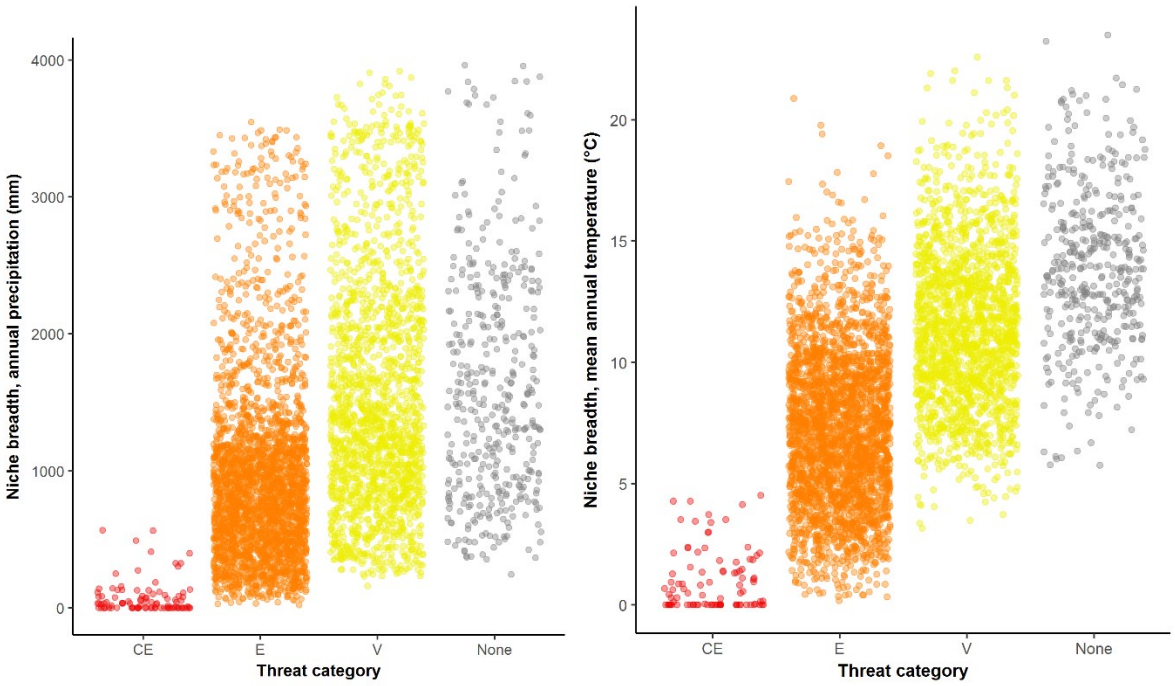



Area of Occupancy (km²)
10,000
1,000
100
10
1
CE
E
V
None
Threat category

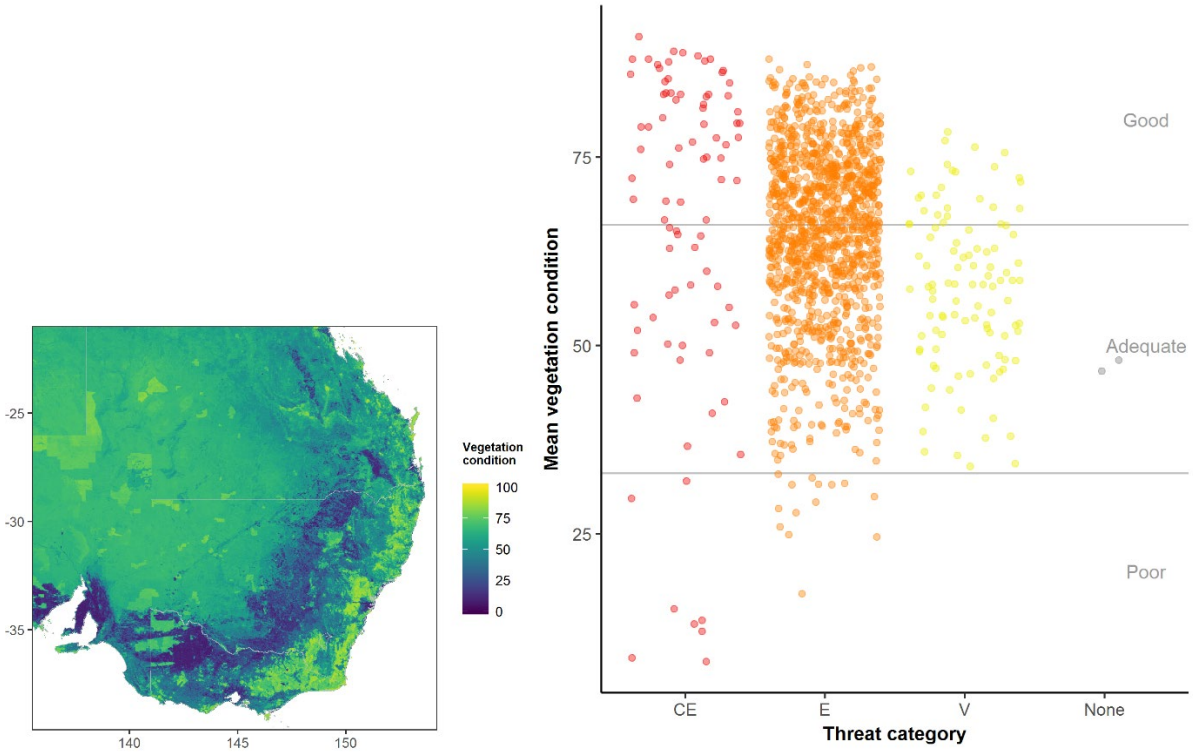

Extent of Occurrence (km²)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01
0.001
CE
E
V
None
Threat category


Extent of Occurrence (km²)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01
0.001
10
100
1,000
10,000
Area of Occupancy (km²)
Threat category
CE
E
V
None

Abiotic niche breadths across threat categories



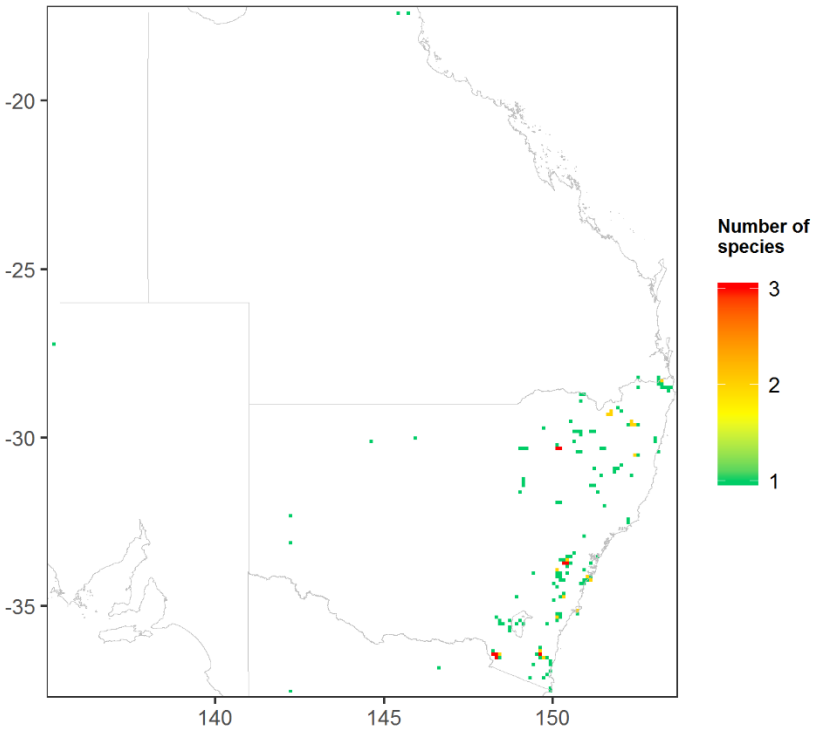
Vegetation condition across threat categories



Mapping of extinction risk categories across NSW

Maps below show spatial clusters of potentially extinction prone species in each threat category at a 10km x 10km gird cell resolution.

CRITICALLY ENDANGERED



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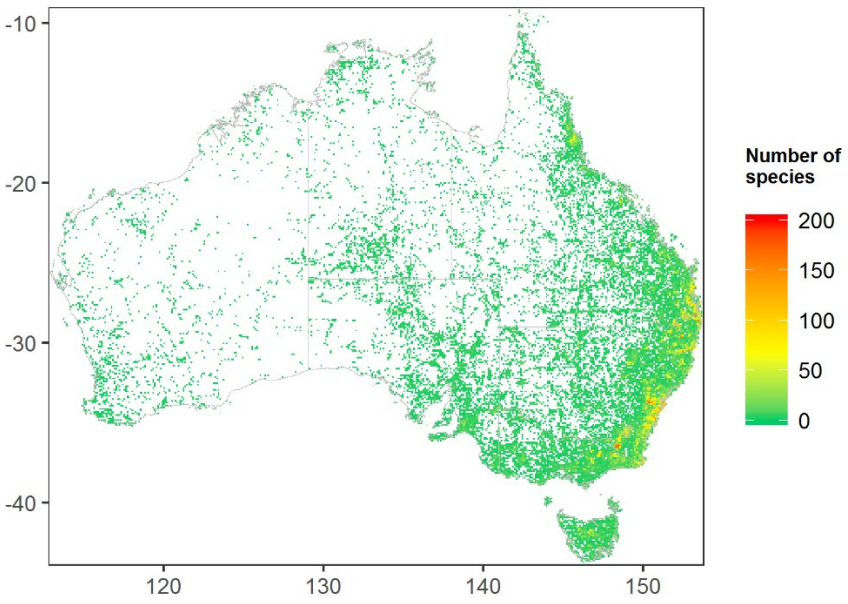
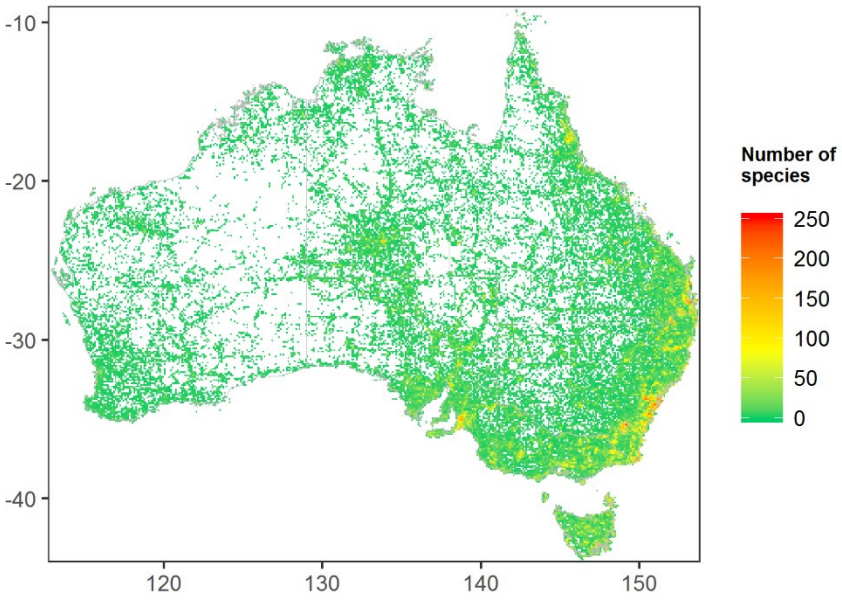
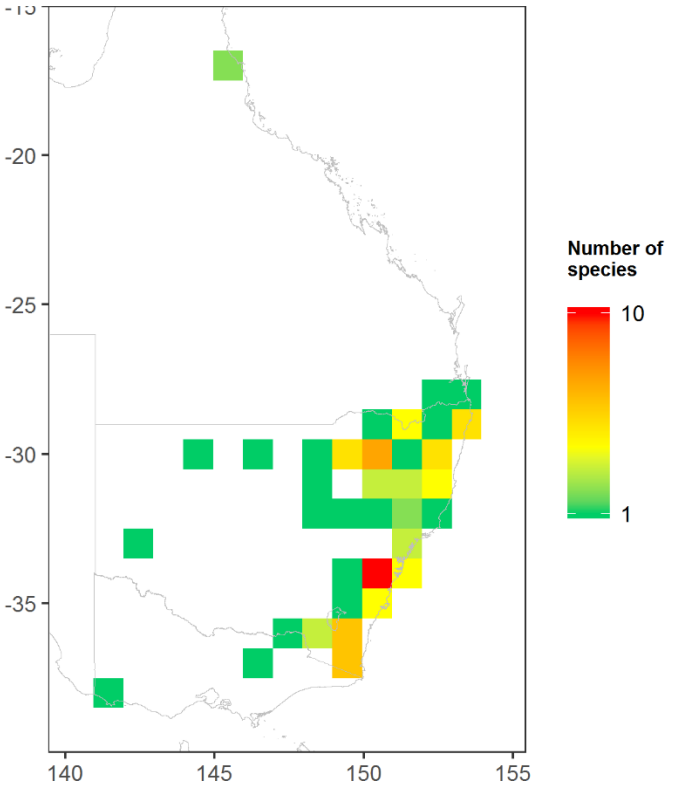


VULNERABLE



Maps below show spatial clusters of potentially extinction prone species in each threat category at a 100km x 100km gird cell resolution.

CRITICALLY ENDANGERED



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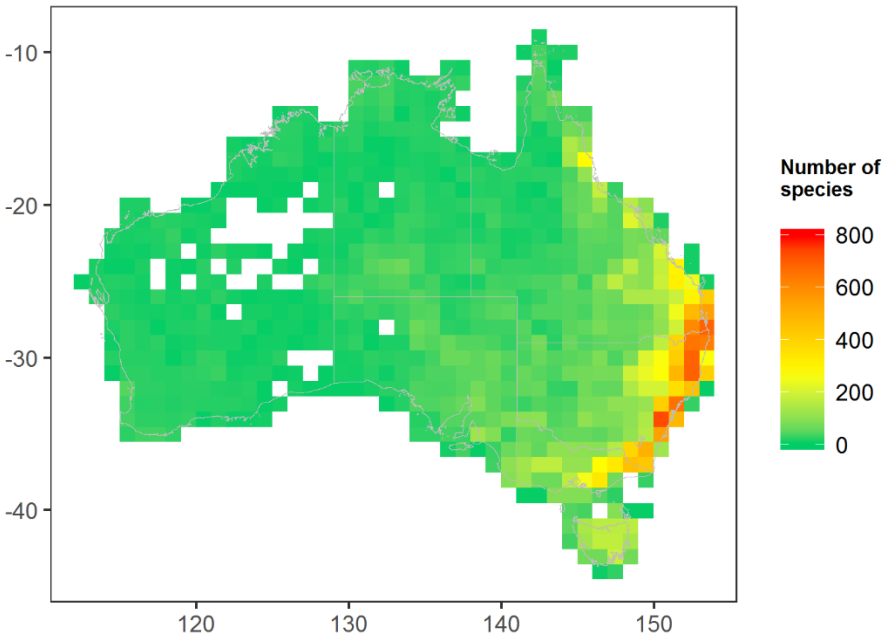
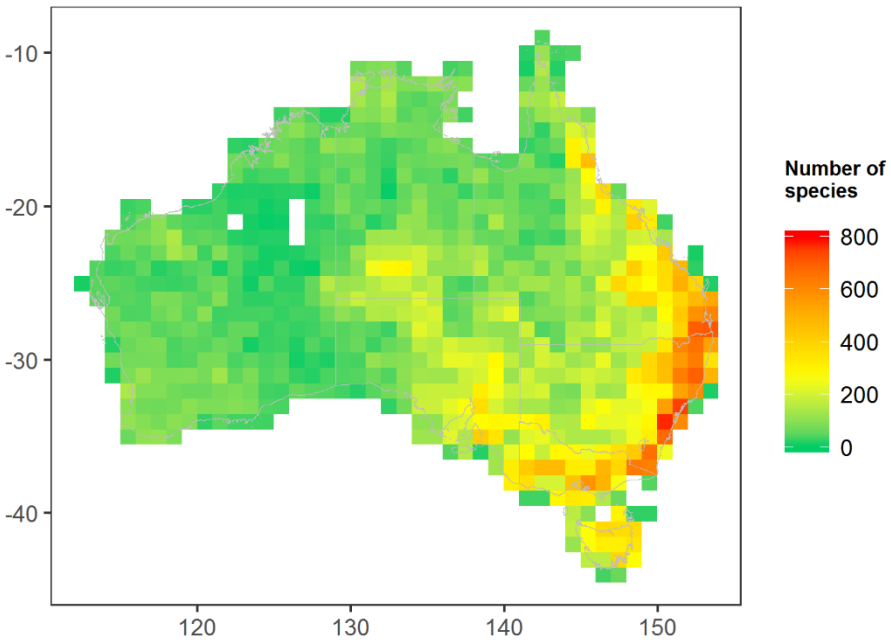


VULNERABLE



Mapping of extinction risk categories across NPWS Regional Operations Branches

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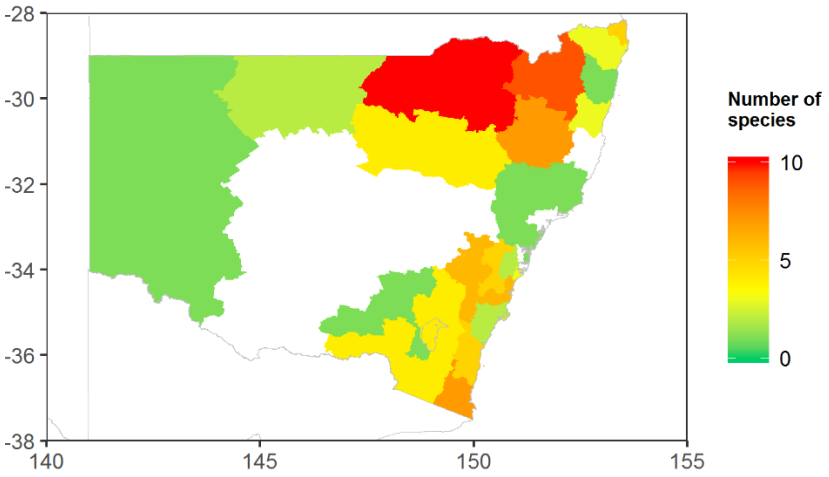

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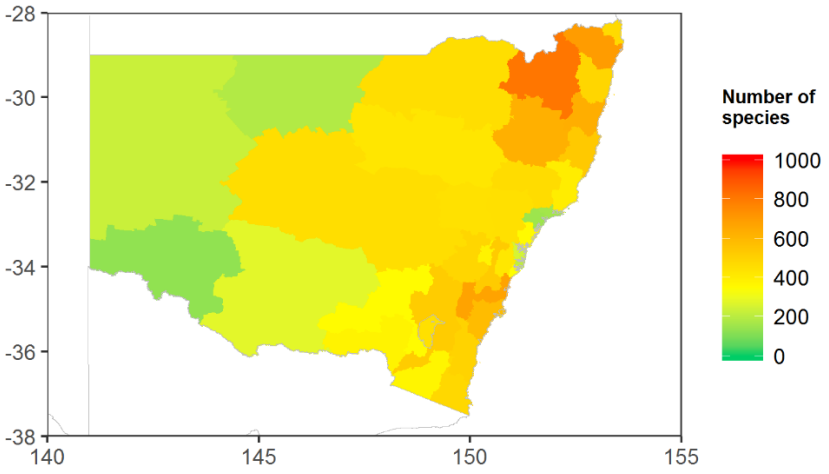
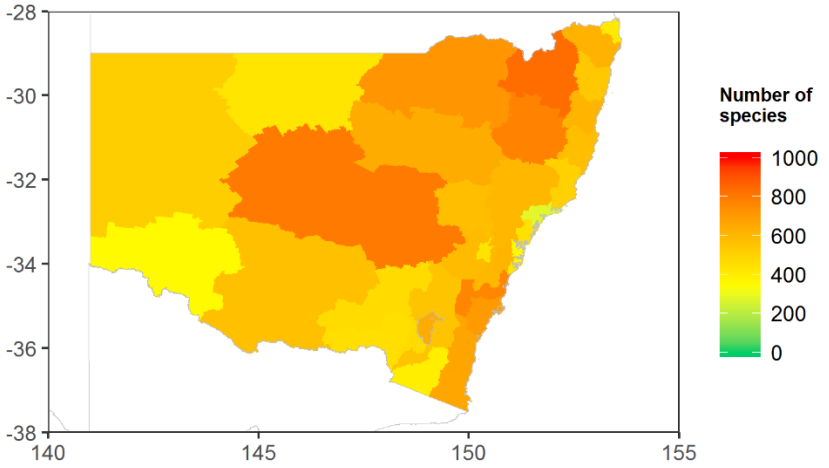


VULNERABLE



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