Identifying Climate Refugia for Key Species in New South Wales - Final Report from the BioNode of the NSW Adaptation Hub

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Contents

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Abbreviations

AUC—Area under the Receiver Operating Characteristic curve
ALA—Atlas of Living Australia
AVH—Australasian Virtual Herbarium
BCC—Bioclimatic Class
DXS—Deserts and Xeric Shrublands
GCM—Global Climate Model
GER—Great Eastern Ranges
HRR—High Richness Refugia
HSM—Habitat Suitability Model
MFWS—Mediterranean Forests, Woodlands and Scrub
MGS—Montane Grasslands and Shrublands
NARCliM—NSW/ACT Regional Climate Modelling
NSW—New South Wales
OEH Atlas—Office of Environment and Heritage BioNet Atlas
RCM—Regional Climate Model
SD—Standard deviation
TBMF—Temperate Broadleaf and Mixed Forests
TGSS—Temperate Grasslands, Savannas and Shrublands
TrGSS—Tropical/Subtropical Grasslands, Savannas and Shrublands

Glossary

Areas with translocation potential: These are grid cells that are projected to have suitable climate now and in the future, but for which there are no high quality occurrences for the target species. Such sites may be explored further to determine their capacity to support species' persistence.

External refugia: Grid cells that are currently unsuitable but are projected to become suitable in the future.

High quality occurrence records: Records of species' occurrences that remain after undergoing data cleaning. These records were used to fit habitat suitability models.

IBRA subregions: Subregions make up IBRA (Interim Biogeographic Regionalisation for Australia) Bioregions and contain areas that have similar geology, vegetation and other biophysical attributes, and form the basis for determining the major regional ecosystems (http://www.environment.nsw.gov.au/bioregions/BioregionsExplained.htm).

Internal refugia: Grid cells classified as suitable for the target species in the current time period, which remain suitable over consecutive future time periods and are located within an IBRA subregion that has one or more high quality occurrence records.

Multi-species refugia: Areas that serve as internal refugia for multiple species.

Occurrence records: Records of species' occurrences derived from sources such as the Atlas of Living Australia, NSW OEH BioNet Atlas, and the Victorian Biodiversity Atlas.

Refugia: Grid cells classified as retaining suitable climate across consecutive time periods.

Regions of consensus: Grid cells classified as refugia under all of the climate scenarios.

Executive summary

Rapid climate change poses a significant threat to biodiversity at all levels of biological organisation. Detrimental effects have already been observed, including shifts in species' ranges, altered timing of key seasonal events leading to phenological mismatches between interacting species, and extinction of populations and species. As was the case during historical periods of climate change, climate refugia — areas retaining suitable habitat despite regional climate change — are likely to be critical in preventing considerable loss of biodiversity. For some species, regions where populations are currently located may continue to be climatically suitable into the future, and such regions are termed 'internal refugia'. Identifying internal refugia that are likely to remain suitable under the breadth of plausible climate scenarios will aid species' management substantially. Similarly, identifying areas suitable now and in the future, but which are currently unoccupied, provides critical information if translocation is to be a viable management option.

By quantifying the rate of climate change and its impacts on species, and identifying the locations of putative climate refugia, this report aids decision-making for the conservation of New South Wales (NSW) biodiversity in the face of uncertain climate change. A key advance provided by the work reported here is its acknowledgement and treatment of uncertainty about future climates in south-eastern Australia. We have drawn on climate data developed by the NARCliM project and have considered a range of future climate scenarios that encompasses the spectrum of plausible changes for the region. Our primary objective was to assess the potential impacts of climate change on the distribution of suitable habitat for key species occurring in NSW, and in doing so (1) identify *internal* climate refugia (i.e. regions currently occupied by the species and projected to remain climatically stable), as well as areas of climate vulnerability, for 117 dominant plant species in the six NSW bioregions; (2) identify areas of either *internal* climate refugia or that have *translocation potential* for 319 threatened plant and animal species within the site- and landscape-managed streams of the Saving our Species (SoS) program; and (3) develop a web-based tool for visualising and querying outputs from this project (www.nswclimaterefugia.net).

The foundation of this research is Maxent, a habitat suitability model that is used to assess the relationship between species' occurrence patterns and environmental characteristics. By itself, the output of Maxent does not indicate the probability that a target species will successfully colonise an area, rather, it provides a first-estimate of which regions are likely to retain conditions broadly suitable for the species. Further, by assessing habitat suitability across the range of plausible future climate scenarios, it is possible to identify those areas that are more, or less, likely to serve as refugia throughout the century. The output of Maxent can also help to prioritise species for further assessments aiming at developing a deeper understanding of vulnerability to climate change and long-term conservation requirements.

The key findings from this research can be summarised as:

1. The size and longevity of climate refugia vary substantially across species and ecoregions.
2. Large tracts of multi-species refugia for dominant plant species are projected to persist, until at least 2070, in the Montane Grasslands and Shrublands ecoregion, likely because species need only shift small distances in high altitude regions to track movement of climate zones.
3. Other key refugial regions for dominant plant species include the Darling Plains, which is presently in poor condition, and we caution that the capacity for degraded landscapes to withstand climate change is likely compromised.
4. The east coast region of NSW will likely be heavily impacted by climate change – several important refugia for dominant species are projected to be located close to heavily-urbanised regions.
5. Threatened species, and particularly site-managed species, are highly sensitive to climate change. For half of the site-managed species, more than 77% of their current habitat is projected to become unsuitable by 2070. For half of the landscape-managed species, more than 34% of current habitat is projected to become unsuitable.
6. Potential areas for translocation are likely to be greater for landscape- compared to site-managed species.
7. In total, 45% of landscape- and 72% of site-managed species are likely to have little to no internal refugia or areas for translocation. This includes eight Critically Endangered species.
8. Key refugia regions for threatened species are likely to occur in the north-east of the state, around the Sydney Basin, and in the southern regions of the South Eastern Highlands.

Our project provides valuable information for decision-makers, enabling them to visualise the arrangement of refugia and areas of vulnerability for dominant plant species as well as a variety of threatened species. This can be used to reveal conservation options in the context of climate uncertainty, and to facilitate the prioritisation of species and landscapes. We highlight, however, that this report provides a first estimate of responses to climate change, and is not a definitive assessment. It considers only one aspect of species' sensitivity to climate change. We strongly suggest that the adaptive capacity and a greater assessment of sensitivity of each species should be undertaken when determining actions to facilitate species' survival.

Highlights for Managers

Internal climate change refugia are areas currently occupied by a species, and that are projected to remain climatically suitable in the future.

Regions with translocation potential are those areas currently climatically suitable for a species (but in which there are no populations) and that are projected to remain suitable in the future.

Although for a given species, and region, there is considerable variation in projections under the various NARCliM scenarios, this does not need to prevent management decisions being made. Assessing agreement across climate scenarios is a useful approach to aid decision-making.

For a given species, populations in regions that are projected to remain climatically suitable under *all* climate scenarios in NARCliM should be prioritised for long-term conservation.

For a given species, populations in regions that are projected to become climatically unsuitable under *all* climate scenarios are at substantial risk from climate change.

Protection of areas containing internal refugia for multiple species offer a means of prioritising conservation efforts.

Unless reversed, degradation and other stresses may to erode the capacity of some key refugial regions, such as in the Darling Plains.

Additional resources should be placed into assessing the vulnerability to climate change of threatened species in the North Coast, Hunter and Greater Sydney regions, as well as the Shoalhaven. Habitat suitability models indicate that threatened species in these regions face substantial threat from climate change.

Our website, nswclimaterefugia.net, can be used to visualise projections of climate suitability. Note, that environmental variables in addition to those used in our study, as well as biotic interactions, will ultimately influence the suitability of a site for occupation. Our habitat suitability models provide a first estimate of suitability only.

1. Introduction

At a broad spatial scale, climate defines the structure and composition of ecosystems. Consequently, Earth's biodiversity is threatened by rapid contemporary climate change, a global phenomenon that is likely to accelerate in the coming decades (Walther et al. 2002; Urban 2015). By the end of the century climate zones will be rearranged. Novel conditions will emerge with some climate profiles disappearing completely (Beaumont et al. 2011; Williams & Jackson 2007; Radeloff et al. 2015). These changes will undoubtedly have substantial ramifications for biodiversity, with shifts in the structure, distribution and functioning of ecosystems, communities, species and their genetic constituents (Robledo et al. 2005). Indeed, the impact of the changing climate is already evident in natural environments across the world, including changes in species' distributions and phenologies (Thomas et al. 2004; Parmesan 2006; Beaumont et al. 2015), and in the ranges, composition, structure, and functioning of ecosystems (McCarty 2001), as well as shifts in the distribution of climate zones (Williams & Jackson 2007).

The reality of climate change is apparent in Australia. The period 1910–2011 was 0.9 °C warmer than the long-term average (CSIRO and Bureau of Meteorology 2015), and, consistent with trends in the Northern Hemisphere (IPCC 2013), each decade since 1950 has been warmer than the last (Gallant & Karoly 2010). Warming is apparent across all seasons and all Australian states and territories, with minimum night-time temperatures having warmed at a greater rate than daytime maximum temperatures (CSIRO and Bureau of Meteorology 2015). Associated with this warming is an observed increase in the number of hot days (i.e. > 35°C), particularly in central and northern Australia (CSIRO and Bureau of Meteorology 2015).

While anthropogenic greenhouse gas emissions are implicated in recent temperature increases, precipitation trends are more difficult to discern and attribute, particularly for regions with large interannual and decadal variation in rainfall (CSIRO and Bureau of Meteorology 2015). However, there have been discernible increases in wet season (October–April) rainfall across northern and central Australia since the 1970s (CSIRO and Bureau of Meteorology 2015). Declines in rainfall have been experienced in south-western Australia throughout the 20th century, and in many parts of south-eastern Australia since the 1960s (CSIRO and Bureau of Meteorology 2015), with a shift from relatively wet to drier conditions during mid to late autumn (Cai & Cowan 2012). There is also evidence of increases in heavy rainfall events since the 1970s, albeit with substantial regional variability. Some east coast regions, for instance, have undergone declines in the number of heavy rainfall events since the 1970s (CSIRO and Bureau of Meteorology 2015).

As the century progresses, increases in the magnitude of climate disruptions will intensify with serious repercussions across natural systems and processes in Australia. For the state of NSW, climate projections for this century are summarised in Table 1.1 below.

Table 1.1. Summary of climate changes projected for NSW. See AdaptNSW (http://climatechange.environment.nsw.gov.au/) for more information.

	2020–2039	**2060–2079**
Temperature	Mean increase of 0.68°C, ranging from 0.42°C in winter to 0.90°C in summer.	Mean increase of 2.08°C, ranging from 1.66°C in winter to 2.41°C in summer. Number of hot days will increase.
Precipitation	Little change in annual rainfall, but large seasonal differences and highly variable across State. Generally, an increase in autumn (11.8%) and decline in winter (-4.7%) and spring (-5.7%).	Slight annual increase throughout most of NSW but decline in high altitude southern regions. Averaged across the state with increases in summer (10.7%) and autumn (13.9%), decline in spring (-4.9%).
Fire	Little change to eastern NSW. Increases to the west, particularly in north-west.	Increases in severe fire weather across most of NSW, particularly to the west.
Days above 35°C	Average annual increase of 8.7 days year^{-1} > 35°C, ranging from 0 days increase in winter to 6 days increase in summer. Greater increases to west.	Average annual increase of 26.4 days year^{-1} > 35°C, ranging from 0 days increase in winter to 15.2 days increase in summer. Greatest increases in northwest.
Nights < 2°C	Average annual decline of 5.9 days year^{-1}, ranging from no change in summer to -3.1 days year^{-1} in winter. Greater declines in southern highlands.	Average annual decline of 17.3 days year^{-1}, ranging from little change in summer to -12.3 days year^{-1} in winter.

Projected climate change will jeopardize the persistence of many taxa, with local extirpation of numerous species likely, and may contribute to extinction (Aitken et al. 2008; Warren et al. 2013; Urban 2015). However, species might also respond to climate change through micro-evolution, phenotypic plasticity (e.g., a wide range of physiological tolerance, or behavioural adaptation), or, if they are sufficiently mobile, by migrating to more favourable habitat (Bellard et al. 2012). It is likely, though, that the survival of numerous species will require that some currently occupied regions remain suitable (Loarie et al. 2008), and/or that corridors or stepping-stones exist to enable species to track shifting climate zones.

Such regions of suitability within a generally unfavourable landscape are referred to as ‘refugia’. The persistence of species throughout the climatic disruptions of the late Quaternary was likely facilitated by the survival of relictual populations within refugia (Correa-Metrio et al. 2014). Thus, refugia represent areas that biodiversity can retreat to or persist in, and then expand from if, in the future, the surrounding landscape once again becomes favourable (Keppel et al. 2012).

1.1 Species-specific refugia

Refugia have been classified and defined in several ways (Ashcroft 2010; Keppel & Wardell-Johnson 2012; Reside et al. 2014), and their value can be assessed by evaluating a range of alternative features, such as environmental stability, size, and accessibility (Keppel et al. 2015). However, climate refugia are generally dichotomised according to their spatial relationship with species' current known distributions (Figure 1.1). Internal (or *in situ*) refugia are portions of a species' current range projected to retain suitable conditions through time despite regional climate change (Ashcroft 2010). Such refugia may arise as a result of range contraction or incomplete range shifts (Gavin et al. 2014). Internal refugia may facilitate the persistence of existing populations (Patsiou et al. 2014; Ashcroft et al. 2009), and serve as reservoirs of biodiversity during eras of climatic instability (Correa-Metrio et al. 2014). Conversely, external (or *ex situ*) climate refugia refer to regions that are located outside the species' current range. External refugia are frequently identified as regions currently unsuitable, but that become suitable in the future (Ashcroft 2010; Loarie et al. 2008). A slightly different definition is that these are areas suitable now and in the future, but that are *currently unoccupied* by the target species. The identification of these regions is likely to be of value for species management as they represent *potential sites for species' translocation*. Access to external refugia may require rapid or long distance dispersal or, in some cases, human assistance (Hoegh-Guldberg et al. 2008; Vitt et al. 2009), depending on the distance from existing populations (Holderegger & Thiel-Egenter 2009).

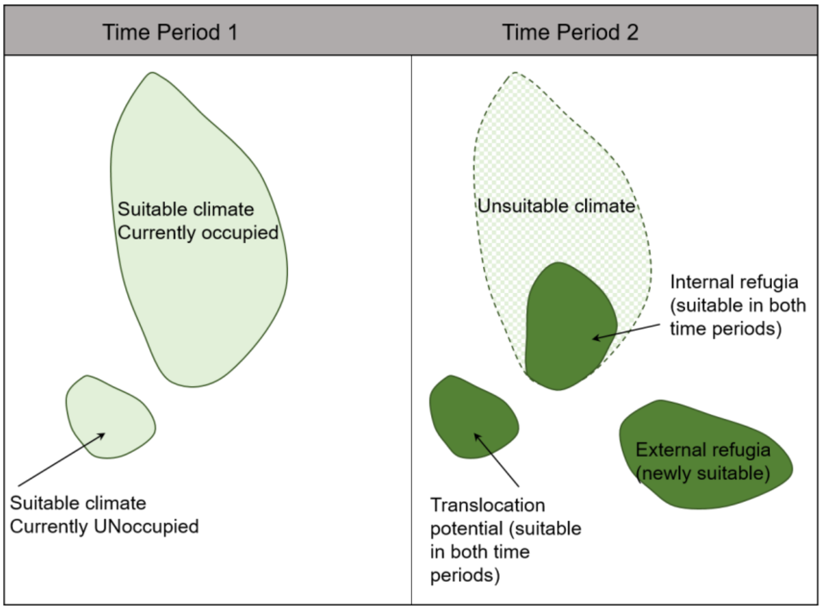


Figure 1.1. Diagrammatic representation of internal and external refugia, and areas with translocation potential.

The potential for refugia to mitigate the effects of climate change and safeguard the persistence of biodiversity is an important consideration for climate change adaptation planning (Maher et al. 2017; Mokany et al. 2017; Keppel et al. 2015). A given region may serve as climate refugia for multiple species, and the protection, conservation and effective management of such regions can optimise conservation practice and policy. Further, by conserving climate refugia, ecological and evolutionary factors may be captured, as sites that were refugia during historical climate change are likely to contain endemic and threatened species (Reside et al. 2013). Therefore, the identification of climate refugia is considered a key priority in mitigating the effects of climate change and safeguarding the persistence of biodiversity (Game et al. 2011; Groves et al. 2012; Shoo et al. 2013). As such, the NSW Government's *Priorities for Biodiversity Adaptation to Climate Change* (DECCW 2010) explicitly states that a key action for strengthening the protected area system is to "identify characteristics and locations of climate refugia in NSW bioregions and prioritise these in criteria for protection" (Action 2.6). However, uncertainty about the complexities of future climate and the velocity of climate change poses major challenges for conservation practitioners, and adaptation strategies must be robust to these uncertainties.

1.1.1 Identifying refugia using habitat suitability models

Habitat suitability models (HSMs) are the primary means of estimating species' responses to environmental gradients. These models estimate suitability for species based on the assumption that the environmental tolerances and preferences of species are described by the location of their current populations (Franklin 2010; Elith & Leathwick 2009). HSMs can then be used to map the distribution of suitable habitat for the target species, identify suitable areas beyond the species' known occupied range, and assess the suitability of a region under scenarios of past or future climate (Box 1). The complexity of HSMs range from the simple (e.g., range limits drawn on maps by species experts) to the highly sophisticated (e.g., approaches that explicitly consider the biophysical and behavioural mechanisms that translate environmental conditions to performance of individual organisms) (Kearney et al. 2008; Kearney & Porter 2009). However, due to their balance of flexibility, rapid development, and accuracy, HSMs are typically correlative, regression-like methods that estimate statistical relationships between species observations and environmental characteristics (Elith & Leathwick 2009; Franklin 2010). HSMs can play a critical role in supporting spatial conservation decision-making (Loiselle et al. 2003; Addison et al. 2013; Guisan et al. 2013), though their practical adoption by decision-makers remains rare (Guisan et al. 2013).

Box 1. Caveats regarding the interpretation of HSM output

While HSMs are useful tools for exploring the distribution of suitable habitat, several factors should be considered when interpreting their output. First, HSMs do not 'predict' where a species will be. These tools identify where suitable habitat occurs *with respect to the environmental variables used to calibrate the model*. An area may be classified by the HSM as suitable, yet the target species may be absent because of dispersal limitations or biotic factors (e.g. competition from other species or lack of resources). Alternatively, a variable important for the species (such as vegetation type) may have been excluded from the model, leading to predictions that indicate suitability of the considered environmental factors, under the assumption that vegetation is suitable. There are also likely to be some regions that are suitable for the species, but that the model suggests are either marginal or unsuitable. This is particularly relevant for species that have suffered substantial habitat loss or that are exotic to a region — the set of occurrence records used to calibrate the HSM may not span all climate combinations that the species can tolerate, and may underestimate the potential environmental and geographic ranges of the species.

Second, some occurrence records may occur in areas projected to be unsuitable. This may arise due to the value selected to convert continuous scores of suitability to binary scores of 'suitable' or 'unsuitable', or because not all occurrence records were used to calibrate the model (e.g., where those of low spatial quality were omitted). We term those records that passed our quality control check, and hence were used to fit models, as *high quality occurrence records*.

Third, with regards to the distribution of habitat in the future, HSMs may project a region to become unsuitable under climate change. However, populations may continue to occur there if they acclimatize or have sufficient plasticity, undergo genetic adaptation, or their micro-habitat buffers the change in climate. Similarly, an area currently unsuitable may be projected to become suitable in future, yet the species may not be able to disperse to occupy this area or the area may lack a necessary resource.

Finally, it must be remembered that HSMs are models, and models provide only a limited representation of reality. In order to develop a comprehensive understanding of species' responses to climate change, the output of HSMs should be used in conjunction with other information about the biology and ecology of species.

1.2 Choice of future climate scenarios for impacts assessments

When assessing biological responses to climate change, a key consideration is *which climate scenario should be used*? Frequently, this decision is based on convenience (Evans et al. 2014), and the selected scenario(s) may not necessarily be derived from climate models that perform well across a region of interest. Further, a chosen subset of climate scenarios may not reflect the range of uncertainty in future conditions represented by a broader set of scenarios. Hence, consideration of a greater number of climate futures may be necessary to capture the range of possible impacts.

Climate uncertainty can be explicitly incorporated into HSM analyses in several ways. Models can be projected onto a broad range of climate scenarios, yielding a set of predictions that better represents the plausible range of impacts. Unfortunately, computational constraints may render this approach infeasible, particularly for studies investigating outcomes for many species. Instead, climate projections from multiple climate models can be summarised into a smaller number of representative scenarios, e.g. the 10th, 50th and 90th percentiles of their projections. These summaries, however, may reflect conditions that are inconsistent with any particular climate model, or that are highly unlikely to occur (Beaumont et al. 2008). Alternatively, the suite of climate scenarios can be simplified to a set that captures a range of relevant, qualitatively contrasting futures. For instance, as part of the NSW and ACT Regional Climate Modelling (NARCliM) project, the performance of 23 climate models over south-eastern Australia was analysed (Evans et al. 2014). Those climate models with poor skill in simulating historical climate were excluded and the remaining climate models ranked based on their independence. This approach enabled identification of a group of models that spanned the broadest range of plausible futures. Rankings were mapped onto a biplot of future climate space framing changes in temperature, from warm to hot (relative to the baseline) and precipitation from decline to increase. A climate model from each of the four quadrants was then identified. These scenarios are now being used for a broad range of impacts assessments across south-eastern Australia. Importantly, variation across the resulting modelled impacts clearly captures uncertainty associated with future climate, and enables visualisation of spatial patterns of agreement about, in the case of HSMs, the distribution and suitability of habitat.

1.3 Objectives of this study

In this report, we combine best-practice HSM techniques with the climate data developed by the NARCliM project to assess the potential impacts of climate change on suitable habitat for key species occurring in NSW. Our objectives are to: (1) identify *internal* climate refugia, as well as areas of vulnerability to climate change, for species representative of plant communities in each of the six NSW bioregions; (2) identify areas that are *internal* climate refugia or that may be suitable sites for *translocation* for plant and animal species within the landscape- and site-managed streams of the Saving our Species (SoS) program; and (3) develop a web-based tool for visualising and querying outputs from this project.

2. Target Species

We included two sets of species in this project: a) 117 'representative' plant species [Appendix Table A1]; and b) 319 threatened species (81 landscape-managed species and 238 site-managed species; Appendix Table A2]).

2.1 Identification of 'representative' plant species

Six terrestrial ecoregions exist in NSW, defined by the Interim Biogeographic Regionalisation for Australia (IBRA Version 7; IBRA 2012) to facilitate conservation planning at large spatial scales: Deserts and Xeric Shrublands (hereafter DXS; ~71 950 km^2); Mediterranean Forests, Woodlands and Scrubs (MFWS; ~79,520 km^2); Montane Grasslands and Shrublands (MGS; ~5175 km^2); Temperate Broadleaf and Mixed Forests (TBMF; ~286,175 km^2); Temperate Grasslands, Savannas and Shrublands (TGSS; ~304,400 km^2); and Tropical/Subtropical Grasslands, Savannas and Shrublands (TrGSS; ~56,300 km^2). For each ecoregion, we used occurrence records from the NSW Office of Environment and Heritage BioNet Atlas (OEH Atlas) to identify the 30 most commonly recorded native plant species. This led to 154 unique species (some species were among the most common in more than one ecoregion). We filtered this list to retain only those species noted as representative (characteristic, abundant, or otherwise prominent) of floristic communities across the state (Keith 2004). The final list totaled 117 species (Appendix Table A1), with 24 species in DXS, 27 species in MFWS, 11 species in MGS, 23 species in TBMF, 28 species in TGSS, and 28 species in TrGSS.

2.2 Threatened species

This study focused on species included in the landscape- and site-managed streams of the Saving our Species (SoS) program. However, we excluded species found on Lord Howe Island as well as fungi and invertebrates, and taxa with < 20 'high quality' records from unique (i.e. 1 km x 1 km grid cells) locations.

2.2.1 Landscape-managed species

Landscape-managed species are threatened plants and animals that need broad landscape scale conservation projects. The objective of this management stream is to maximise the viability of species and their habitat by strategically investing in priority locations and management actions and working in partnership with stakeholders across NSW (OEH 2016). Some landscape-managed species might be widely distributed, highly mobile, or affected by landscape-scale threats. Thus, recovery for these species should address threats such as habitat loss or degradation within the landscape. There are 98 landscape-managed species, of which 81 had sufficient data for HSMs to be developed (Appendix Table A2). These consisted of nine Endangered and 72 Vulnerable species (Figure 2.1).

2.2.2 Site-managed species

Site-managed species are threatened plants and animals that can be secured by conservation projects at specific locations within NSW. For these species the objective is to maintain a 95% probability of having a viable population in the wild 100 years from now, and ensure that the species' status under the TSC Act does not decline (OEH 2016). Different conservation actions can be implemented for these species, including controlling erosion, controlling weeds and exotic predators, revegetation, and monitoring, among others. These actions allow the long-term protection of these species, enhancing their probability of persistence. There are approximately 440 site-managed species, and we developed models for 238 species (34 vertebrates and 204 plants) (Appendix Table A2). These consisted of 13 Critically Endangered (CR), 125 Endangered (EN), and 100 Vulnerable species (V) (Figure 2.1).

Figure 2.1. Number of Landscape- and Site-managed species for which habitat suitability modelling was undertaken, and their threat status.

2.3 Occurrence records

Occurrence records for the species included in this study were obtained from (a) OEH BioNet Atlas; (b) Victoria's Biodiversity Atlas; and (c) the Australasian Virtual Herbarium (AVH) hub of the Atlas of Living Australia (ALA, www.ala.org.au). ALA is a database comprising records arising from incidental observations and planned surveys. We used occurrence data from species' entire Australian ranges, rather than restricting our analysis to the subset of records from NSW. We cleaned occurrence data before use, removing records that met any of the following criteria: recorded prior to 1950; not georeferenced; coordinate uncertainty greater than 1000 m; invalid coordinate reference system; or noted by ALA as a spatial/environmental outlier, a duplicate record, an invalid scientific name, or cultivated. The AVH data were limited to records with associated voucher specimens, for which taxonomic identity is more certain. Finally, records for each species were overlaid on a 1 × 1 km raster grid (see Climate Data) and reduced to a single point per species within each cell. We note that this process *will have removed records from some regions known to contain the species, and that this will impact our calculations of internal refugia* (see Section 3.6 and Box 2). However, this process was necessary to maximise performance of the HSMs.

Generally, HSMs are not generated for species with few occurrence records, as there is insufficient information to statistically model the relationship between occurrences and the environment. As such, following the data cleaning process, species with records in < 20 grid cells were excluded from further analyses. We therefore developed models for 117 representative plant species, 81 landscape-managed vertebrate species and 238 (34 vertebrates and 204 plants) site-managed species. The number of records per representative plant species ranged from 37 (*Chionochloa frigida*) to 8543 (*Lomandra longifolia*), with an average of 2337 (SD = 2047) (Appendix Table A1). The number of records per threatened species ranged from 20 (seven species) to 17,647 (*Daphoenositta chrysoptera*, the Varied Sittella) (mean = 839; SD = 2134) (Appendix Table A2).

3. Methods

3.1 Derivation of climate data

3.1.1 Climate data

We used current and future climate data generated by the NSW and ACT Regional Climate Modelling (NARCliM) project (Evans et al. 2014). The standard set of 19 bioclimatic variables (BIOCLIM; Busby 1991) was obtained at 0.01 arc-degree (~1 km) resolution (Hutchinson and Xu 2014) for baseline climate (1990–2009), near-future (2020–2039), and distant future (2060–2079). We considered the three periods to be representative of the long-term average climate around their midpoints: 2000, 2030, and 2070.

3.1.2 Future Climate Scenarios

Future climate data were derived from NARCliM climate surfaces projected by four CMIP3 (Meehl et al. 2007) Global Climate Models (GCMs): MIROC3.2(medres), ECHAM5/MPI-OM, CCCMA CGCM3.1(T47), and CSIRO-Mk3.0. As part of the NARCliM project, the projections of these models were dynamically downscaled to 0.1 arc-degree resolution using three configurations of the Weather and Research Forecasting (WRF version 3; Skamarock et al. 2008) Regional Climate Model (RCM). The GCMs assumed the SRES A2 emissions scenario (Nakicenovic et al. 2000), which roughly follows the trajectories of the newer RCP8.5 scenario in terms of projected radiative forcing and global mean annual temperature (i.e., high emissions; IPCC 2013).

Our study used data from 12 climate scenarios (four GCMs, each downscaled using three RCMs), that encompass a range of equally plausible climate futures for south-eastern Australia (Evans and Ji 2012). Broadly, with respect to baseline (1990–2009) mean annual temperature and annual precipitation, MIROC3.2 represents a future that is warmer and wetter, particularly in the north-east of the state, although alpine regions are projected to become drier. CCCMA represents a future that is hotter than MIROC3.2, and one that is also wetter across most of the state, although areas in the north-west and south-east may be slightly drier. CSIRO represents a warmer future and is the driest of the four models. ECHAM5 projects the greatest increase in temperature, with the precipitation trend varying across the state (slightly wetter in the north-west and coastal regions and slightly drier elsewhere) (Table 3.1, Figures 3.1-3.4). Hereafter we refer to the scenarios as Warmer/Wetter (MIROC3.2), Hotter/Wetter (CCCMA), Warmer/Drier (CSIRO), and Hotter/Little change (ECHAM5).

Table 3.1. Climate futures used in this study. GCMs assumed the SRES A2 emissions scenario (Nakicenovic et al. 2000).

Climate Future	GCM	Represents a future that is:
Warmer/Wetter	MIROC3.2(medres)	Warmer and wetter than present, particularly in NE NSW, although alpine regions are projected to become drier.
Hotter/Little Change in Precipitation	ECHAM5/MPI-OM	Has the greatest increase in temperature of the four scenarios. Precipitation trend varies across the state (slightly wetter in the NE and coastal regions, slightly drier elsewhere).
Hotter/Wetter	CCCMA CGCM3.1(T47)	Warmer than MIROC, and wetter across most of the state, although areas in NW and SE of the state may be slightly drier.
Warmer/Drier	CSIRO-Mk3.0	Warmer than present, and the driest of the four models.

Climate data were further statistically downscaled to a resolution of 0.01 degrees (~1000 m) by M. Hutchinson (The Australian National University, Canberra) using thin-plate smoothing splines implemented in ANUSPLIN version 4.4 (Hutchinson & Xu 2013) and summarised to the standard set of 19 bioclimatic (BIOCLIM) variables using ANUCLIM version 6.1.1 (Xu & Hutchinson 2011). These data were generated for each of the NARCliM time periods, representing baseline climate (1990–2009), near-future (2020–2039), and far future (2060–2079).

Finally, climate data were transformed to the Australian Albers Equal-Area Conic projection (EPSG:3577) at 1 × 1 km resolution.

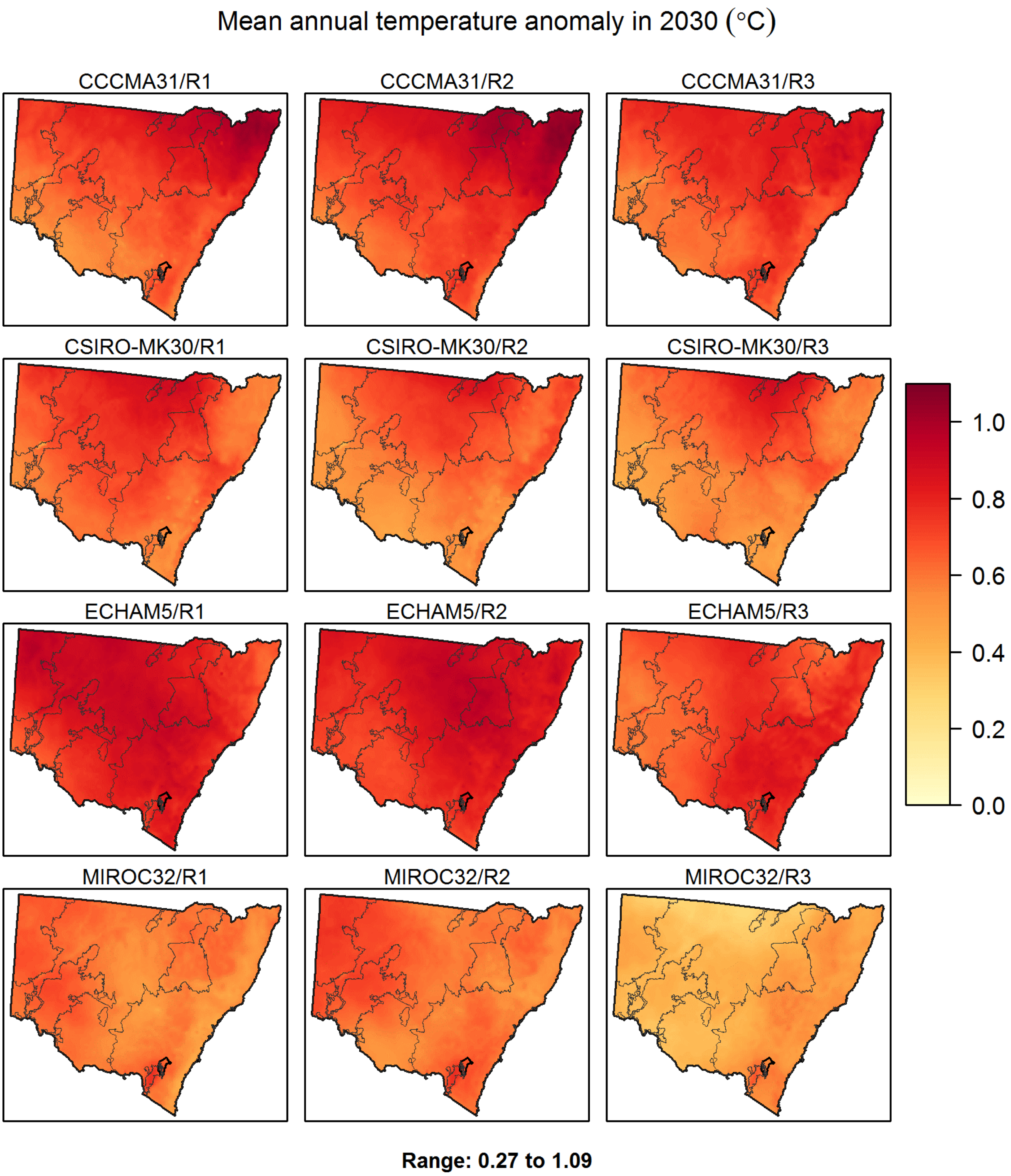


Figure 3.1. Difference between mean annual temperature (°C) in the period 1990–2009 and mean annual temperature in the period 2020–2039 (i.e. the latter minus the former). R1, R2, and R3 refer to the three alternative parameterisations of the RCM (see 3.1.2).

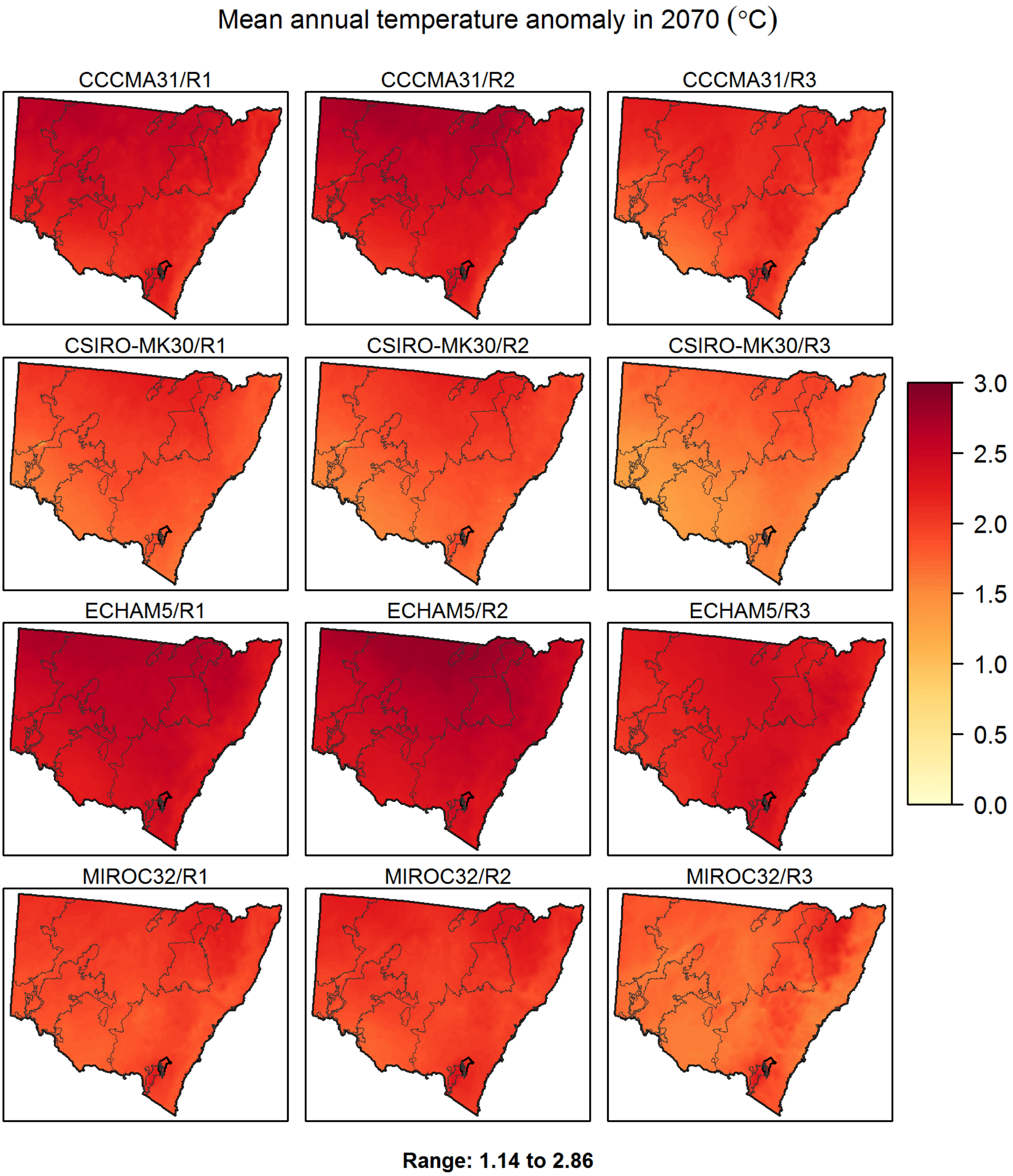


Figure 3.2. Difference between mean annual temperature (°C) in the period 1990–2009 and mean annual temperature in the period 2060–2079 (i.e. the latter minus the former). R1, R2, and R3 refer to the three alternative parameterisations of the RCM (see 3.1.2).

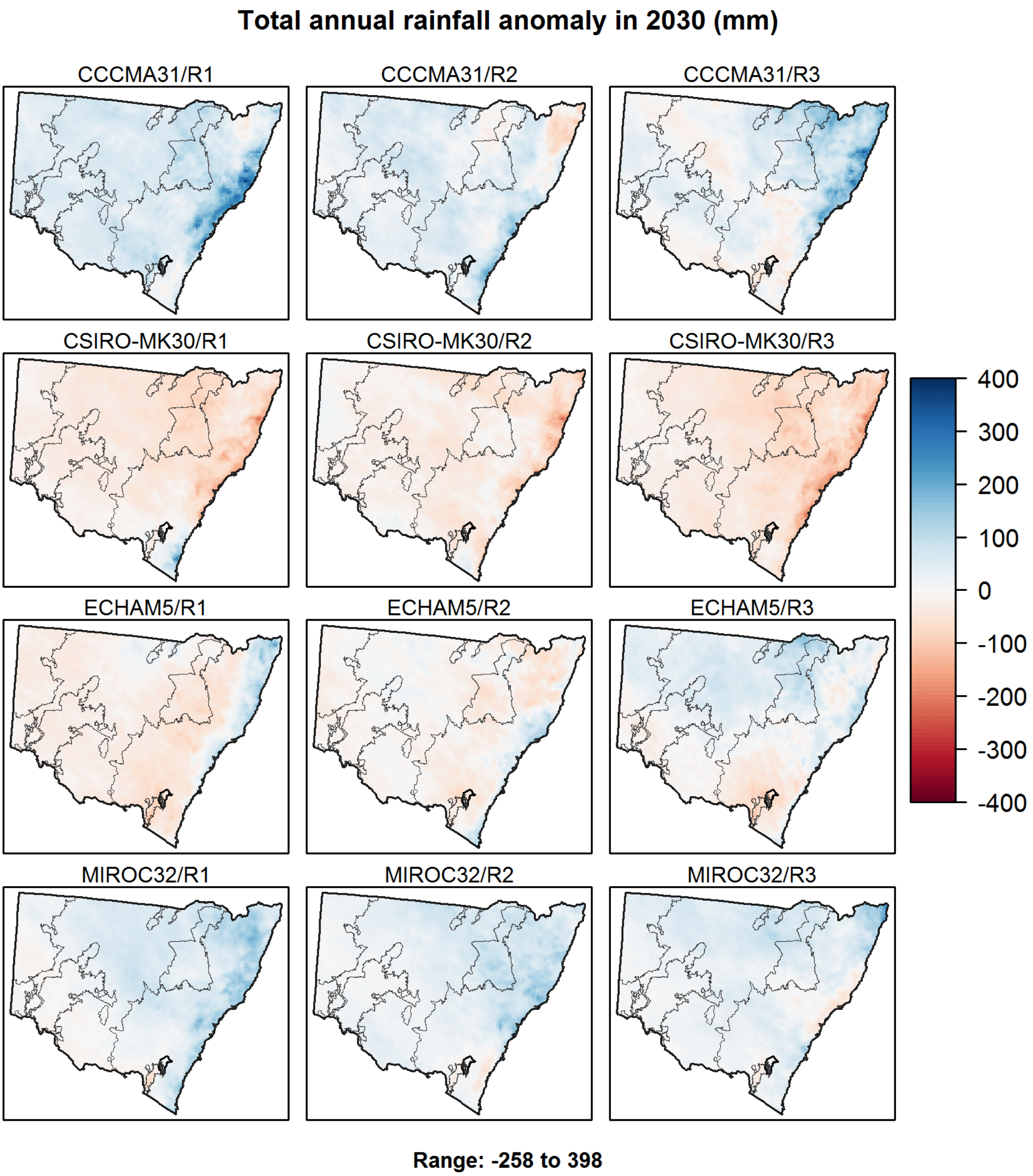


Figure 3.3. Difference between total annual rainfall (mm) in the period 1990–2009 and total annual rainfall in the period 2020–2039 (i.e. the latter minus the former). R1, R2, and R3 refer to the three alternative parameterisations of the RCM (see 3.1.2).

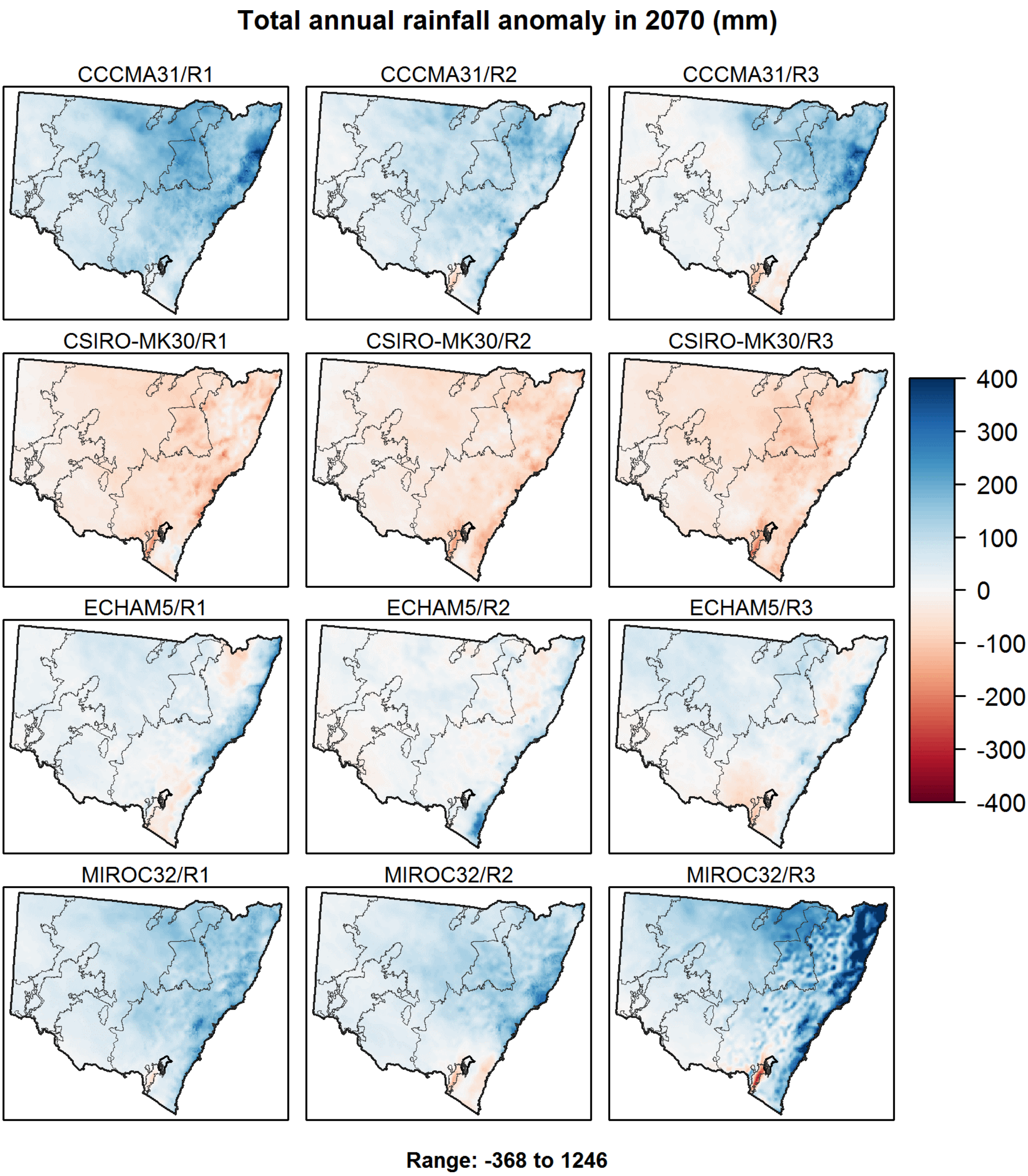


Figure 3.4. Difference between total annual rainfall (mm) in the period 1990–2009 and total annual rainfall in the period 2060–2079 (i.e. the latter minus the former). R1, R2, and R3 refer to the three alternative parameterisations of the RCM (see 3.1.2). Note that the colour ramp is truncated at 400 mm; some small regions receive rainfall as high as 1246 mm.

3.2 Environmental variables for HSMs

3.2.1 Current Climate

Of the 19 BIOCLIM variables derived by Hutchinson & Xu (see Section 3.1.2 above), we selected seven to develop HSMs: (1) mean weekly diurnal temperature range; (2) temperature seasonality (the coefficient of variation of weekly mean temperature); (3) maximum temperature of the warmest week; (4) minimum temperature of the coldest week; (5) precipitation of the wettest week; (6) precipitation of the driest week; and (7) precipitation seasonality (the coefficient of variation of total weekly precipitation). These represent a common set of climatic variables that influence ecophysiological functions, and hence, species distributions (Table 3.2).

Table 3.2. Set of bioclimatic predictors derived from BIOCLIM used for modelling. T_{max}, T_{min} and T_{mean} refer to daily maximum, minimum and mean temperature, respectively.

Variable	Definition
Mean Diurnal Range (MDR)	Mean of weekly (T_{max} – T_{min})
Temperature Seasonality (TS)	Coefficient of variation of weekly T_{mean}
Maximum Temperature of Warmest Week (T_{max}WW)	Highest T_{max} across all weeks of the year
Minimum Temperature of Coldest Week (T_{min}CW)	Lowest T_{min} across all weeks of the year
Precipitation of Wettest Week (PrWW)	Total precipitation of the wettest week
Precipitation of Driest Week (PrDW)	Total precipitation of the driest week
Precipitation Seasonality (PS)	Coefficient of variation of weekly total precipitation

3.2.2 Static environmental data

Environmental variables other than climate may also play a key role in delimiting species' distributions, and their incorporation in HSMs can refine projections of habitat suitability for some species (Hageer et al. 2017). We obtained several static environmental datasets describing soil properties and topographic characteristics. These layers were originally developed at a 3 arc-second (~90 m) resolution, which we aggregated to 1 × 1 km by calculating the average of contributing cells. Each of the layers was assumed to remain static for the projections of future habitat suitability.

Soil data: We used data describing soil attributes derived from measurements of the spectra of surficial (0–20 cm depth) topsoils (Viscarra Rossel & Chen 2011). These data represent the first three principal components (soil1, soil2, and soil3) from a principal components analysis performed on spectral characteristics of soil samples from across Australia. These data contain information about fundamental soil characteristics, including colour, particle size, and the amount of clay, iron oxide, organic matter, and water, which are likely to relate to plant species' distributions (Viscarra Rossel & Chen 2011). Soil1 describes the distribution of highly weathered soils, soil2 the distribution of soils with large amounts of organic matter, and soil3 the distribution of low relief landscapes with soils containing abundant smectite (clay) minerals (Viscarra Rossel & Chen 2011). We acknowledge that some soil attributes will change over relatively short time spans; however, data describing future states are presently unavailable. Furthermore, a number of studies have demonstrated that including edaphic variables can enhance the predictive capacity of HSMs (Hageer et al. 2017; Austin & Van Niel 2011).

Weathering intensity index (WII): Weathering intensity is a key characteristic of soil/regolith. This layer was developed by Wilford (2012) at a resolution of 100 × 100 m, and was based on airborne gamma-ray spectrometry imagery and the Shuttle Radar Topography Mission (STRM) elevation data. We aggregated this layer to 1 × 1 km by calculating the average of contributing cells.

Topographic Characteristics: We used two layers characterising topography. The Topographic Position Index (TPI) uses relative elevation as a fraction of local relief, classifying cells into classes corresponding to upper, mid, and lower slopes. The Topographic Wetness Index (TWI) estimates the relative wetness within a catchment.

3.3 Habitat Suitability Model

We modelled habitat suitability with Maxent version 3.3.3k (Phillips et al. 2006; Elith et al. 2011), a machine learning approach to habitat suitability modelling known for its high performance (Elith et al. 2006). A fitted Maxent model can be projected to environmental data, producing a continuous probability surface that can be interpreted as a relative index of habitat suitability with respect to the included predictors. Locations with higher values are deemed to have greater suitability for the modelled species (Phillips et al. 2006; Phillips & Dudik 2008). Detailed descriptions of Maxent are given elsewhere (Merow et al. 2013; Elith et al. 2011).

Model settings and parameterisation: Models were fit using default settings, besides disabling hinge and threshold features to minimise the incidence of locally-overfit response curves. Absence data were unavailable for this study, and it is highly likely that occurrence records sourced from natural history collections represent spatially- or environmentally-biased samples. To reduce this bias, our background samples comprised random samples of up to 100 000 cells from the pool of cells that (a) contained occurrence records for native fauna or flora (for animal and plant target species, respectively) and (b) fell within 200 km of records for the target species (i.e., a buffered target-group background, see Elith & Leathwick 2007; Phillips & Dudik 2008).

Ideally, when modelling a limited number of species, the use of alternate predictor variables should be explored to ensure that variables most relevant to the target species are used to fit the HSM. Such an individualised approach was not feasible during the first part of this study (i.e. modelling representative plant species). However, given the broad range of environments inhabited by species targeted in this study, we compared the performance of models fitted with three sets of environmental predictors (Table 3.3). Hence, for each species we generated three models (one for each of the variable 'sets'), assessed model performance (described below), and projected the model with the highest performance score onto the future climate scenarios. The remaining two models were discarded.

Table 3.3. Alternative environmental predictor sets used in the different models.

Environmental Predictor	Set 1	Set 2	Set 3
Mean Diurnal Range (MDR)	X	X	X
Temperature Seasonality (TS)	X	X	X
Maximum Temperature of Warmest Week (T_{max}WW)	X	X	X
Minimum Temperature of Coldest Week (T_{min}CW)	X	X	X
Precipitation of Wettest Week (PrWW)	X	X	X
Precipitation of Driest Week (PrDW)	X	X	X
Precipitation Seasonality (PS)	X	X	X
Soil characteristics (soil1, soil2, and soil3)		X	X
Weathering Intensity Index		X	X
Topographic Position Index			X
Topographic Wetness Index			X

Model performance: Classification performance was estimated for each model by calculating the average test AUC (Area Under the Receiver Operating Characteristic curve (see Swets 1988) and the maximum True Skill Statistic (TSS; Allouche et al. 2006) through five-fold cross-validation. This involved splitting occurrence data into five subsets of roughly equal size (i.e., folds), fitting the model to four of the five folds and predicting to the fifth. This process was repeated until each fold was used four times for model fitting and once for model evaluation (Stone 1974). Following this, models were fit a final time using the complete set of species data, and these final models were used for subsequent analyses.

3.4 Current Habitat Suitability

Habitat suitability for each species was estimated for the baseline period (2000), as well as for the 12 alternative future climates (i.e. three RCMs × four GCMs) for 2030 and 2070, by projecting final fitted models (described above) onto spatial data representing the corresponding states of climate and soil predictors. Continuous suitability predictions (where values range from 0 [unsuitable] to 1 [most suitable]) were then converted to binary layers indicating suitable/unsuitable habitat. The threshold for converting continuous to binary data was chosen to maximise the sum of sensitivity and specificity, a frequently-recommended approach that tends to reflect the prevalence of the modelled species well (Liu et al. 2013; Liu et al. 2016; Jiménez-Valverde & Lobo 2007). The actual value of this threshold was species specific, and represented a trade-off between false positive errors (classifying a grid cell as suitable when it is not) versus false negative errors (classifying a grid cell as unsuitable when it is suitable).

3.4.1 Changes to the size of suitable habitat

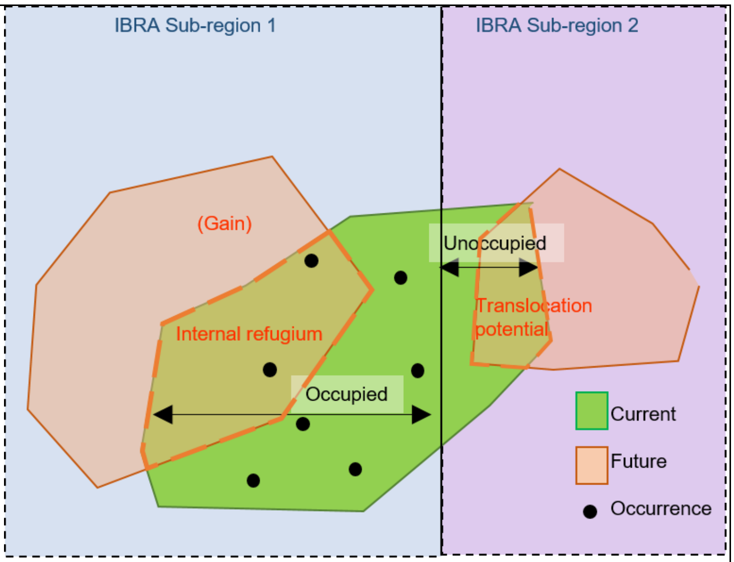
Using thresholded maps for each species, we calculated the projected change in the area with a) suitable habitat throughout the state (state-wide) and b) suitable *occupied* habitat within the state (i.e. where *occupied* refers to IBRA sub-regions[1] projected to be suitable and for which we have high quality occurrence records, see Box 2). We distinguish between these two areas because the former (state-wide) assumes that species can disperse to any location deemed suitable, whereas the latter assumes dispersal is more limited. Further, for representative species, we restricted our analysis to the ecoregions for which *that species was amongst the most prevalent* (i.e., the species was representative of those ecoregions).

Change in area is calculated as:

$$\frac{A_{future} - A_{current}}{A_{current}}$$

where $A_{current}$ is the area of currently suitable habitat and A_{future} is the area of habitat suitable under future climate. Note that changes in range size can come about if areas currently suitable are projected to become unsuitable in the future (*Loss*) or if areas that are currently unsuitable become suitable (*Gain*).

[1] IBRA sub-regions are spatial units defined by common climate, geology, landform, and vegetation, (IBRA 2012).



Box 2. Definitions of habitat area within an area of interest (AOI)

The above conceptual diagram illustrates the various partitions of climatically suitable habitat used in this report. In the example, an AOI (e.g. a section of NSW such as a Local Government Area) intersects two IBRA subregions. Areas of climatically suitable habitat for a hypothetical species are shown as polygons (green for currently suitable and orange for suitable in a future scenario). Black dots represent high quality occurrence records for the species. The region marked as Suitable is the total area with currently suitable habitat (green) within the AOI. The region marked as *occupied* is that portion of currently suitable habitat in the AOI that is also found within IBRA subregion 1, for which there are high quality occurrence records. The region marked as *unoccupied* is that portion of currently suitable habitat in the AOI that is found within IBRA subregion 2, for which there are no high quality occurrence records. These definitions allow us to distinguish between areas that are projected to contain suitable habitat and that are currently occupied versus areas with suitable habitat but are currently unoccupied. We can then calculate the proportion of current habitat (either *occupied* or *unoccupied*) that is no longer suitable in a future scenario – this represents 'loss'. Similarly, the proportion of current habitat that remains suitable under the future scenario is termed 'Stable'. For *occupied* habitat, these areas represent internal refugia. For *unoccupied* habitat, these represent areas potentially suitable for translocation. In contrast, an area within the AOI that is currently unsuitable but is projected to become suitable under a future scenario is termed 'Gain' and represents areas that could be considered as external refugia.

3.5 Identifying climate refugia for species

For a given species, the three RCMs belonging to each GCM were aggregated by consensus, considering a cell to be suitable only if it was suitable under all three RCMs (see Figure 3.5). This approach led to four alternative projections of suitability (one for each GCM) for each time period. Maps for different time periods were then stacked to identify cells that were projected to retain suitable climate across consecutive time periods. These cells are referred to as *refugia*. That is, a grid cell classified as an internal refugium in 2030 has been projected to be suitable under the climate scenario for 2000. Similarly, a grid cell classified as an internal refugium in 2070, has also been projected to be suitable under climates for 2000 and 2030.

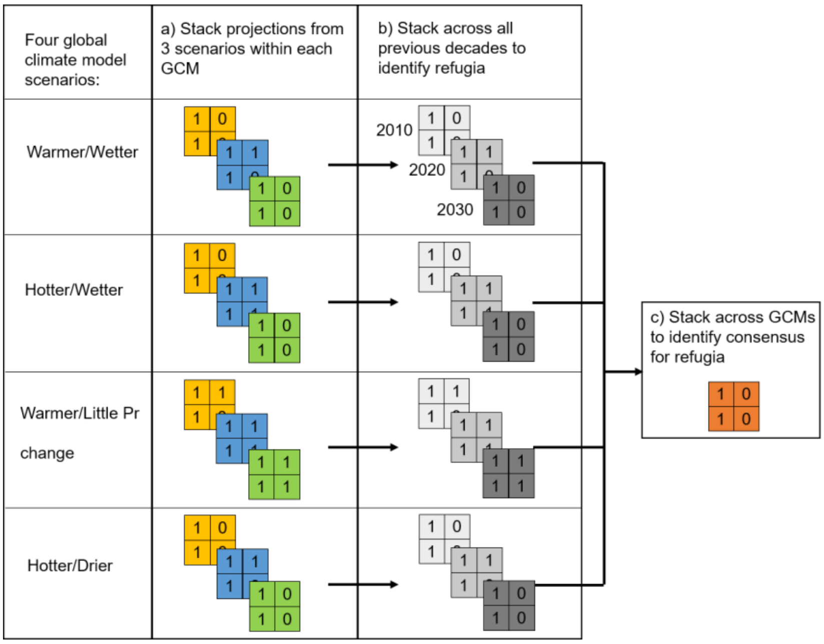


Figure 3.5. Diagrammatic representation of our approach to identifying internal refugia, regions with consensus for internal refugia, and regions with consensus for translocation potential.

3.5.1 Representative Species

For each ecoregion, we stacked maps for that region's representative species, calculated the number of species currently in the subregion and the proportion of these species for which suitable climate remains under each of the four climate futures. Next, we identified subregions projected to a) retain ≥ 50% of their representative species (*high richness refugia*), and b) lose ≥ 50% of their representative species (*areas of vulnerability*) under individual climate futures and across all four scenarios combined.

3.5.2 Threatened Species

In addition to calculating the size of internal refugia (areas occupied and projected to be suitable for a given climate scenario at the time of interest and at all preceding times) for a given species, we calculated the area covered by grid cells that were classified as internal refugia for that species under all climate scenarios. These are termed *regions with consensus for internal refugia*, and represent locations for which we are most confident about future habitat suitability irrespective of the climate scenario that prevails. Similarly, we calculated the size of *regions with consensus for translocation potential*. These are regions of *unoccupied* habitat projected to remain suitable under all climate scenarios and across time periods (see Box 2). We then placed species into one of four categories depending upon the proportion of their current range projected to have consensus for internal refugia or consensus for translocation potential.

Finally, we stacked maps of *consensus for internal refugia* for all species to identify *multi-species refugia*[2]. We suggest that *multi-species refugia* are sensible conservation targets, as these areas are likely to be robust to future variation in regional climate for multiple species (see Section 3.6 for more information). Maps of habitat suitability can be viewed and downloaded from the website www.nswclimaterefugia.net.

3.6 Analyses

All modelling and calculation of statistics were performed in R version 3.1.2 (R Development Core Team 2014). We used the gdalUtils (Greenberg & Mattiuzzi 2015), rgeos (Bivand & Rundel 2016), sp (Pebesma & Bivand 2005), and raster (Hijmans 2015) packages for representation, comparison, and manipulation of spatial data, the dismo package (Hijmans et al. 2016) to fit Maxent models, and custom R code for rapid projection of fitted models.

4. Results

4.1 Projected changes in suitable habitat for representative species

Across the 117 plant species included in this part of our report, average cross-validated test AUC ranged from 0.77 (*Pomax umbellata*; SD = 0.004) to 0.99 (*Chionochloa frigida*; SD = 0.006), indicating high classifier performance (Table A1) (Swets 1988).

Our goal was to identify areas that may serve as internal refugia from climate change. By definition, the extent of such areas relative to the baseline period can remain stable over time, or may decline. Expansion cannot occur, since a refugium must remain suitable across all considered time periods. Here, this implies that sites classified as internal refugia in 2030 must be occupied in 2000, and suitable in both 2000 and 2030, and for classification as internal refugia in 2070, sites must be occupied in 2000, and suitable in 2000, 2030, and 2070.

Averaged across the 117 species, refugia in the near (2030) and far (2070) future were projected to be more extensive under the Warmer (rather than Hotter) scenarios (e.g. under the Warmer/Wetter scenario refugia encompass, on average, 70.2% ± 20.5% [SD] of current suitable habitat by 2030, and 56.2% ± 26.3% by 2070) (Figure 4.1). In contrast, the smallest total area with refugia generally corresponded to the Hotter/Wetter scenario (2030: 52.4% ±

[2] These are conceptually similar to High Richness Refugia (HRR) identified for the representative plant species. However, to be classified as a HRR a grid cell needed to retain suitable conditions for 50% of its representative species. Multi-species refugia are simply refugia for > 1 threatened species.

30.9% of current habitat; 2070: 43.9% ± 32.1%). By 2070, between eight (Warmer/Wetter) and 23 (Hotter/Wetter) species are projected to have internal refugia that span < 10% of the extent of current habitat. In contrast, 11–14 species are projected to have refugia covering > 90% of their current habitat. The size and location of refugia can, however, vary substantially among species and ecoregions (see Figure 4.2 for location of each ecoregion).

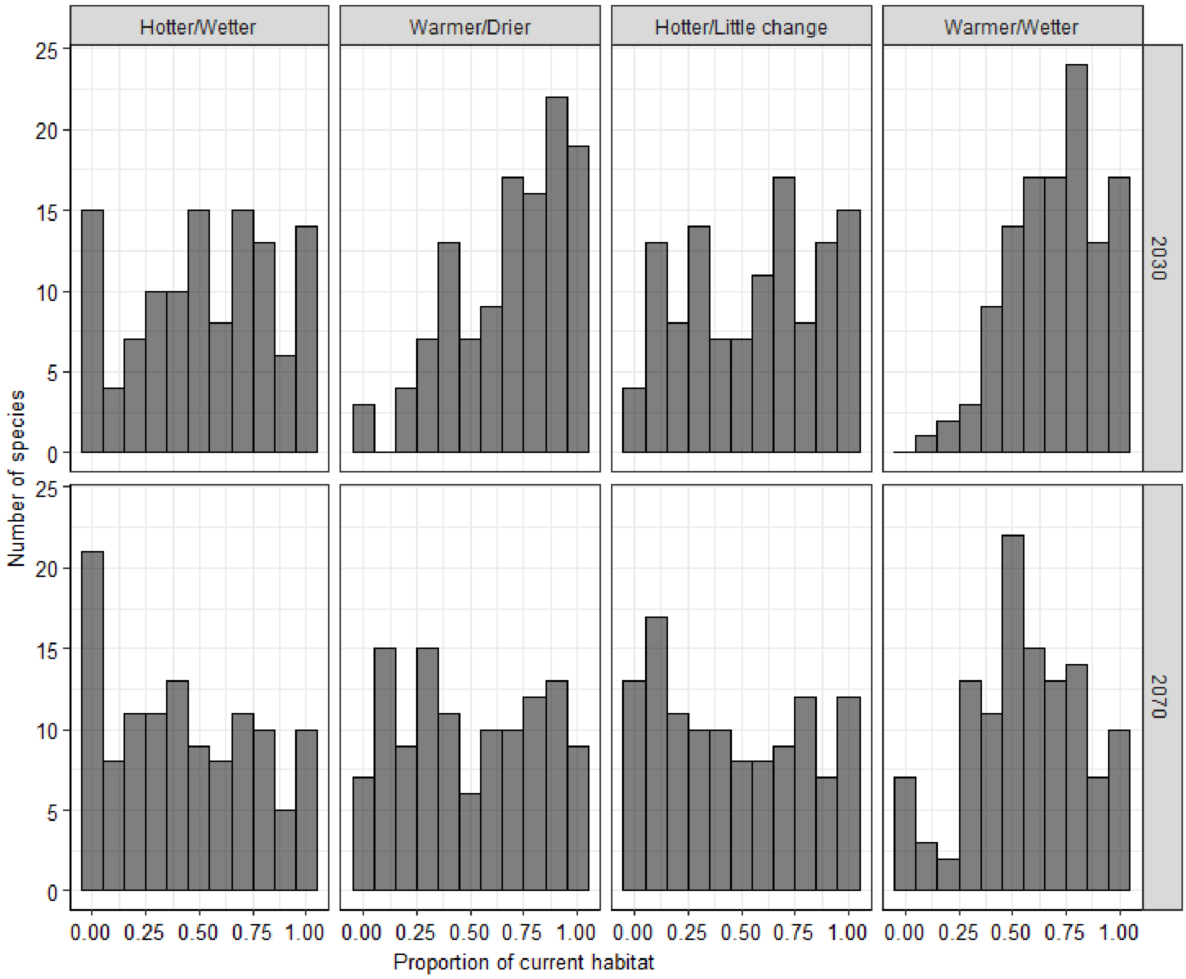


Figure 4.1. The histograms indicate the proportion of current habitat that is projected to remain suitable in 2030 and 2070, for 117 representative plant species across NSW.

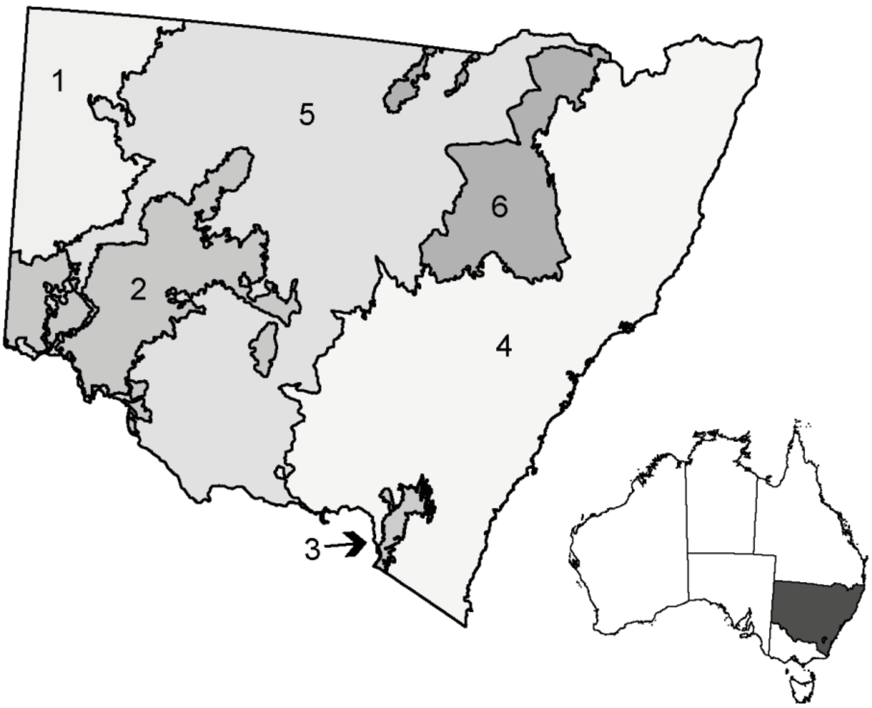


Figure 4.2. Ecoregions within NSW. 1. DXS = Deserts & Xeric Shrublands; 2. MFWS = Mediterranean Forests, Woodlands & Shrublands; 3. MGS = Montane Grasslands & Shrublands; 4. TBMF = Temperate Broadleaf & Mixed Forests; 5. TGSS = Temperate Grasslands, Savannas & Shrublands; 6. TrGSS = Tropical/Subtropical Grasslands, Savannas & Shrublands.

Deserts and Xeric Shrublands (DXS)

Across the 24 species representative of DXS, the median proportion of current habitat projected to offer refugia in 2030 ranged from 66.5% [8.3%, 87%] (Hotter/Wetter scenario; here and elsewhere, pairs of values given in square brackets indicate the 25th and 75th percentiles, respectively) to 78.9% [62.4%, 93.2%] (Warmer/Wetter) (Figure 4.3). Current habitat will likely remain very stable for some species. For example, for *Senna artemisioides*, *Sclerolaena lanicuspis*, and *Acacia victoriae*, more than 95% of current habitat is projected to be retained until at least 2070, regardless of the climate scenario. In contrast, other species (e.g., *A. ligulata*, *A. loderi*, and *Maireana sedifolia*) are projected to have limited, if any, refugia under at least three of the four scenarios.

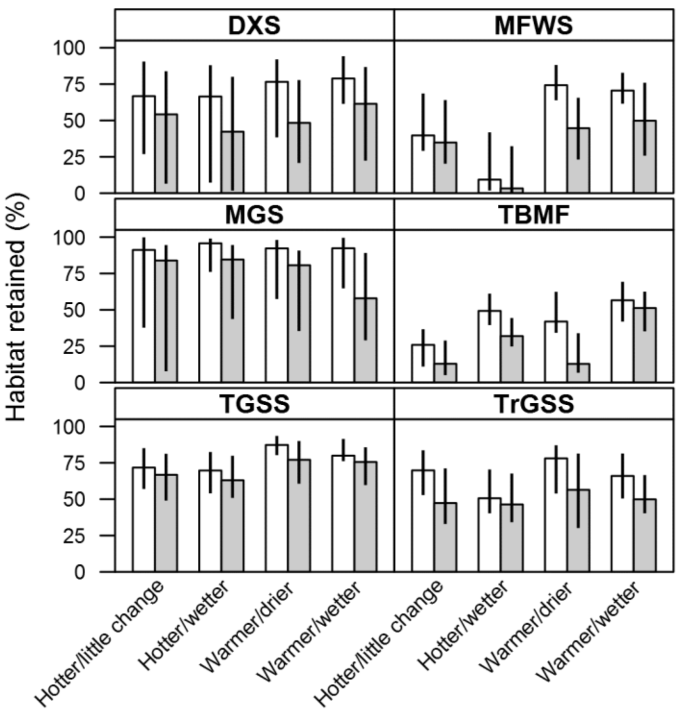


Figure 4.3. The proportion of currently suitable occupied habitat that remains suitable at 2030 (white bars) and at 2070 (grey bars). Results are presented for each ecoregion, and for each of four Global Climate Models (Hotter/Little precipitation change; Hotter/Wetter; Warmer/Drier; Warmer/Wetter, compared to mean annual temperature and annual precipitation for the period 1990–2009). Note that this is equivalent to the proportion of habitat that is considered to be internal refugia. Bar height indicates the median across species representative of the ecoregion, and error bars show the 25th and 75th percentiles. Ecoregion abbreviations are as in Figure 4.2.

We identified areas of 'high richness refugia' (HRR), that is, areas within ecoregions that are projected to retain refugia for at least 50% of their representative species (Figure 4.4, Appendix Figure A1.1). There are considerable differences in the projected location of HRR across the four climate scenarios. HRR are projected to be most extensive under the Warmer/Wetter scenario, particularly across the southern region of DXS by 2030, although these areas will fragment and reduce in size greatly by 2070. In contrast, a greater extent of the north-west quadrant is projected to be refugia by 2030 under the Hotter/Little change scenario, although much of this – particularly in the west – will likely be lost by 2070. Very small, scattered HRR are projected under the Hotter/Wetter scenario for 2030, and disappear before 2070. In contrast, there is some overlap in the arrangement of HRR in the Warmer/Drier scenario with that under the Hotter/Little change and Warmer/Wetter scenarios, for 2030, although these are no longer suitable by 2070.

In summary, there is little overlap across the four scenarios in the location of HRR in DXS (as indicated in Figure 4.4 by how few pixels in the Consensus panel are dark blue [suitable under three scenarios] or red [suitable under all scenarios]). The primary area with consensus falls within the eastern range of Sturt National Park, in the northwest of the state. However, by 2070 this region may likely represent refugia under the Hotter/Little change scenario only. A key area with vulnerability lies in the south-east of this ecoregion, an area that currently supports a high proportion of representative species but which is projected to be unsuitable for most by 2070 (Figure 4.5, Appendix Figure A2.1 – bright blue represents areas of high vulnerability).

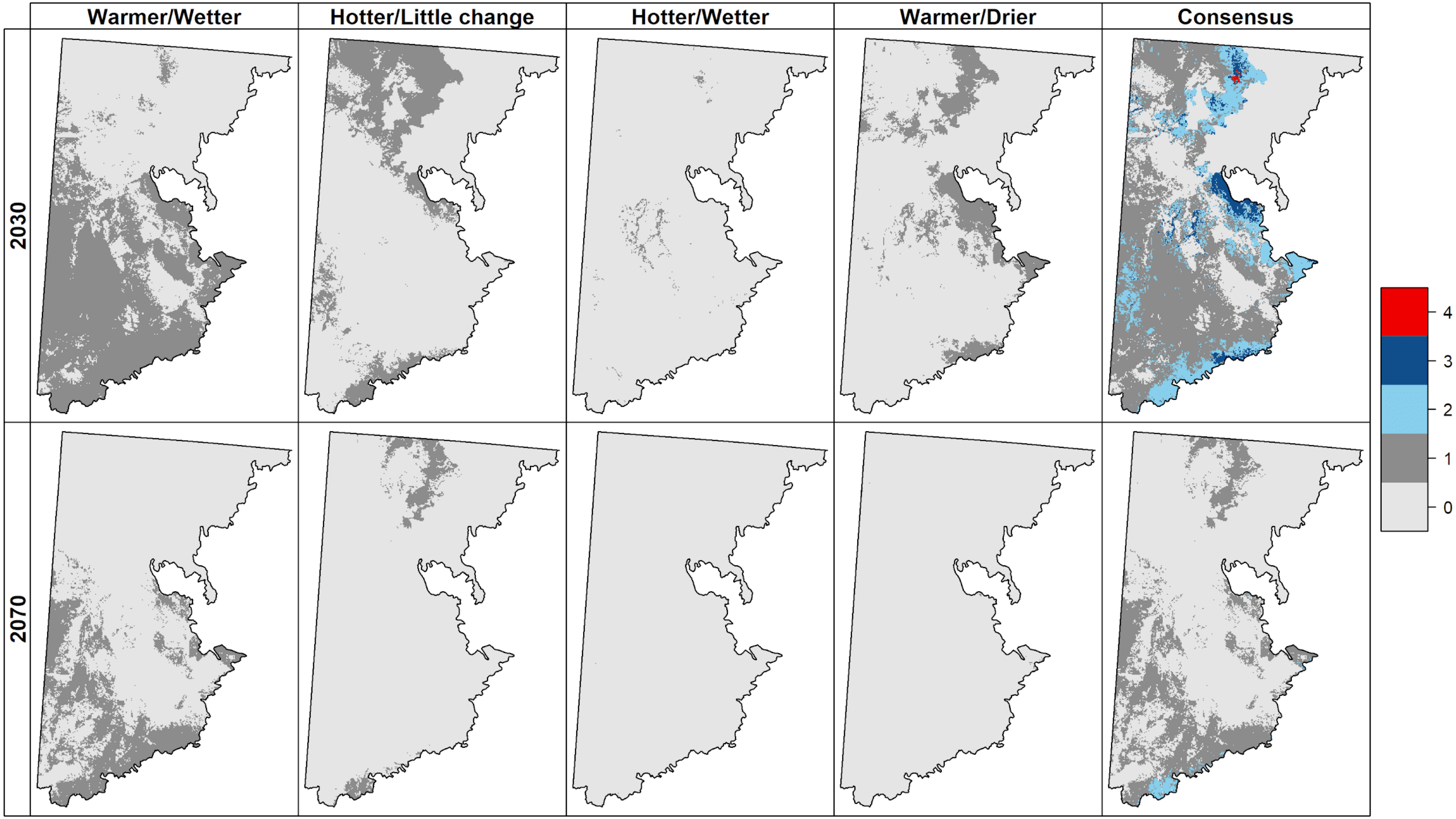


Figure 4.4. The distribution of High Richness Refugia (HRR) in the Deserts & Xeric Shrublands ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.1.

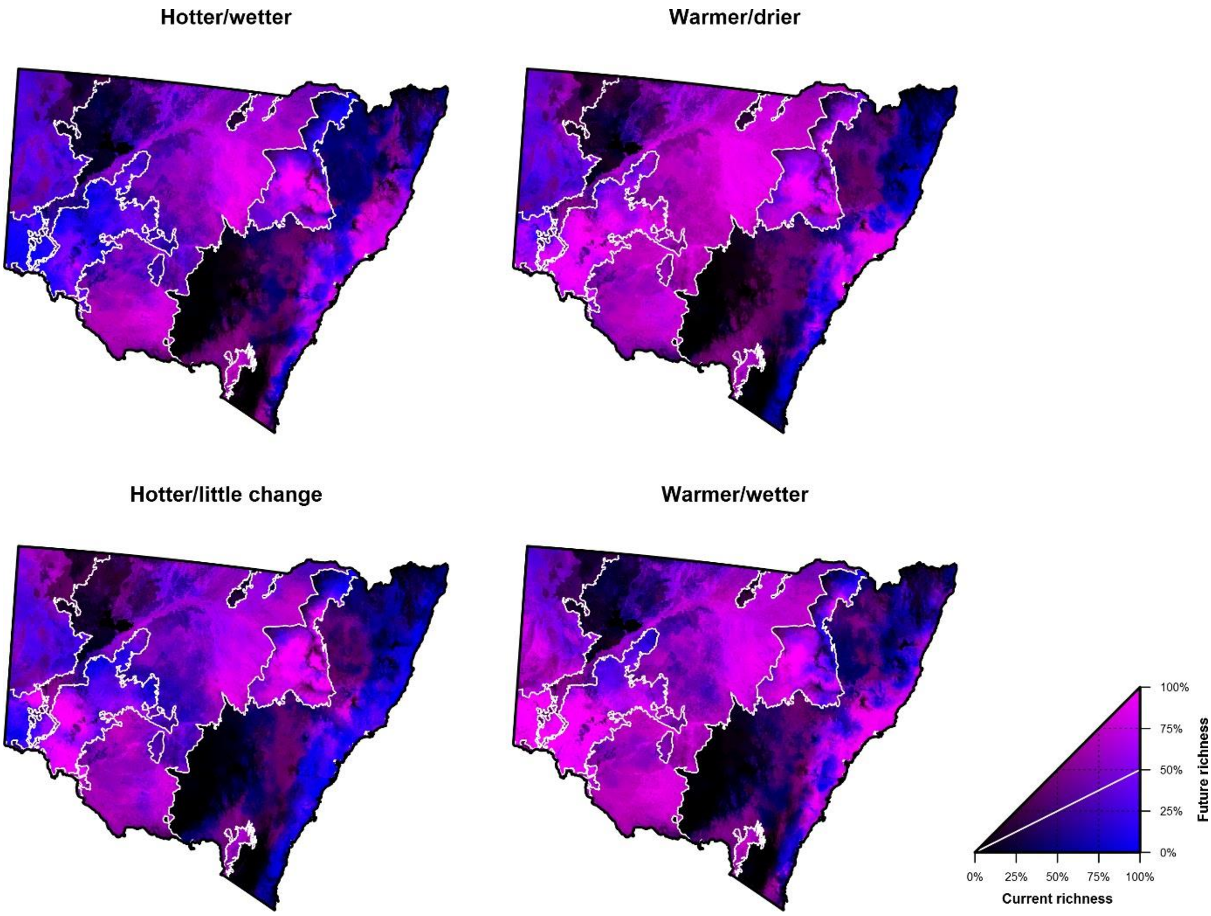


Figure 4.5 Refugia and areas of vulnerability across New South Wales under four future climate scenarios for 2030 and 2070. Colours are interpreted as in the triangular legend at right, which shows current and future richness as a proportion of the number of representative species for each of the six ecoregions (which ranges from 11-27). Purple colours (above the white line in the legend) indicate that habitat is retained for more than 50% of initially occurring, representative species, while blue colours (below the white line) indicate that habitat is lost for more than 50% of initially occurring representative species. Darker colours indicate that initial richness was low relative to the pool of representative species. Bright blue indicates vulnerable high-richness areas (i.e. where current projected richness is high, but future richness is low); dark blue indicates vulnerable low-richness areas (current richness is low, future richness is lower); bright purple areas indicate high richness refugia (HRR; both current and future richness are high); and dark purple indicates low richness refugia (current richness is low but maintained into the future). For larger maps of each ecoregion, see Appendix Figures A2.1– A2.6.

Mediterranean Forests, Woodlands and Scrub (MFWS)

Within this ecoregion, the size of refugia for the 27 representative species varies greatly across the four scenarios. In 2030, refugia are projected to cover the greatest proportion of current habitat under the warm scenarios (median for Warmer/Drier = 74.3% [64.9%, 87.1%]; Warmer/Wetter = 70.6% [62.5%, 81.8%]), and the smallest under the Hotter/Wetter scenario (median = 9.3% [2.9%, 40.8%]) (Figure 4.6, Appendix Figure A1.2). Only one species, the shrub *S. artemisioides*, is projected to retain all current habitat by 2070, regardless of climate scenario. In contrast, for 15 species refugia in 2070 will span < 10% of current habitat under the Hotter/Wetter scenario, although the habitat of only two will decline to this extent in the Warmer/Wetter scenario.

HRR are projected to be extensive under the two warmer scenarios, spanning most of the ecoregion by 2030 (Figure 4.6, Appendix Figure A1.2), and are located across a number of protected areas, including Mungo National Park. By 2070, contraction of HRR is projected in the north under the Warmer/Wetter scenario, and in central and western regions under the Warmer/Drier scenario (Figure 4.6, Appendix Figure A1.2). HRR are projected to be least extensive under the Hotter/Wetter scenario, remaining only in scattered regions in the south-east by 2070, with the western fringes and central regions projected to be particularly vulnerable (Figure 4.6, Appendix Figure A1.2). All four scenarios project a large, contiguous area with HRR south of Mungo National Park. Another area with vulnerability, given the number of representative species with current habitat there, is the northern-central region to the south of Wilcannia (Figure 4.5, Figure A2.2).

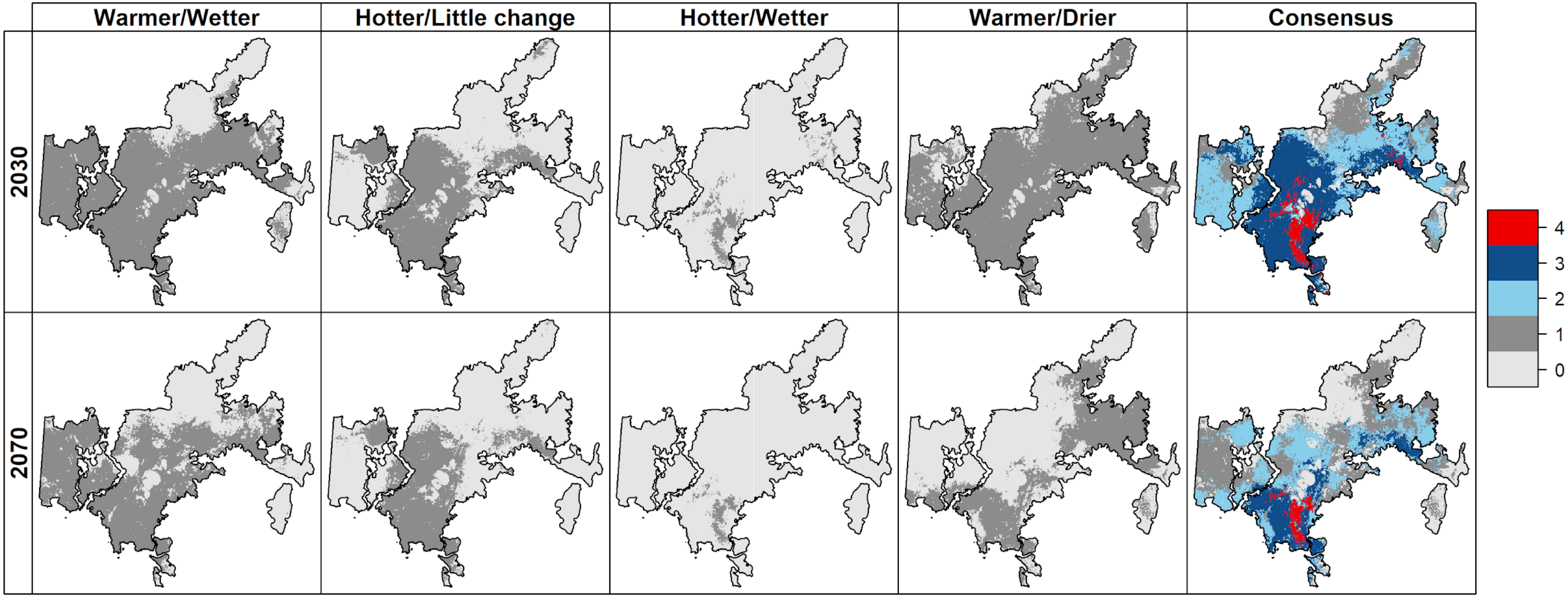


Figure 4.6.The distribution of High Richness Refugia (HRR) in the Mediterranean Forests, Woodlands and Shrublands ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.2.

Montane Grasslands and Shrublands (MGS)

This is the smallest ecoregion within NSW, and is predominantly contained within protected areas. Although we refer to climate scenarios by the titles stated in Methods (e.g., Warmer/Wetter; Warmer/Drier, etc.), note that almost all models project drying to occur in MGS (Figure 4.7, Appendix Figure A1.3). Compared to other ecoregions, substantial refugia are projected for all 11 representative species, with > 90% of current habitat remaining suitable by 2030 for five species, regardless of climate scenario (Figure 4.7, Appendix Figure A1.3). Generally, little loss is projected for the representative *Eucalyptus* species across most scenarios, while refugia are less extensive for ground cover species.

Both of the Wetter scenarios project HRR to exist throughout much of this ecoregion in 2030, while the Drier and Little Change scenarios exclude the central spine of the ecoregion (Figure 4.7). By 2070, lower altitude margins are no longer projected to be HRR, and there is less agreement across the four scenarios (also see Appendix Figure A2.3).

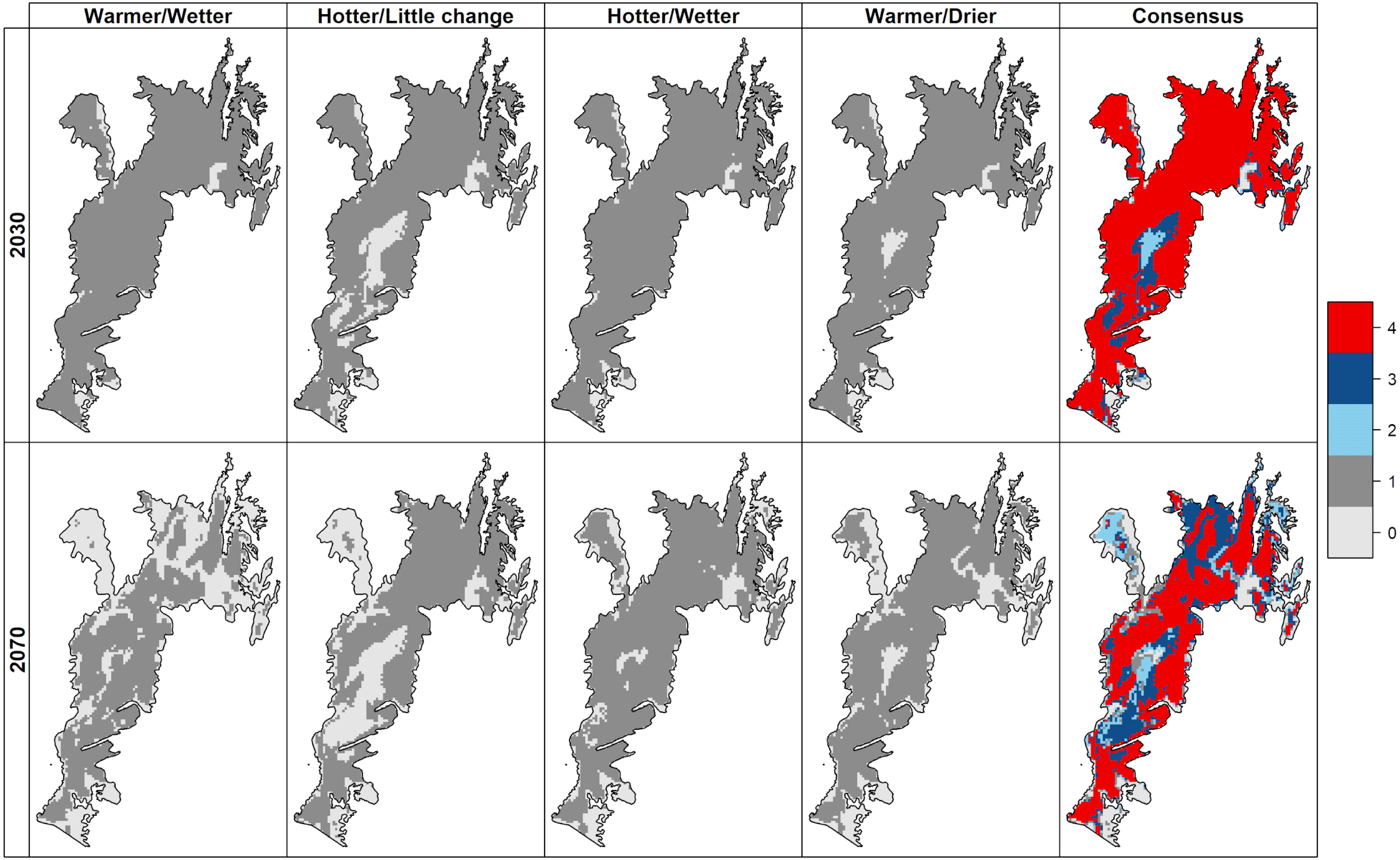


Figure 4.7. The distribution of High Richness Refugia (HRR) in the Montane Grasslands and Shrublands ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.3.

Temperate Broadleaf and Mixed Forests (TBMF)

This ecoregion is vast, spanning the latitudinal extent of the state and including the entirety of the heavily urbanised eastern seaboard. Across the 23 representative species, the median proportion of current habitat in refugia at 2030 ranges from 25.9% [12.0%, 35.6%] under the Hotter/Little change scenario, to 56.5% [42.9%, 68.3%] under the Warmer/Wetter scenario (Figure 4.3). While there is substantial variation in projections for individual species, there are no species protected to either retain or lose most of their current habitat across all four scenarios.

HRR are primarily limited to the central coastal zone of this ecoregion (Figure 4.8, Appendix Figure A1.4), and are more extensive and persistent under the Wetter scenarios. Few areas are classified as HRR under the Hotter/Little change scenario, with north, south and west regions mostly devoid of HRR regardless of scenario. Thus, even by 2030 there is little overlap in the placement of HRR across scenarios, although two small areas of agreement lie within or nearby national parks such as Mount Royal, Myall Lakes, and Wollemi NP, north of Sydney, and Kangaroo Valley to the south (Figure 4.8, Appendix Figure A1.4). By 2070, only small sections of Myall Lakes and Wollemi NP are projected to remain suitable across all scenarios. Key areas of vulnerability in the north and south of this ecoregion include numerous large, well-connected protected areas along the Great Dividing Range. As such, much of the eastern coastal margins are classified as areas of vulnerability by 2070 (Figure 4.5, Figure A2.4).

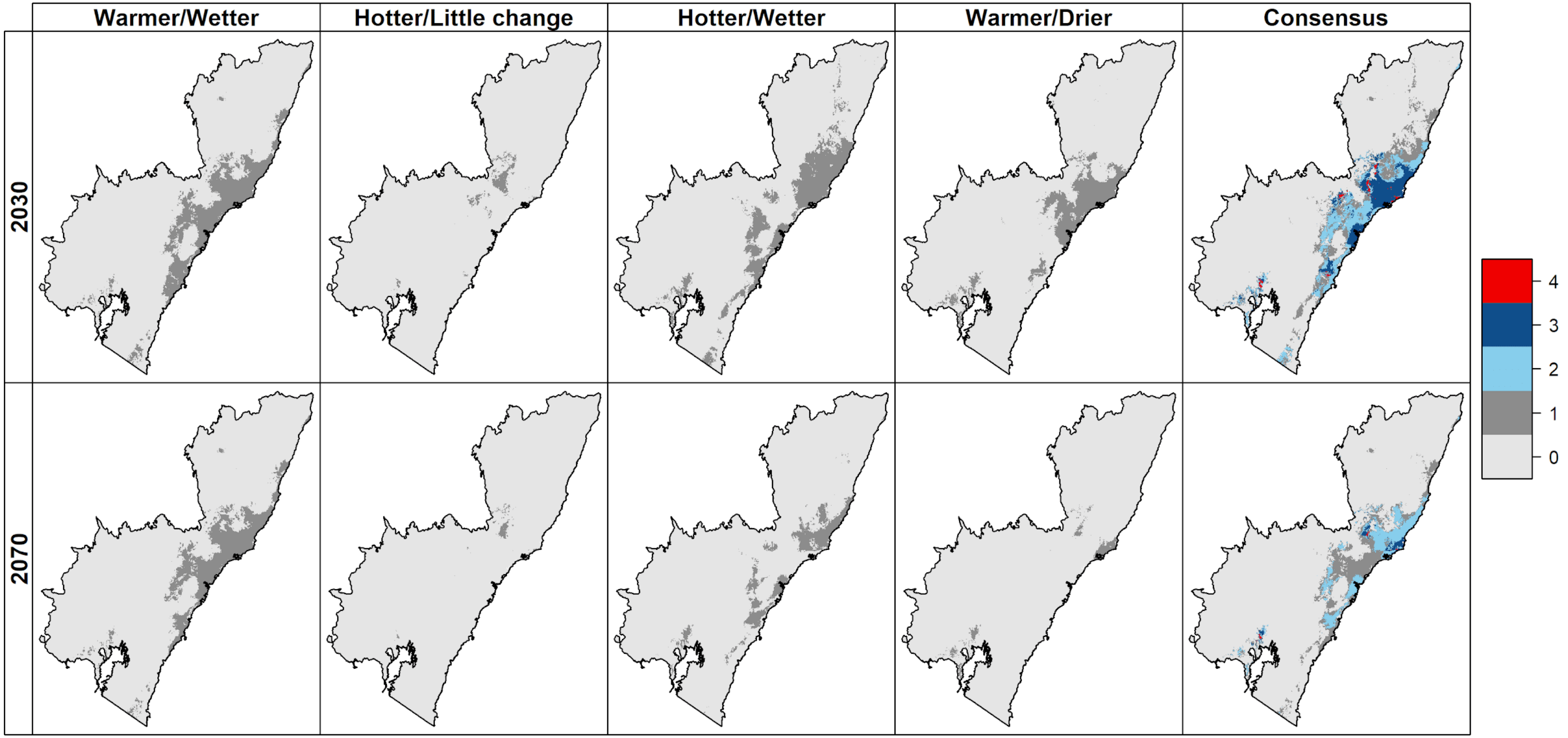


Figure 4.8. The distribution of High Richness Refugia (HRR) in the Temperate Broadleaf and Mixed Forests ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.4.

Temperate Grasslands, Savannas and Shrublands (TGSS)

Although refugia are less extensive under the Hotter scenarios, few species are projected to lose > 50% of current habitat by 2030 (and none under the warm scenarios) (Figure 4.9, Appendix Figure A1.5). Several species (e.g., *Acacia stenophylla*, *Eucalyptus coolabah*, *Eremophila mitchellii*) are likely to retain all current habitat within this ecoregion, regardless of scenario. By 2030, median refugia are projected to span between 67.5% [55.0%, 81.4%] of current habitat under the Hotter/Wetter scenario to 87.3% [81.3%, 92.5%] under the Warmer/Drier scenario.

HRR are projected to be extensive in 2030, particularly under the Warmer scenarios, with little decrease in size by 2070 (Figure 4.9, Appendix Figure A1.5). There is considerable overlap in HRR across the four scenarios, with large contiguous refugia projected in the northeast (within the Darling Riverine Plains bioregion) and the south (within the Riverina bioregion). HRR in both of these regions span several isolated protected areas. In contrast, there is greater uncertainty in the central region of this ecoregion (Cobar Peneplains), which is projected to retain HRR under only 1-2 of the scenarios. Although few HRR are identified for the northwestern portion of this ecoregion, there are also very few of the representative species present (Figure 4.5, Appendix A2.5).

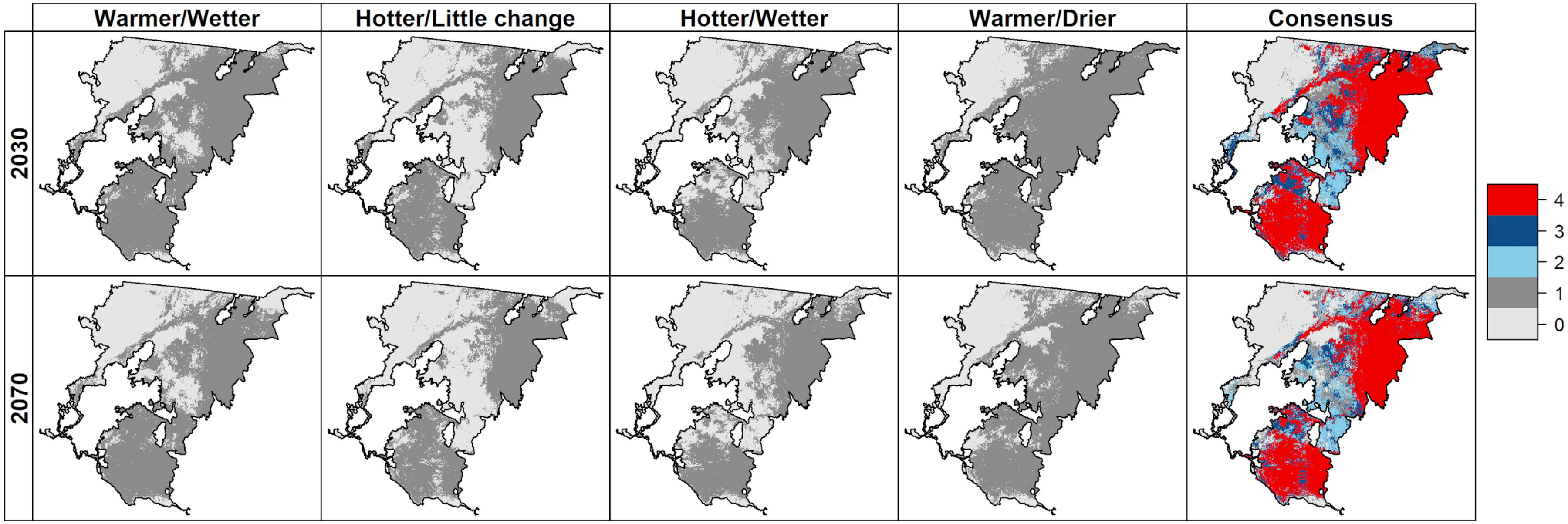


Figure 4.9. The distribution of High Richness Refugia (HRR) in the Temperate Grasslands, Savannas and Shrublands ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.5.

Tropical/Subtropical Grasslands, Savannas and Shrublands (TrGSS)

Across this ecoregion, refugia in 2030 cover the greatest proportion of current habitat under the Warmer/Drier scenario (median = 78.1% [54.9%, 86.1%]) and least under the Hotter/Wetter scenario (median = 50.6% [41.3%, 69.4%]) (Figure 4.10, Appendix Figure A1.6). All representative species are projected to retain refugia across all scenarios, although for some species substantial variation occurs. For instance, refugia for the spear-grass *Austrostipa verticillata* is projected to be restricted to < 25% of its current distribution under the Hotter/Wetter scenario for 2030, but > 85% under the Warmer/Drier scenario.

HRR projected in the north-eastern part of this ecoregion, primarily under the Warmer/Drier scenario, for 2030 will likely be lost before 2070 (Figure 4.10, Appendix Figure A1.6). This region will be a key area with vulnerability, currently containing habitat for a high proportion of the representative species, few of which will retain habitat here by 2070 (Figure 4.10, Appendix Figure A1.6). In contrast, all scenarios project HRR in the south, extending across the Pilliga region and its associated protected areas. These refugia, however, will contract in size by 2070, and fragment, particularly in the south-east (Figure 4.10, Appendix Figure A1.6). The north western fringes of the ecoregion are currently highly suitable for only a few of the representative species and will likely remain so until at least 2030 (Figure 4.5, Figure A2.6).

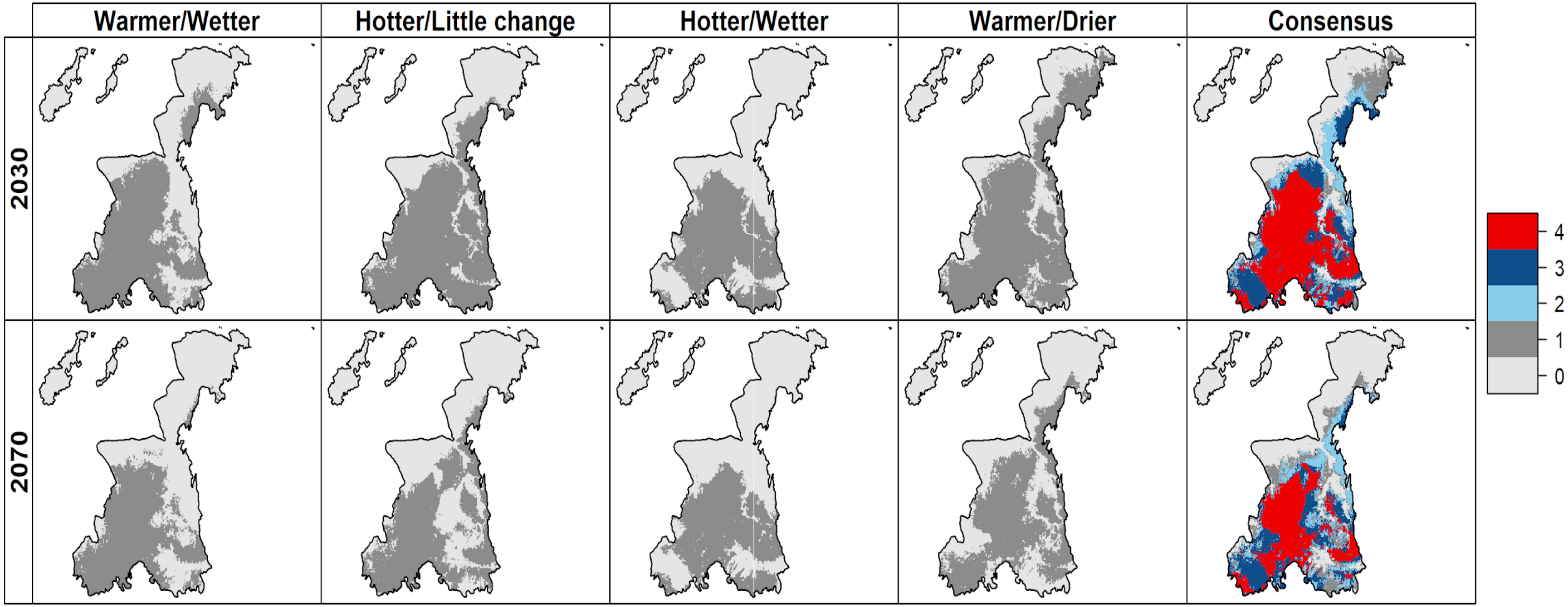


Figure 4.10. The distribution of High Richness Refugia (HRR) in the Tropical/Subtropical Grasslands, Savannas and Shrublands ecoregion under four contrasting climate scenarios for 2030 (top row) and 2070 (bottom row). In columns 1–4, dark gray indicates HRR; the final column combines the first four columns, showing whether cells are HRR under 0 (light gray), 1 (dark gray), 2 (light blue), 3 (dark blue), or all 4 (red) scenarios. For a larger image of consensus, see Figure A1.6.

4.2 Current and future suitable habitat for threatened species

We modelled habitat suitability for 81 landscape-managed and 238 site-managed species. Further, we have developed breviated reports summarising results for landscape- and site-managed species in each Local Government Area (LGA), Local Land Service area (LLS), State Planning Region (SPR), National Resource Management region (NRM), and large National Parks (NP) within the state. These can be downloaded from our associated website www.nswclimaterefugia.net.

For the species included in this part of our report, average cross-validated test AUC ranged from 0.627 (± 0.004 [SD]) (*Hieraaetus morphnoides*, Little Eagle) to 0.999 (± 0.0003) (*Eucalyptus canobolensis*, Silver-leaf Candlebark). As the average AUC across the 319 species was 0.916 (± 0.072), this indicates generally high classifier performance (Appendix Table A2) (Swets 1988). We note, however, that in addition to *H. morphnoides*, models were only fair for *Daphoenositta chrysoptera* (Varied Sittella, AUC = 0.634 ± 0.003) and *Circus assimilis* (Spotted Harrier, AUC = 0.697 ± 0.005), meaning that less confidence can be placed in these models. On average, temperature seasonality, minimum temperature of the coldest week, and precipitation of the wettest week contributed most to models (17.3% ± 19.1%, 17.3% ± 20.0%, 14.1% ± 15.1%, respectively). In contrast, the topographic position index and the second soil variable (Soil 2, PC2) contributed least on average (0.8% ± 1.6%, 2.2% ± 3.9%, respectively). Contributions of variables to the model (permutation importance, reported by Maxent) are given for each species in the Appendix Table A3.

Both landscape- and site-managed species are primarily found along the east coast of Australia. Key SPRs containing high numbers of landscape-managed species include the North Coast, Hunter Central Coast and Greater Sydney SPR, and the Central West and South West Riverina. Suitable habitat (Figure 4.11) for site-managed species is predominantly located in the north-east corner of the North Coast SPR and the Greater Sydney SPR. We initially quantified the area within NSW classified as climatically suitable for each species irrespective of distance to high quality occurrence records (i.e. 'state-wide habitat'). On average, state-wide habitat was projected to span 62,096 km^2 (± 104,846 km^2). This area is considerably larger for landscape-managed species (146,798 km^2, ± 156,754 km^2) compared those that are site-managed (33,268 km^2, ± 56,292 km^2). However, when only areas that are *occupied* were considered (where *occupied* is defined as all suitable grid cells within any IBRA sub-region polygons for which high quality occurrence records were located, see Box 2), suitable habitat is projected to span 125,568 km^2 (± 154,014 km^2) and 8,391 km^2 (± 17,999 km^2) for landscape- and site-managed species, respectively.

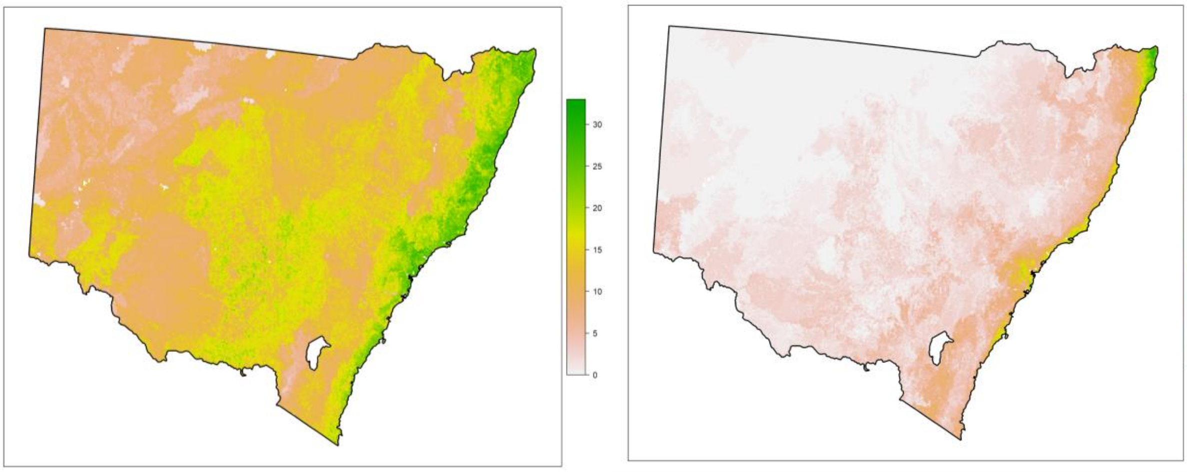


Figure 4.11 Projected distribution of current (2000) suitable habitat for landscape-managed (left) and site-managed (right) species.

4.2.1a Changes to the size of suitable habitat

Extent of habitat across New South Wales — landscape-managed species: By 2030, the median spatial extent of suitable habitat for landscape-managed species is projected to remain similar to the current period. The median change under the Hotter/Wetter scenario represents a slight decline of -1.3% [-31.2%, 15.1%] (*values given in square brackets indicate the 25th and 75th percentiles, respectively*), relative to the size of current habitat. The median change under the other scenarios represents minor increases of 1.0 to 2.4% [Hotter/Little Change: -41.3%, 57.8%; Warmer/Drier: -19.4%, 19.8%; Warmer/Wetter: -15.5%, 25.0%] (Figure 4.12). Slightly larger changes, with considerably more variation across species are projected for 2070. For this time period, the median change ranged from a decline, relative to the size of current habitat of -3.4% under the Warmer/Drier scenario [-50.1%, 32.6%] to a 6.8% increase under the Warmer/Wetter scenario [-24.0%, 54.9%].

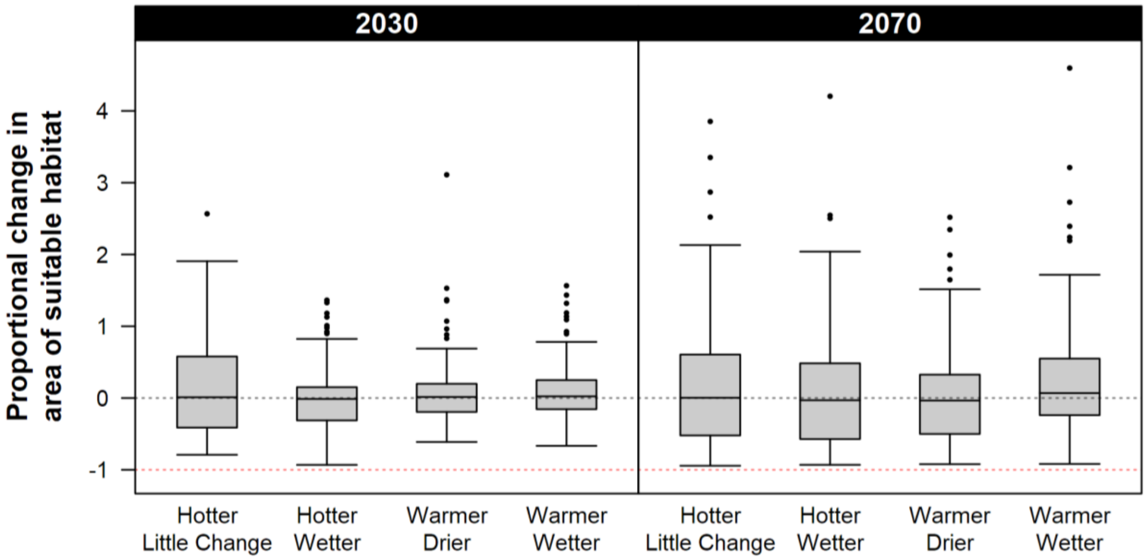


Figure 4.12 Boxplot showing proportional changes to the size of suitable habitat across NSW for landscape-managed species compared to the size of current suitable habitat. Projections were made for 2030 and 2070, under four climate scenarios. Each box represents encompasses 25-75th percentiles, with the horizontal line indicating the median range change. The black dashed line indicates no change, and the red dashed line indicates no future habitat.

Extent of habitat across New South Wales — site-managed species: For 2030, opposite trends are projected for site-managed species under the Hotter versus Warmer scenarios: the median projected change in habitat area, relative to the current period, is 14.6% [-21.6%, 72.8%] and 16.3% [-27.6%, 113.0%] under the Warmer/Drier and Warmer/Wetter scenarios, respectively (Figure 4.13). Median decreases of -9.6 [-58.7%, 91.0%] to -10.8% [-75.1%, 127.1%] are projected under the Hotter/Wetter and Hotter/Little Change scenarios, respectively. By 2070, however, the median size of habitat is projected to increase only under the Warmer/Wetter scenario (24.0% [-47.8%, 144.7%]). Under the three other scenarios, there is a median decline of between -12.4% (Warmer/Drier -64.1%, 109.0%] to -26.5% [Hotter/Little change -85.6%, 122.8%]. Clearly, as indicated by the 25-75th percentile, there is substantial variation across species, with suitable habitat projected to greatly expand for some species.

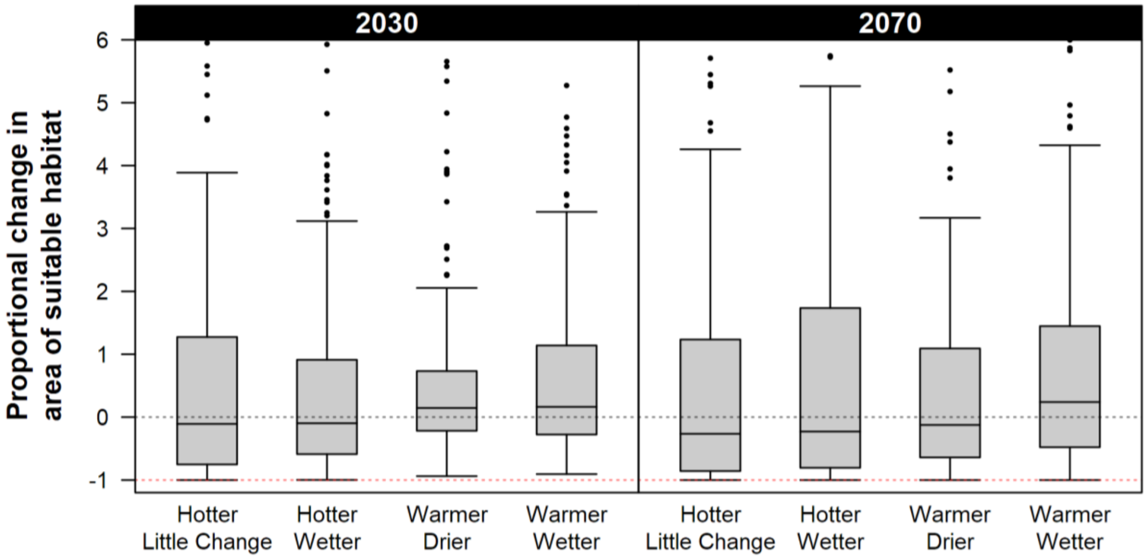


Figure 4.13 Boxplot showing proportional changes to the size of suitable habitat across NSW for site-managed species compared to the size of current suitable habitat. Projections were made for 2030 and 2070, under four climate scenarios. Each box represents encompasses 25-75th percentiles, with the horizontal line indicating the median range change. The black dashed line indicates no change, and the red dashed line indicates no future habitat. Note that the y-axis has been truncated at an upper limit of 6, though outliers extend beyond this in some cases.

However, the above projections are based on the extent of suitable habitat across the *entire* state — irrespective of distance from current populations. Yet many threatened species, particularly those that are site-managed, are unlikely to be able to disperse to colonise regions projected to become suitable in the future. Hence, changes in *occupied* habitat (Box 2) may be more realistic, and are summarised below.

Extent of occupied habitat — landscape-managed species: By 2030, the median size of *occupied* habitat is projected to be similar to that of the current period under the Hotter/Little change (<1% [-36.2%, 34.3%]) and Warmer/Wetter scenarios (<1%, -16.8%, 14.4%]) (Figure 4.14). Slight declines in median size are projected for the other two scenarios (Warmer/Drier: -4.4% [-21.8%, 13.3%]; Hotter/Wetter: -7.7% [-31.4%, 9.3%]). By 2070, the median size of *occupied* habitat is projected to remain similar to the current period under the Warmer/Wetter scenario only (i.e. 1.8% [-25.8%, 32.7%]), and decline under the other three scenarios (ranging from -5.7% under the Hotter/Wetter scenario [-61.9%, 22.8%] to -16.3% under the Warmer/Drier scenario [-63.9%, 25.0%]).

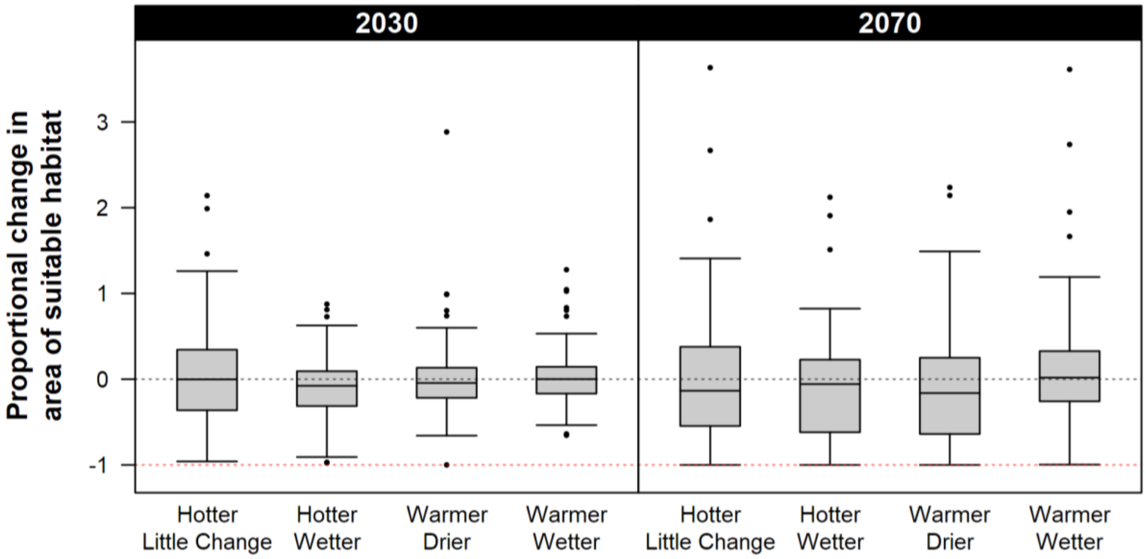


Figure 4.14 Boxplot showing proportional changes to the size of local suitable habitat within NSW for landscape-managed species compared to the size of current suitable habitat. Projections were made for 2030 and 2070, under four climate scenarios. Each box represents encompasses 25-75th percentiles, with the horizontal line indicating the median range change. The black dashed line indicates no change, and the red dashed line indicates no future habitat.

Gains (Box 2) represent regions that may be external refugia (i.e. areas currently unsuitable but that are projected to become suitable by a given future time period), although these regions may ultimately remain unoccupied if they do not meet the species' biotic and abiotic requirements or are beyond its dispersal distance (see Discussion). Identifying whether *gains* in climatically suitable habitat may occur elsewhere in an IBRA subregion in which populations are currently found, may be useful for the management of species that can disperse limited distances. Depending on the climate scenario, for 36–40 landscape-managed species, >10% of suitable habitat in 2030 represents *gains*; 7–15 species have > 50% of future suitable habitat be represented by *gains*. By 2070, the number of species with > 50% of future habitat represented by *gains* is projected to increase slightly to 12–18. However, as indicated by the overall projected decline in range size, *gains* in suitable habitat elsewhere will be insufficient to offset losses of current habitat.

Extent of occupied habitat — site-managed species: Site-managed species are projected to be faced with greater declines in the size of *occupied* habitat than landscape-managed species. By 2030, the median size of habitat is projected to remain similar to the current period under the two Warmer scenarios (Warmer/Drier: -3.5% [-35.0%, 43.2%]; Warmer/Wetter: 4.7% [-38.0%, 65.5%] (Figure 4.15). In contrast, median declines are projected for the Hotter scenarios (Hotter/Wetter: -20.1% [-71.2%, 33.2%]; Hotter/Little change: -28.0% [-82.0%, 62.2%]). By 2070, the median size of habitat is projected to decline under all scenarios. This decline is the greatest under the Hotter/Wetter scenario (-51.4% [-96.6%, 55.7%]) and least under the Warmer/Wetter scenario (-16.2% [-77.8%, 63.6%]).

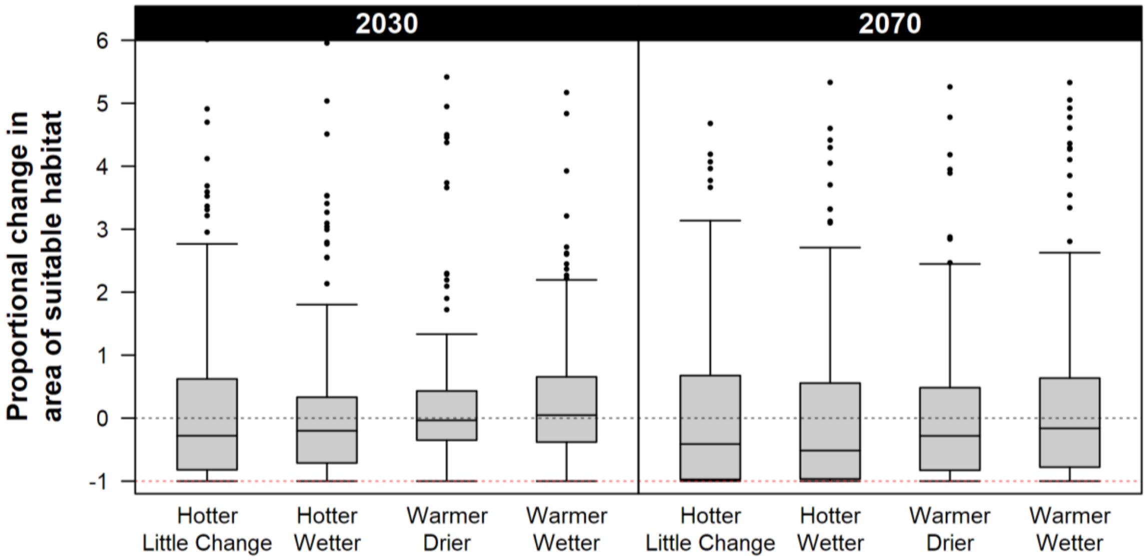


Figure 4.15 Boxplot showing proportional changes to the size of local suitable habitat for site-managed species compared to the size of current suitable habitat. Projections were made for 2030 and 2070, under four climate scenarios. Each box represents encompasses 25-75th percentiles, with the horizontal line indicating the median range change. The black dashed line indicates no change, and the red dashed line indicates no future habitat. Note that the y-axis has been truncated at an upper limit of 6, though outliers extend beyond this in some cases.

As with landscape-managed species, although future *gains* in suitable habitat may occur elsewhere in IBRA subregions that have current populations, for the majority of species these will be insufficient to offset losses. For 29–36% of site-managed species, more than 50% of suitable habitat in 2030 and 2070 represents *gains*, depending on the climate scenario.

4.2.1b Internal climate refugia and regions with consensus for internal refugia

The size of internal refugia is the inverse of the loss of current *occupied* suitable habitat. As such, **refugia are projected to be most extensive under the Warmer scenarios and least extensive under the Hotter scenarios**.

Landscape-managed species: By 2030, a quarter of species are projected to have internal refugia spanning > 88.2% of their current range under a Hotter/Wetter scenario and > 94% under the other three scenarios (Figure 4.16). By 2070, these values are projected to decrease to > 81.5% for Hotter/Wetter, and approximately 90% under the other scenarios (with Hotter/Little Change retaining the highest value for this 75th percentile, 91.2%). This indicates that much of their current habitat is likely to remain suitable under at least one of the future climate scenarios.

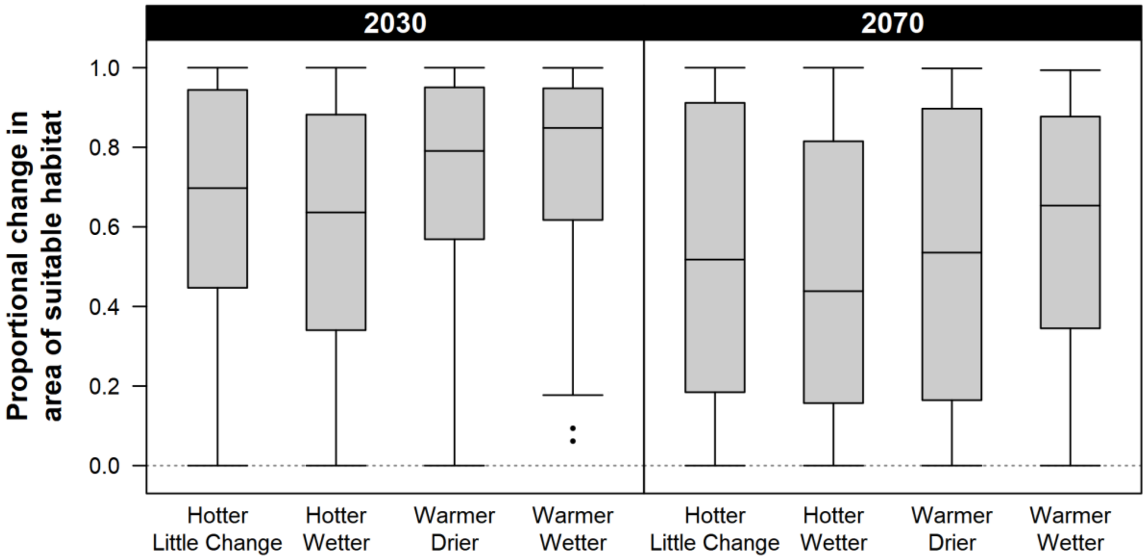


Figure 4.16 Boxplot showing the proportion of current suitable habitat likely to remain suitable (i.e. internal refugia) under four climate scenarios for 2030 and 2070, for 81 landscape-managed species. For a cell to be considered an internal refugium at 2030, it must be suitable in 2000 and in 2030, while to be considered an internal refugium in 2070 it must be suitable in 2000, 2030, and 2070.

Twelve landscape-managed species, all listed as Vulnerable (V), are projected to have refugia spanning > 90% of their current *occupied* habitat under all four climate scenarios by 2070 (Appendix Table A4), indicating that **these species may be least sensitive to climate change.** Among the nine listed as Endangered (EN) for which we developed models, only *Burhinus grallarius* (Bush stone-curlew) is projected to have refugia in 2070 spanning > 85% of its current *occupied* habitat under the four future scenarios. Of the remainder, five species have refugia spanning > 50% of their current *occupied* habitat under either one scenario (*Botaurus piociloptilus*, Australasian Bittern; *Mixophyes iteratus*, Giant Barred Frog; *Wollumbinia belli*, Bell's turtle), two scenarios (*Aprasia inaurita*, Mallee Worm-lizard), or three scenarios (*Lathamus discolor*, Swift Parrot).

As early as **2030, one landscape-managed species is projected to have < 10% of current *occupied* habitat remain internal refugia**, under all four scenarios (*Delma impar*, Striped Legless Lizard, V). By 2070, four more species (*Eulamprus leuraensis*, Blue Mountains Water Skink, EN; *Menura alberti*, Albert's Lyrebird, V; *Ningaui yvonneae*, Southern Ningaui, V; *Philoria loveridgei*, Loveridge's Frog, EN) are also projected to have small areas of internal refugia (<10% of current habitat) under all scenarios. In addition, *Wollumbinia belli* (Bell's Turtle, EN) is projected to have internal refugia only in the Warmer/Drier scenario. It must be noted, however, that where species are projected to have areas of internal refugia under all climate scenarios, *this does not imply that these areas always overlap* (i.e. there may be variation in the location of refugia between climate scenarios).

Therefore, as the trajectory of future climate change is not yet clear, we identified regions where there is consensus about internal refugia (i.e. grid cells projected to be internal refugia in *all* climate scenarios) for each species. To summarise, species with the largest *occupied* habitat generally have a large proportion of this habitat projected to remain suitable under all climate scenarios. However, there is no such relationship for species with small amounts of *occupied* habitat: internal refugia may span little to almost the entirety of this region. By 2030, half of the landscape-managed species are projected to have regions with consensus for internal refugia that span 12.0–76.2% (i.e., 25th to 75th percentile) of current habitat, declining to 3.9–60.0% by 2070 (Figure 4.17, Appendix Table A5). **One quarter of species are projected to have regions with consensus that span < 3.9% of their current *occupied* habitat in 2070.** Five species are projected to have either no regions with consensus by 2030 (*Delma impar*, Striped Legless Lizard, V; *Eulamprus leuraensis*, Blue Mountains Water Skink, EN) or areas that amount to < 1% of their current *occupied* habitat (*Sminthopsis leucopus*, White-Footed Dunnart, V; *Philoria loveridgei*, Loveridge's Frog, EN; *Hylacola cautus*, Shy Heathwren, V). An additional ten species are projected to have regions with consensus for internal refugia that span 0–1% of their range by 2070, including two more Endangered species (*Mixophyes iteratus*, Giant Barred Frog; *Wollumbinia belli*, Bell's Turtle) (Appendix Table A5).

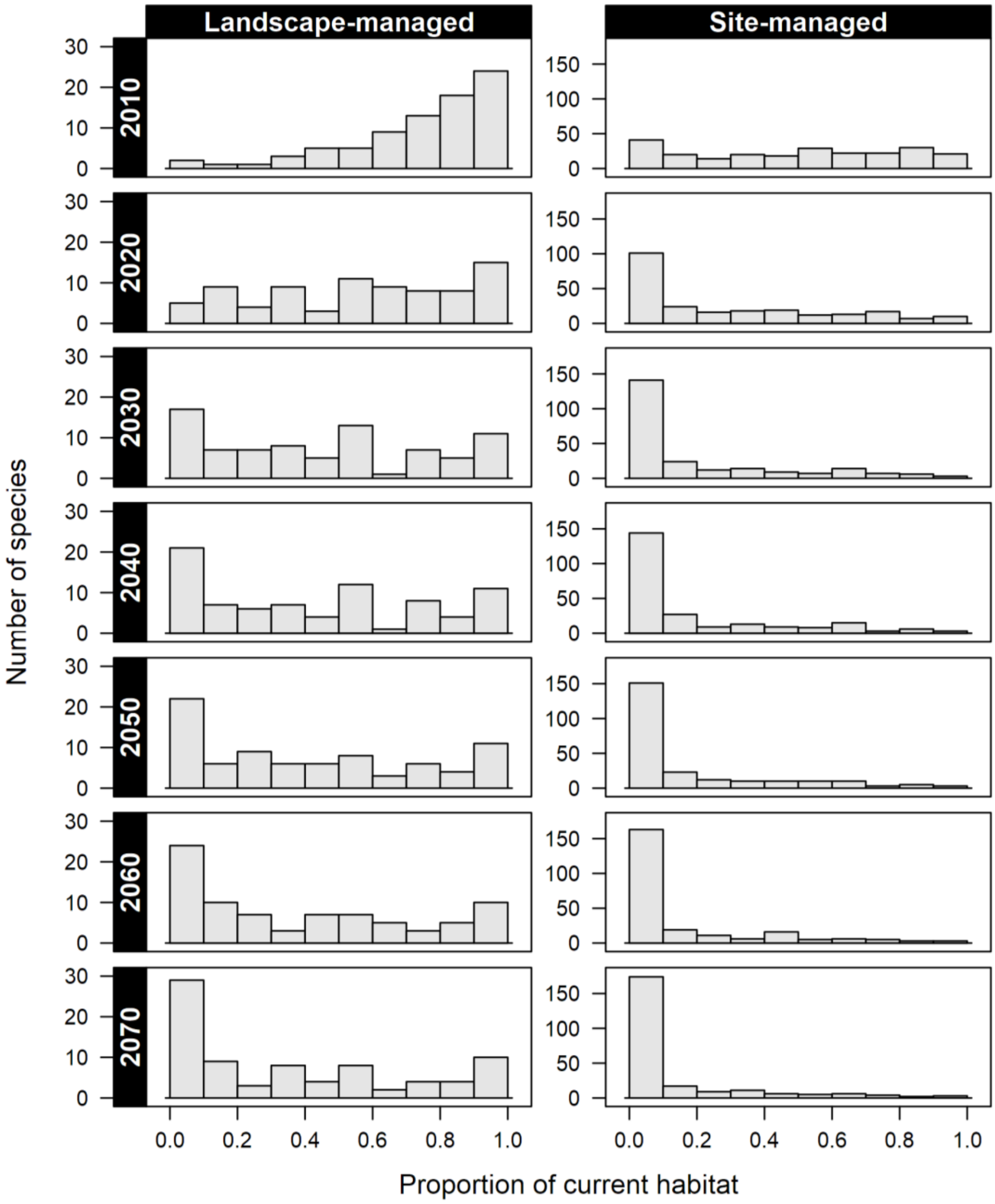


Figure 4.17. Proportion of current occupied habitat that is projected to remain suitable across all climate scenarios, for each time period. These grid cells are classified as regions with consensus for internal refugia, and represent areas that are most likely to retain suitable conditions for the modelled species. As the time horizon increases, the size of these areas, relative to current habitat, declines substantially for both landscape- and site-managed species.

Site-managed species: By 2030, a quarter of species are projected to have internal refugia spanning > 64% of their current *occupied* habitat under a Hotter/Wetter scenario, and > 86.4% under a Warmer/Wetter scenario (Figure 4.18). By 2070, these values are projected to fall to 38.6% and 62.1%, respectively.

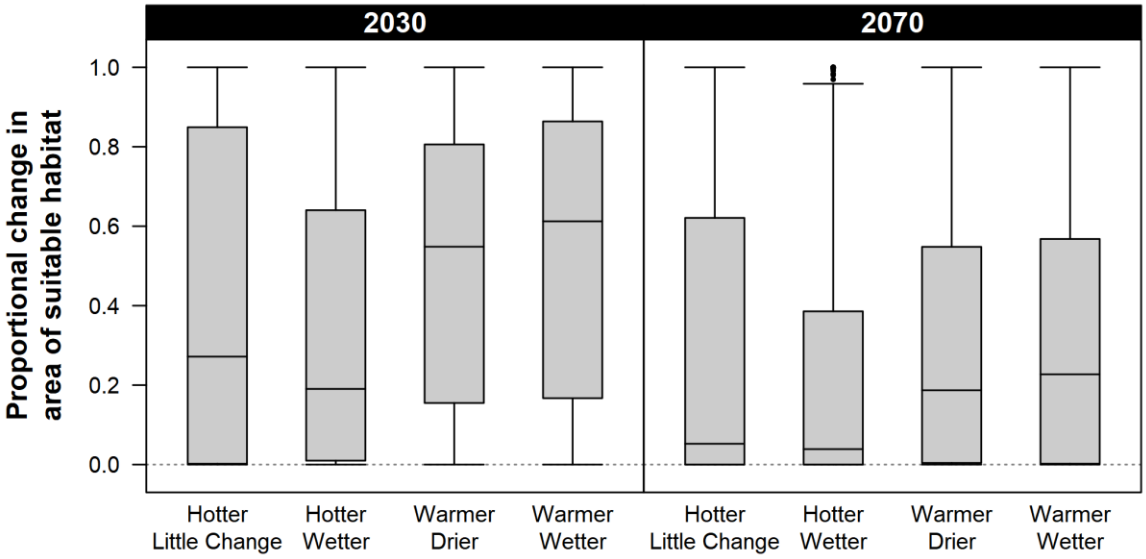


Figure 4.18 Boxplot showing the proportion of current suitable habitat likely to remain suitable (i.e. internal refugia) under four climate scenarios for 2030 and 2070, for 238 site-managed species. For a cell to be considered an internal refugium at 2030, it must be suitable in 2000 and in 2030, while to be considered an internal refugium in 2070 it must be suitable in 2000, 2030, and 2070.

Only three species (*Bertya opponens*, Coolabah Bertya, V; *Diuris arenaria*, Sand Doubletail, EN; *Esacus magnirostris*, Beach stone-curlew, CR) are projected to have refugia spanning > 90% of their current range under all four climate scenarios by 2070 (Appendix Table A4), suggesting that these species will have little sensitivity to climate change. Note that due to the manner in which we classified *occupied* habitat (see Box 2) we could not calculate refugia for *Myriophyllum implicatum* (CR) as no high quality records in NSW existed in our dataset. Of the remaining Critically Endangered species, both *Hibbertia sp. Bankstown* and *Anthochaera phrygia* (Regent Honeyeater) are projected to have internal refugia spanning > 70% of their current habitat in all scenarios.

By 2030, internal refugia are projected to span < 10% of the current habitat of 46 species under the Warmer/Wetter scenario, and 99 species under the Hotter/Little change scenario. For 22 species, internal refugia are likely to be less than this size in all four scenarios. By 2070, internal refugia are projected to decline substantially, spanning < 10% of current habitat for 97 species under the Warmer/Wetter scenario and 133 species under the Hotter/Wetter scenario. Sixty-nine species are projected to have internal refugia spanning < 10% of current habitat in each of the scenarios by 2070 (although the spatial arrangement of these refugia may differ across scenarios), suggesting high sensitivity to climate change. This includes 36 Endangered species and the two Critically Endangered orchids, *Genoplesium littorale* and *Pterostylis despectans*. The two remaining Critically Endangered species, *Pseudomys fumeus* (Smoky Mouse) and *Pachycephala rufogularis* (Gilbert's Whistler) have their largest projected internal refugia under the Warmer/Wetter (~17%) and Warmer/Drier (34.6% of current range) scenarios, respectively.

For 50% of site-managed species, the area with consensus for internal refugia at 2030 is projected to span only 0–31.4% of current habitat (Appendix Table A5). **By 2070, ~73% of species will have regions with consensus spanning < 10% of their current range (Appendix Table A5), including five of the 13 Critically Endangered species** (*Genoplesium littorale,* Tuncurry Midge Orchid; *Grevillea caleyi,* Caley's Grevillea; *Pachycephala rufogularis*, Red-lored Whistler; *Pseudomys fumeus*, Smoky Mouse; *Pterostylis despectans*). However, for 16 species (including the Critically Endangered birds *Anthochaera phrygia* (Regent Honeyeater) and *Esacus magnirostris* (Beach Stone-curlew) as well as the shrub *Hibbertia sp. Bankstown*), this area is projected to span > 60% of their current occupied habitat.

4.2.1c Consensus for regions with translocation potential

Regions most likely to be candidates for translocation are those that are currently suitable (enabling translocation to be explored in the near future) and remain suitable across all climate scenarios and time periods. The key difference between these regions and internal refugia is that the latter are classified as *occupied* habitat (i.e. grid cells in an IBRA sub-region that currently contains high quality occurrence records) that remain suitable in the future. In contrast, regions with translocation potential lie in *unoccupied* habitat, or IBRA sub-regions for which we do not have a high quality occurrence record (and so assume the species may be absent) (see Box 2). We point out that because of how we define *occupied* versus *unoccupied* habitat, some sections of an IBRA sub-region may be classified as internal refugia although no occurrence record may be in close vicinity, making these grid cells actually fit the definition of regions with translocation potential. For example, see *occupied* areas in Box 2 that remain suitable but that do not have an occurrence record close by. Hence, we recognise that there are limitations to our definition of areas of internal refugia and translocation potential.

In summary, across all 319 species, state-wide *unoccupied* habitat is projected to average 23,951 km^2 (± 45,603 km^2). *Unoccupied* habitat is slightly smaller for landscape-managed species (average 21,230 km^2, ± 24,495 km^2) than site-managed (24,877 km^2 ± 50,838 km^2).

Landscape-managed species: By 2030, a quarter of landscape-managed species are projected to have regions with consensus for translocation potential that span > 60% of current *unoccupied* habitat (i.e. an area exceeding 8,577 km^2). Conversely, an additional quarter will have regions with translocation potential spanning < 6.3% of current *unoccupied* habitat, an area covering < 321 km^2. **Two landscape-managed species (*Hylacola cautus*, Shy Heathwren V; *Delma impar*, Striped Legless Lizard V) are unlikely to have any areas suitable for translocation over all climate scenarios**. Additionally, regions with translocation potential for six Vulnerable or Endangered species are likely to span < 1% of current *unoccupied* habitat (ranging from 15–619 km^2) (*Cinclosoma castanotum*, Chestnut Quail-thrush; *Petroica phoenicea*, Flame Robin; *Polytelis swainsonii*, Superb Parrot; *Pachycephala inornata*, Gilbert's Whistler; *Tyto novaehollandiae*, Masked Owl; *Aprasia inaurita*, Mallee Worm-lizard), highlighting the importance of conservation of these species' current populations.

By 2070, *C. castanotum*, *P. swainsonii* and *Ningaui yvonneae* (Southern Ningaui, V) are projected to have no regions with consensus for translocation potential (in addition to the species that already had no such areas in 2030, *D. impar* and *H. cautus*), while for 11 other species this area will span < 1% of current *unoccupied* habitat. This includes three Endangered species: *Aprasia inaurita* (Mallee Worm-lizard); *Mixophyes balbus* (Stuttering Frog); *Mixophyes iterates* (Giant Barred Frog).

By 2070, 12 Vulnerable species are projected to have regions with consensus for translocation potential that span > 80% of current *unoccupied* habitat, an area ranging in size from 5917–69,393km^2. This includes two marsupials (*Sminthopsis macroura*, Stripe-faced Dunnart; *Petaurus norfolcensis*, Squirrel Glider), eight birds (*Certhionyx variegatus*, Pied Honeyeater; *Glossopsitta pusilla*, Little Lorikeet; *Lophochroa leadbeateri*, Major Mitchell's cockatoo, *Ninox connivens*, Barking Owl; *Falco subniger*, Black Falcon; *Grantiella picta*, Painted Honeyeater; *Lophoictinia isura*, Square-tailed Kite; *Hieraaetus morphnoides*, Little Eagle[3]), and one bat species (*Saccolaimus flaviventris*, Yellow-bellied Sheathtail-bat). However, it must be remembered that not all of these areas will ultimately be suitable for translocation, as our models considered only climate, soil and/or topographic characteristics.

Site-managed species: By 2030, 36 species are projected to have no suitable habitat available for translocation. This includes the Critically Endangered orchid *Pterostylis despectans* and Northern Corroboree Frog, *Pseudophryne pengilleyi*. Thirty-nine additional species will have regions with consensus for translocation potential spanning < 1% of current *unoccupied* habitat, including *Pseudomys fumeus* (Smoky Mouse) and *Genoplesium littorale* (Tuncurry Midge Orchid), both Critically Endangered.

[3] Note that the Maxent model for this species had low predictive power. As such, less confidence can be placed in this result.

By 2070, these values increase to 65 species projected to have no suitable habitat for translocation and 47 species with regions with consensus for translocation potential being restricted to < 1% of current *unoccupied* habitat. Conversely, by this time frame, eight species are projected to have these areas span > 80% of current *unoccupied* habitat, i.e. representing sizes ranging from 345–384,201km^2. This includes the Critically Endangered *Esacus magnirostris* (Beach Stone-curlew) and the Endangered *Haematopus longirostris* (Pied Oystercatcher), two Endangered orchids (*Genoplesium baueri*, Bauer's Midge Orchid; *Caladenia arenaria*, Sand-hill Spider Orchid), an Endangered fern (*Lindsaea incisa*, Slender screw Fern), two Endangered Herbs/Forbs (*Lepidium peregrinum*, Wandering Pepper Cress; *Eleocharis tetraquetra*, Square-stemmed Spike-rush), and a Vulnerable Shrub, *Bertya opponens* (Coolabah Bertya).

4.2.1d Combining regions with consensus for internal refugia and regions with consensus for translocation potential

For each species, we calculated the number of grid cells that met the definition of regions with consensus for internal refugia or translocation potential. Species were then grouped into four categories, depending on whether these areas spanned < 20% or ≥ 20% of current *occupied* or *unoccupied* habitat, respectively. Categorising species in this manner can help to identify suitable actions for their management under climate change.

Limited regions with consensus for internal refugia AND limited regions with consensus for translocation potential: By 2030, 16 landscape-managed species fall into this category, including four Endangered species (*Mixophyes balbus*, Stuttering Frog; *M. iterates*, Giant Barred Frog; *Botaurus poiciloptilus*, Australasian Bittern; *Eulamprus leuraensis*, Blue Mountains Water Skink). **By 2070, this is projected to increase to 35 species**.

Of the 238 site-managed species, 140 fall into this category by 2030, increasing to 172 by 2070. This includes (in 2070) the Critically Endangered *Eucalyptus sp. Cattai*, *Pseudophryne pengilleyi* (Northern Corroboree Frog), *Thinornis rubricollis* (Hooded Plover), *Pachycephala rufogularis* (Red-lored Whistler), *Genoplesium littorale* (Tuncurry Midge Orchid), *Pterostylis despectans*, *Grevillea caleyi* (Caley's Grevillea), and *Pseudomys fumeus* (Smoky Mouse). Of the 172 species in this category by 2070, **89 have < 1% of their current *occupied* and < 1% of their *unoccupied* habitat remain suitable remain suitable under all scenarios**.

Some regions with consensus for internal refugia but limited regions with consensus for translocation potential: By 2030, this category includes 10 landscape-managed species, including an Endangered reptile, *Aprasia inaurita* (Mallee Worm-lizard), and decreases to seven species by 2070 (*Nyctophilus corbeni*, Corben's Long-eared Bat; *Myotis macropus*, Southern Myotis; *Petroica phoenicea*, Flame Robin; *Stagonopleura guttata*, Diamond Firetail, *Callocephalon fimbriatum*, Gang-gang Cockatoo; *Chthonicola sagittata*, Speckled Warbler, in addition to the Mallee Worm-lizard).

Among the site-managed species, 22 and 18 fall into this category by 2030 and 2070, respectively. Those for 2070 include two Critically Endangered animals, *Litoria castanea* (Yellow-spotted Tree Frog) and *Anthochaera phrygia* (Regent Honeyeater).

Limited regions with consensus for internal refugia but some regions with consensus for translocation potential: This category includes eight landscape-managed species (including the Endangered *Philoria loveridgei*, Loveridge's Frog). By 2070, this number declines to three – *Coeranoscincus reticulatus* (Three-toed Snake-tooth Skink, V), *Philoria sphagnicola* (Sphagnum Frog, V), and *Coracina lineata* (Barred Cuckoo-shrike, V).

Among the site-managed species, 25 and 19 species fall into this category by 2030 and 2070, respectively. This includes the Critically Endangered herb, *Myriophyllum implicatum*.

Some regions with consensus for internal refugia and for translocation potential: Most landscape-managed species fall into this category (i.e. 47 by 2030, although this is projected to decline to 36 species by 2070).

Fifty-one site-managed species fall into this category for 2030, declining to 29 by 2070. Of the four Critically Endangered species in this category at 2030, only two retain sufficient currently suitable habitat through to 2070 (*Hibbertia sp. Bankstown*; *Esacus magnirostris*, Beach stone-curlew). We also point out that the actual areal extent of suitable habitat for several species is projected to be very small (e.g., area with consensus for translocation potential for *Elaeocarpus williamsianus*, Hairy Quandong EN, is < 80 km^2).

4.2.1e Multi-species internal refugia

To visualise areas likely to be putative internal refugia across multiple species, irrespective of future climate, maps identifying regions with consensus about internal refugia were stacked for the 81 landscape-managed and 238 site-managed species (Figure 4.19). We refer to these areas as 'multi-species internal refugia'.

Presently, regions containing the greatest number of landscape-managed species modelled in this project occur primarily along the northern and central eastern coast, and throughout scattered regions to the south of the South Western Slopes (Figure 4.19).

However, by 2070, multi-species internal refugia along the coast are projected to be greatly diminished in spatial extent and the number of species they support, with the most important coastal regions being to the north of Upper Myall, Wingham, and Evans Head. Furthermore, the primary multi-species refugia will likely shift to the southern (e.g. around Albany) and eastern regions of the South Western Slopes, and the centre of the Cobar Peneplains. Scattered multi-species internal refugia are also likely to be found in other areas, such as the southern parts of the Murray Darling Depression (e.g. north of Mallee Cliffs) and South Brigalow Belt. Unfortunately, in many instances these areas occur in highly modified environments.

Multi-species internal refugia for site-managed species are presently located in the north-eastern corner of the state, as well as around Myall Lakes, the Sydney region, and Jervis Bay. While these areas are likely to remain important, it will be for a greatly reduced subset of species. By 2070, there are likely to be few multi-species refugia for site-managed species. Other areas that may remain important for at least three species include northern areas of the North Coast SPR, and the southern and eastern area of the South Western Slopes.

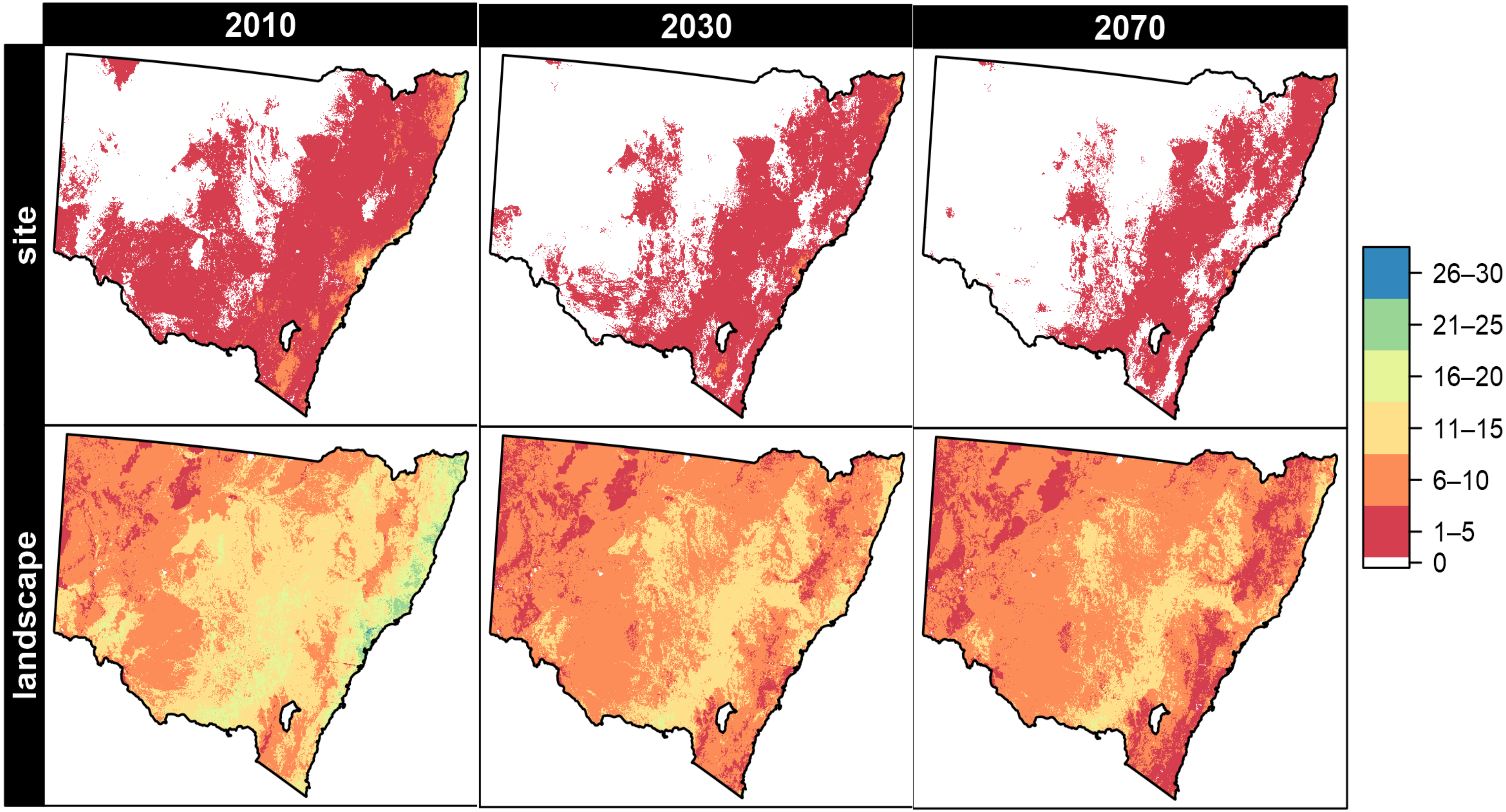


Figure 4.19. Multi-species refugia for site and landscape-managed species in NSW. Multi-species refugia are defined as area with consensus (i.e. grid cells projected to be suitable across all climate scenarios for a given time period) for multiple species. Colour scale indicates the number of species.

5 Discussion

The spatial extent and longevity of climate refugia throughout the state of New South Wales (NSW), Australia, varies substantially across ecoregions. We identified internal refugia for 117 plant species that were representative of one or more of the six ecoregions in NSW, as well as for 81 landscape-managed and 238 site-managed species. Importantly, given uncertainty in the magnitude of warming and direction of precipitation trends, we identified refugia across four plausible scenarios describing futures that are, relative to mean annual temperature and precipitation over the 1990–2009 baseline period, Warmer/Wetter, Warmer/Drier, Hotter/Wetter, and Hotter/Little change in precipitation. Our approach provides valuable information for decision-makers, enabling them to visualise the spatial arrangement of refugia and areas of vulnerability. This reveals conservation options in the context of climate uncertainty and facilitates prioritisation of competing management actions.

5.1 Refugia for representative species

The location of climate refugia is context dependent. For the first part of this report, we identified climate refugia for species that are 'representative' of ecoregions in NSW. In this instance, we hypothesised that retention of suitable habitat that is also currently occupied by a representative species will facilitate survival of its populations, and will likely cause less disruption to ecosystem functions than if conditions were to exceed these species' tolerances. Hence, we also assume that refugia catering for representative species will also support a general suite of species native to the area (Crase et al. 2015).

Our projections indicate that internal refugia of varying sizes will exist until at least 2070 for most of the 117 representative species included in this study. In general, however, refugia for individual species in the arid (DXS) and mediterranean (MFWS) ecoregions, and in the temperate and tropical grasslands (TGSS, TrGSS) are likely to be less extensive if a Hotter/Wetter future prevails. In contrast, refugia for species in the montane (MGS) and temperate broadleaf (TBMF) ecoregions are likely to be more extensive if conditions by 2030 are wetter than present.

From a land management perspective, *regions with consensus*, where refugia are projected to occur under all four climate scenarios, may be sensible conservation targets for a risk-averse manager. These areas are robust to future variation in regional climate, leading to high stability in habitat suitability for the existing species pool. For some NSW ecoregions, large tracts of *high richness refugia* (HRR) are projected to persist until at least 2070, irrespective of the climate scenario. These dominate the MGS, most of which is already incorporated into the national reserve system (Figure 4.7). Other key areas include the Darling Riverine Plains bioregion and the Riverina bioregion in north-eastern and southern TGSS, respectively. However, habitat condition across the Darling Plains is currently poor (Drielsma et al. 2015), and the capacity for disturbed or degraded landscapes to withstand climate change may be compromised (Field et al. 2014; Zomer et al. 2008).

Of particular concern are those ecoregions with limited HRR or with little consensus across climate scenarios. For example, TBMF spans eastern NSW and is the most heavily urbanised region in Australia. Species representative of this ecoregion are projected to lose a greater proportion of their current habitat compared with species elsewhere, in all scenarios except Hotter/Wetter. While HRR are projected along coastal areas, these are located close to heavily-urbanised regions (e.g., Gosford, Newcastle) where demand for land is likely to increase substantially.

Also of interest are the refugia, or lack thereof, along the Great Eastern Ranges (GER). Previous studies have identified putative refugia in higher altitude or topographically complex regions within Australia (Ashcroft et al. 2012; Keppel et al. 2015) and elsewhere (Allen & Lendemer 2016; Dirnböck et al. 2011; Guarnizo & Cannatella 2013), and it has been suggested that the GER may play an important role in providing refugia or corridors to aid species migration in response to climate change (Mackey et al. 2010). However, with the exception of the MGS, there was a distinct lack of consensus across the four scenarios with respect to the location of HRR along the GER. Further, regardless of scenario, few HRR were projected in the northern and southern NSW regions of the GER, although refugia will remain for individual species. This does not preclude the usefulness of conservation connectivity corridors being invested in across the GER — rather, it highlights the potential dynamic nature of ecosystems across this region.

This topographically complex range is also likely to have micro-refugia that cannot be identified from the spatial resolution of our study. Several recent studies have undertaken different approaches to identify refugia from climate change for biodiversity across Australia. Williams et al. (2014) developed community-level models for the continent at a spatial resolution of 250 m, for four biological groups: vascular plants, mammals, reptiles and amphibians. Projections of future vegetation patterns indicate south- or coast-ward shifts of vegetation types, with areas of high topographic relief offering the greatest refugial potential.

Building upon Williams et al.'s (2014) plant community-level models, Drielsma et al. (2015) identified 250 bioclimatic classes (BCCs, which can be viewed as surrogates for biodiversity) across south-east Australia. Previous land clearance, fragmentation and degradation were combined with shifts in BCCs to assess future biodiversity persistence and identify regions where opportunities to facilitate conservation and adaptation may exist. This approach provides a broad overview of whether a given area will continue to remain suitable for existing communities, or the extent to which species composition may be altered by future changes. Their analyses indicated that the general capacity of landscapes to support existing ecosystems will likely decline, particularly across central regions of NSW. Unfortunately, it is not possible to determine which species, rare or dominant, drive the changes projected from community-level models.

As with our study, Reside et al. (2013) employed Maxent to identify potential refugia for Australian terrestrial vertebrates. Patterns varied across taxa: increases in richness were projected to occur in inland NSW for amphibians and reptiles, and in the south-east of the state for birds and mammals. However, their analysis considered shifts in hotspots of suitability resulting from immigration and emigration (Reside et al. 2013), while the present study considers internal refugia, reflecting pervasive uncertainty about dispersal capacity.

5.1.1 Why identify refugia for representative plant species?

Our results extend from previous studies that have undertaken different approaches to identify refugia from climate change for biodiversity across Australia (e.g. Reside et al. 2013; Williams et al. 2014; Drielsma et al. 2015). However, in contrast to these studies, our approach identifies areas most likely to serve as climate refugia for species representative of their respective communities and ecoregions under a range of contrasting, but plausible climate futures. Additionally, using ecoregions enhances the utility for conservation planning at global and regional scales (Olson et al. 2001). Importantly, ecoregions represent the world’s most outstanding examples within each major habitat type and have been defined worldwide for terrestrial, freshwater, and marine ecosystems. Moreover, their objective is to promote conservation by preserving biodiversity and ecological processes.

Previous studies have identified refugia that accommodate endemic or threatened species (e.g., Chitale et al. 2014; Meng et al. 2016; Stratmann et al. 2016), capture a set of critical landscape characteristics (e.g., Molina-Venegas et al. 2016; Sandberg et al. 2016) or aim to protect genetic diversity (e.g., Havrdová et al. 2015; Lourenço et al. n.d.; Sandberg et al. 2016). Here, we focus on refugia for species regarded as ‘representative’ of ecoregions. We identified representative species and used them to represent larger suites of minor, endemic and threatened species. Broadly, they can be used as surrogates for dominant (Grime 1998; Loreau et al. 2001) and umbrella species (Caro & O’Doherty 1999). In this context representative species can be advocated for the management and conservation of natural environment, and by protecting them considering internal refugia.

A substantial body of work has previously described the importance of representative species for ecosystem function (Grime 1998; Loreau et al. 2001; Ellison et al. 2005), control of invasive species (Emery & Gross 2007; MacDougall & Turkington 2005), and buffering against environmental perturbations (Brown et al. 2001; Ellison et al. 2005; Loreau et al. 2001). Regarding environmental perturbations, representative species are highly vulnerable, particularly in early life stages during recruitment. Recruitment of these species might be jeopardised by changes in the environment (e.g. climate change), landscape fragmentation, or changes and losses of rare and minor species (Grime 1998). Moreover, the vulnerability of representative species increases when they are in the limits of their distributions and ecological niches, or are under stress (Brown et al. 2001). Further, ecosystems with few representative species, such as MGS, can be highly vulnerable even to small perturbations, this is because there are less strong biotic interactions (e.g. non-native pathogen) among species (Ellison et al. 2005).

Losses in representative species have an impact on ecosystem processes and can alter the composition of the ecosystem leading to changes in diversity (Brown et al. 2001; Loreau et al. 2001). For instance, these losses might affect the carbon and nutrient cycles as the rates of plant production and decomposition are modified (Scheffer et al. 2001) Nevertheless, if representative species are also dominant, their loss can be beneficial because these species might have negative effects over other species. For instance, the abundance, reproduction and survival of native and subdominant species may be limited by the effect of competition (MacDougall & Turkington 2005; Tilman 1988; Tylianakis et al. 2008). When competition decreases, more resources are available, favouring diversity and changing the hierarchy of the ecosystem (Collins et al. 1998; Bakker & Olff 2003). Further, when these composition changes occur in disturbed ecosystems this might lead to the ecosystem's recovery (Sasaki & Lauenroth 2011).

5.1.3 What are the management implications of identifying refugia for representative species?

A key strength of our approach is that it identifies areas most likely to serve as climate refugia for species representative of their respective communities and ecoregions under a range of contrasting, but plausible climate futures. These internal refugia present clear opportunities for management aimed at maintaining ecosystem function under climate change (Loreau et al. 2001). This is particularly true where their value as refugia is evident across multiple climate scenarios, but such agreement is not always necessary; tolerance for uncertainty can be dictated by a manager's appetite for risk. By explicitly considering and conveying this uncertainty, outputs such as these internal refugia can inform strategic management based on formal decision theory (e.g., Jeffrey 1990; Resnik 1987). We suggest that while additional (external) refugia may exist beyond species' known distributions, the accessibility of internal refugia likely renders them more valuable. The consideration of external refugia in management plans requires additional assumptions about dispersal and colonisation capacities, and the effectiveness of habitat corridors (Ashcroft 2010), which may be poorly understood for many species.

Temporally-persistent climate refugia accommodating the majority of local flora (our HRR) are likely to play a critical role in the long-term endurance of plant communities in the face of climate change. Furthermore, targeting conservation at regions of higher richness should foster the retention of a diversity of ecosystem services (Chan et al. 2006; Egoh et al. 2009) and resilience to climate change (Oliver et al. 2015). However, when allocating conservation resources to managing such refugia, their suitability with respect to key non-climatic factors should also be considered. We found that climatically-suitable HRR sometimes occurred in landscapes with poor habitat condition, such as in cleared or degraded areas, or near urban centres. This challenge to prioritisation can be minimised by comparing the spatial arrangement of HRR to spatial data describing general landscape hospitability (e.g., the vegetation condition layer used herein; Drielsma et al. 2015), or by using such data as predictors in habitat suitability models. We suggest that the former may reveal opportunities where improving non-climatic conditions might yield optimal results, whereas the latter may precipitate methodological problems if, for example, occurrence data are not current with respect to non-climatic condition data. The quality of habitat is thought to relate to its resilience to the additional stress of climate change (Field et al. 2014; Zomer et al. 2008), thus ensuring the management of HRR in areas of good condition is likely to yield more favourable outcomes.

5.2 Refugia for threatened species

We modelled the distribution of current and potential future habitat for 81 landscape-managed and 238 site-managed species. The impact of climate change on suitable habitat for these threatened species will depend substantially upon both the species and climate scenario. Generally, when considering all suitable habitat across the State, *regardless of distance to known populations*, we can conclude that: a) the magnitude of projected changes to the size of suitable habitat are larger under the two Hotter scenarios — approximately half of landscape-managed species may experience some increases to the size of suitable habitat, most site-managed species are projected to experience declines; and b) Warmer/Wetter is the only climate scenario in which the majority of species from either management stream may experience an increase to the size of suitable habitat. However, the above statements assume that a given species can disperse to any area projected to be suitable, regardless of distance from current populations. For many species, this is unlikely to be a reality.

When considering only *occupied* habitat (grid cells within an IBRA sub-region for which we have a high quality occurrence record), we conclude that: a) by 2070, the majority of landscape-managed species will experience declines in the extent of suitable *occupied* habitat under all scenarios except Warmer/Wetter; b) the majority of site-managed species will experience declines in *occupied* habitat irrespective of the future climate scenarios; c) internal refugia are likely to be most extensive under the Warmer/Wetter scenario, and least extensive under the Hotter/Wetter scenario; and d) site-managed species are projected to have considerably smaller internal refugia than landscape-managed species.

While the extent of projected range changes is strongly dependent upon the climate scenario, we emphasize that uncertainty in the magnitude/direction of future climate change need not prevent management decisions from being made. Rather, decisions can be based on agreement across the climate scenarios with respect to the distribution of suitable habitat for the target species. For example, our classification of *regions with consensus for internal refugia* enables populations that are most likely to experience climate change within their tolerance level to be identified. These populations may be more resilient to climate change, hence, additional threats should be managed to maximise the population's resilience. However, by 2030, regions with consensus for internal refugia are projected to span < 20% of current *occupied* habitat for 30% (24/81) and 70% (165/238) of landscape- and site-managed species, respectively. This increases to 47% (38/81) and 80% (191/238) of these species by 2070. This indicates that, in general, **current populations of most species are very sensitive to climate change, irrespective of the future scenario that prevails**.

Given that a large number of threatened species are projected to have limited regions with consensus for internal refugia, we also identified areas that may be suitable for translocation. These are grid cells that fall into the category of *unoccupied* habitat (i.e. presently do not contain a high quality occurrence record) and that are climatically suitable now and in the future, under all climate scenarios. Generally, the extent of areas suitable for translocation is greater for landscape- than site-managed species: this area spans ≥ 20% of current *unoccupied* habitat for 48% (39/81) of landscape-managed species but only 20% (48/238) of site-managed species by 2070. Indeed, for 15% (12/81) and 3% (8/238) of these species (landscape- and site-managed, respectively) regions with translocation potential cover more than 80% of *unoccupied* habitat. However, we caution that this is a preliminary analysis that has only considered the *climatic suitability* of the site. From here, experts need to assess whether these regions meet other criteria necessary for species translocation and persistence.

Of value is the identification of species with a) limited regions with consensus for internal refugia *and* limited regions with consensus for translocation potential, b) limited regions with consensus for internal refugia *but* with some regions with consensus for translocation potential, c) some regions with consensus for internal refugia *but* limited consensus for translocation, and d) some consensus for internal refugia *and* some consensus for translocation. Categorising species in this manner can assist with prioritisation of species and the identification of appropriate management actions. For the purpose of this report, "limited" areas refer to < 20% of either current *occupied* habitat (when referring to consensus for internal refugia) or current *unoccupied* habitat (consensus for translocation). This threshold is arbitrary, and adjusting it will clearly alter the number of species included in each category. We also point out that although a relatively large percentage of some species' current *occupied* or *unoccupied* habitat may remain suitable under all climate scenarios, this may span an areal extent that is insufficient to support a population (e.g. particularly for mobile landscape species). Appendix Table A5 lists which category each species was placed in.

Limited regions with consensus for internal refugia and *limited regions with consensus for translocation potential*: These species are likely to face the greatest sensitivity to climate change, as a large proportion of current occupied habitat is likely to be unsuitable in the future, and there will be few regions to translocate populations to. **The tolerance of these species to climate change needs to be urgently assessed, as do options for ex-situ conservation**. Unfortunately, **this category also includes the largest number of species:** by 2070, this includes 35 landscape- and 172 site-managed species (including several that are Critically Endangered — *Eucalyptus sp. Cattai*, *Pseudophryne pengilleyi* (Northern Corroboree Frog), *Thinornis rubicollis* (Hooded Plover), *Pachycephala rufogularis* (Red-lored Whistler), *Genoplesium littorale* (Tuncurry Midge Orchid), *Pterostylis despectans*, *Grevillea caleyi* (Caley's Grevillea), and *Pseudomys fumeus* (Smoky Mouse).

Some regions with consensus for internal refugia but *with limited regions with consensus for translocation potential*: As there is likely to be little area beyond their current *occupied* habitat that remains suitable under all climate scenarios, **the protection and management of regions with consensus for internal refugia will be particularly important**. This category includes

The Critically Endangered site-managed species, *Litoria castanea* (Yellow-spotted Tree Frog) and *Anthochaera phrygia* (Regent Honeyeater).

Limited regions with consensus for internal refugia but *some regions with consensus for translocation potential*: Currently **populations of these species are likely to have very sensitivity to climate change**. Their resilience needs to be further assessed. Since some regions with translocation potential are likely to exist, the suitability of these areas for population persistence should also be assessed.

Some regions with consensus for internal refugia and *for translocation potential*: Species within this category are likely to have the **lowest sensitivity to climate change**, as at least some current populations are projected to continue to have suitable climate until at least 2070, and potential areas for translocation exist should this option be necessary. We caution, however, that these results are based on the proportion of habitat projected to remain suitable – for some species, the areal size of this area may be insufficient for long-term persistence.

5.2.1 What are the limitations or caveats of this study?

Throughout this study, we made a number of assumptions with respect to species' responses to climate change and our modelling approach, and these need to be borne in mind when considering our results.

We assumed that biotic interactions among species are either adequately reflected by environmental predictors or will remain constant through time (Ashcroft 2010). Even if this is the case, retention of suitable habitat for representative plant species does not preclude changes to community composition, since species will respond idiosyncratically to climate change (Esperón-Rodríguez & Barradas 2015; García-Robledo et al. 2016; Maharaj & New 2013; Malyshev et al. 2016; Pucko et al. 2011). However, the survival of populations of representative plant species is likely to reduce disruption to the community (Crase et al. 2015) and minimise deleterious impacts arising from invasive or new competitor species (Iwamura et al. 2010). Our approach also assumes that the minimum viable population size will be accommodated by individual refugia, and that occurrence records used to identify refugia represent viable populations.

Populations of some species may survive climate changes within patches of micro-refugia too small to be detected by our modelling approach, the resolution of which was limited for computation reasons. For example, MacLean et al. (2015) suggested that micro-refugia may occur along cooler slopes that buffer the effects of warming on plant communities. It is also likely that habitat beyond species' current ranges may become suitable in the future. The identification of external or 'stepping-stone' (Hannah et al. 2014) refugia may be important for achieving conservation goals. However, the role of these areas as refugia is subject to additional assumptions regarding species' ability to disperse to and colonise them.

Our models are based on long-term climate, rather than short-term extremes. Yet, the combination of increased intensity and frequency of extreme events superimposed on climate change may result in conditions beyond the tolerance of species. Indeed, there is already widespread evidence from across Australia demonstrating catastrophic population and ecosystem collapses due this combination of events (Harris et al. 2018).

Our results may be influenced by our methodology. For representative plant species, we excluded regions projected to be currently suitable but in which no high quality occurrence records exist, considering these to be instances of commission error. For threatened species, we classified these regions as *unoccupied* habitat. Yet, a lack of occurrence records does not necessarily mean that populations of those species are absent, particularly for undersampled regions. Also, we excluded areas that fell below our selected suitability threshold, though a small number of these may have contained populations. We acknowledge that this threshold might exclude small regions with suitable habitat, however, the advantage is that this threshold is likely to exclude marginal habitat.

We calibrated models with occurrence records that met certain criteria — recorded prior to 1950; not georeferenced; coordinate uncertainty greater than 1000 m; invalid coordinate reference system; noted by ALA as a spatial/environmental outlier, a duplicate record, an invalid scientific name, or cultivated. This process means that there may be other regions with populations of the target species that we have excluded, and hence some areas classified as *unoccupied* habitat may indeed be *occupied*. However, the data cleaning process is a very important step, enhancing the quality of model output relative to less restrictive processes.

Finally, many threatened species are restricted to particular vegetation types. Since vegetation was not included in our models, the overall amount of habitat available for occupancy is likely to be smaller than the area projected to be suitable.

5.2.2 Additional factors impacting species' vulnerability to climate change

Williams et al (2008) outlined a framework for defining a species' vulnerability to climate change as a function of its **exposure, sensitivity and adaptive capacity**, and these factors should be considered when developing management plans. Exposure is a measure of the magnitude of projected climate change across a species' distribution, and may be based on anomalies in relevant climatic parameters or sea level rise, estimates of analogous/novel climate, velocity indices or with HSMs. Sensitivity refers to the potential for a species to persist in situ, while adaptive capacity is its' ability to persist by dispersing, through plasticity or by undergoing micro-evolutionary adaptation (Foden et al 2013). Both sensitivity and adaptive capacity can be defined with respect to biological, ecological, physiological, and environmental traits. For instance, Foden et al (2013) summarise five traits that are associated with higher sensitivity (habitat/micro-habitat specialization, narrow environmental tolerance; dependence on environmental triggers likely to be disrupted by climate change; dependence on interspecific interactions likely to be disrupted by climate change; rarity) and two traits with lower adaptive capacity (poor dispersal ability [either due to intrinsic limitations or barriers to dispersal]; low potential for evolutionary adaptation) (Figure 5.1).

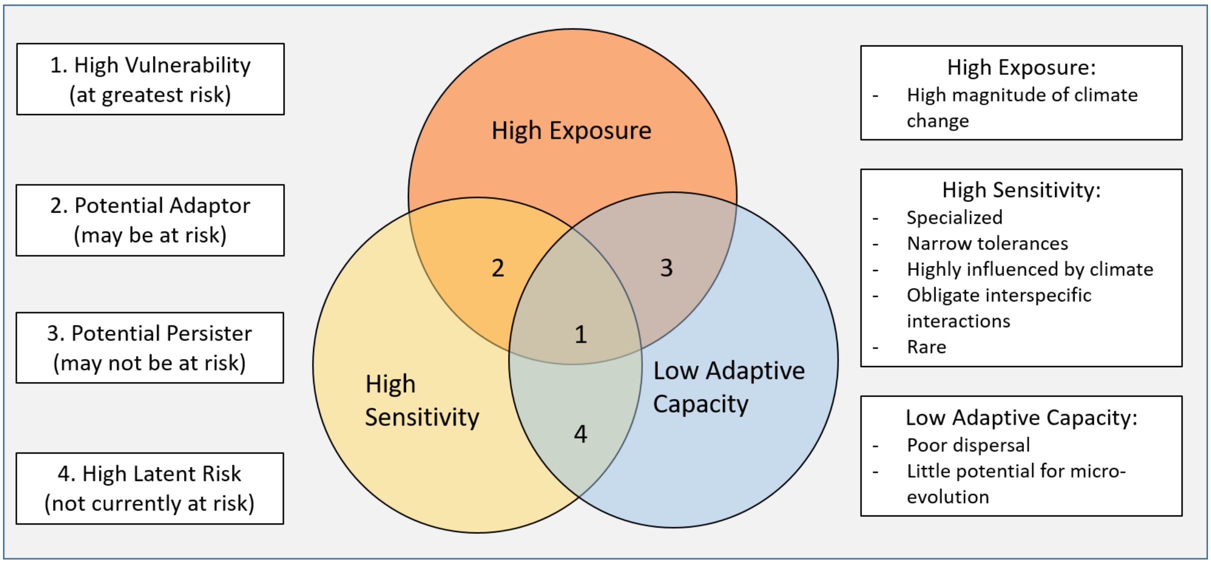


Figure 5.1. The vulnerability of a system to climate change is a function of exposure, sensitivity and adaptive capacity (adapted from William et al (2008) and Foden et al (2013)).

Building upon William et al's (2008) framework, Foden et al (2013) grouped species into four classes, each of which have implications for species prioritisation and management. *High vulnerability* species are at greatest risk: highly exposed and sensitive with low adaptive capacity, these species should be prioritised for monitoring and assessments for interventions be developed. *Potential adaptors* may also be at high risk. Although sensitive and exposed, these species have high adaptive capacity and can likely disperse at sufficient pace to track climate change or undergo micro-evolution. Regardless, monitoring is recommended. *Potential persisters* are less likely to be at risk. Although highly exposed with low adaptive capacity these species are not sensitive to climate change and can likely withstand climate change *in situ*. Monitoring is recommended, however, for both *potential adaptors* and *persisters* to ensure that assumptions are correct. Finally, species at *high latent risk* have little adaptive capacity and are sensitive, but as their exposure to climate change in the near future is low, so too is their risk (although they may become vulnerable in later time periods).

Our study only used a simple measure of sensitivity to climate change. Sensitivity of many site-managed species is lightly to be heightened by habitat specialization and rarity. These species are also likely to have very low adaptive capacity by virtue of small, isolated populations, and a high likelihood of low genetic diversity. In contrast, some landscape-managed species may have higher adaptive capacity, particularly given that these species are relatively mobile. Sensitivity, however, will vary across these species. For instance, species with specific habitat requirements, such as mature hollow-bearing trees (e.g. Sooty Owl (*Tyto tenebricosa*) and Stephen's Banded Snake (*Hoplocephalus stephensii*)) may have higher sensitivity due to the decline in this resource and threats arising from increases in fire frequency, compared to habitat generalists. As such, we consider an important extension of this project to be an assessment of species-specific traits associated with vulnerability to climate change.

5.3 Future research directions

In addition to a Climate Change Vulnerability Assessment (CCVA, above), below we briefly outline three extensions to this project that will advance our understanding of the vulnerability of threatened species in NSW to climate change and aid with prioritisation for monitoring and development of interventions.

1. *Advancing HSMs by accounting for metapopulation persistence and vegetation condition and connectivity.* HSMs suffer from several well-known limitations: species-specific requirements for patch size and dispersal ability are not considered, nor is the landscape matrix. The output of HSMs can be advanced considerably by excluding areas of suitable habitat that do not meet a particular size or that are beyond the dispersal ability of the target species. In addition, by overlaying modified HSM maps with vegetation condition, conservation benefit maps can be developed to quantify the relative benefits of undertaking habitat restoration or revegetation. This is currently the focus of a pilot study by OEH-MQ (led by Dr Michael Drielsma, OEH). Extending the project across all landscape-managed species has the potential to lead to high conservation benefits by identifying priority areas for the persistence of multiple species.
2. *Calibrating HSMs for species with few occurrence records*. It is generally regarded that at least 20 spatially unique occurrence records are required to calibrate HSMs, as

lower numbers of records are likely to result in HSMs with poorer HSM predictive performance (Hernandez et al. 2006; Wisz et al. 2008). For the current project, more than half of all site-managed species lacked sufficient high quality occurrence records to calibrate HSMs. However, recent 'ensemble-based' procedures have been developed to enable models to be fitted for these species (Liu et al. 2018). This technique would greatly expand the set of species we could include in the current project.

3. *Exposure of SoS site-managed locations*. Presently, considerable resources are devoted to a number of locations for the management of site-managed species. A preliminary examination of the climate suitability of these sites for a subset of seven species indicated that only two will likely have all managed sites retaining suitable conditions in the distant future (i.e. 2070). A more detailed analysis across all managed sites will help to identify species for which conservation resources may need to be focused on different populations to ensure the success of the SoS program.

5.4 Conclusions

Rapid climate change is one of the greatest threats to ecosystems, particularly for those unable to keep pace via migration or adaptation (Loarie et al. 2009). For some species, internal climate refugia will represent the most viable option for their survival, underscoring the critical importance of identifying, restoring and protecting these areas. Here, we have demonstrated a straightforward approach to characterising climate refugia, as well as areas vulnerable to community disruption, based on representative species as well as identifying internal refugia and regions with translocation potential for threatened species. However, two key uncertainties remain. First, without concerted efforts to mitigate climate change, the efficacy of refugial areas identified in this project will likely decline beyond 2070. Second, to be effective, refugia must afford protection from not just climate-change related stressors, but also non-climatic threatening processes (Reside et al. 2014) that can diminish their value. Important climate refugia for representative plant species and threatened species are projected to lie in areas of marginal quality with respect to non-climatic factors, such as around the heavily urbanised mid-coastal region of NSW, and the Darling Riverine Plains where habitat is generally in poor condition.

Importantly, our methodology identifies areas likely to support community and species persistence across the spectrum of plausible climate futures. Our consideration of a range of contrasting climate scenarios provides an explicit approach to contextualising climate uncertainty, thereby facilitating transparent, effective management of biodiversity.

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7 Appendix

Table A1. *Names of 117 native plant species included in this study, along with: the ecoregions in which they occur (bold text indicates ecoregions within which the species is amongst the 30 most frequently recorded native plant species); the number of occurrence records used to fit full models (n); and the average cross-validated test AUC. Ecoregion abbreviations indicate: DXS = Deserts & Xeric Shrublands; MGS = Montane Grasslands & Shrublands; MFWS = Mediterranean Forests Woodlands & Scrub; TBMF = Temperate Broadleaf & Mixed Forests; TGSS = Temperate Grasslands Savannas & Shrublands; TrGSS = Tropical/Subtropical Grasslands Savannas & Shrublands.*

Family	Species	Ecoregion	*n*	AUC
Acanthaceae				
	Brunoniella australis	TBMF, TGSS, **TrGSS**	2455	0.86
Aizoaceae				
	Tetragonia tetragonioides	DXS, **MFWS,** TBMF, TGSS, TrGSS	973	0.89
Apiaceae				
	Aciphylla simplicifolia	MGS	143	0.98
	Daucus glochidiatus	DXS, MFWS, MGS, TBMF, **TGSS,** TrGSS	3401	0.78
Asteraceae				
	Leptorhynchos squamatus	**MGS,** TBMF, TGSS, TrGSS	705	0.84
	Olearia pimeleoides	DXS, **MFWS,** TBMF, TGSS	761	0.90
	Vittadinia cuneata	DXS, **MFWS,** TBMF, **TGSS,** TrGSS	3211	0.82
Campanulaceae				
	Lobelia purpurascens	**TBMF,** TGSS, TrGSS		
	Wahlenbergia communis	DXS, MFWS, MGS, TBMF, TGSS, **TrGSS**	3073	0.85
Casuarinaceae				
	Allocasuarina littoralis	**TBMF,** TGSS, TrGSS	3369	0.81
	Casuarina cristata	MFWS, TBMF, **TGSS,** TrGSS	624	0.94
	Casuarina pauper	DXS, **MFWS,** TGSS	681	0.87
Chenopodiaceae				
	Atriplex angulata	**DXS,** MFWS, TGSS	284	0.83
	Atriplex leptocarpa	DXS, MFWS, TBMF, **TGSS,** TrGSS	1048	0.94
	Atriplex lindleyi	**DXS,** MFWS, TBMF, **TGSS,** TrGSS	890	0.90
	Atriplex stipitata	DXS, MFWS, TGSS	744	0.89
	Atriplex vesicaria	**DXS,** MFWS, TBMF, TGSS, TrGSS	1178	0.84
	Chenopodium curvispicatum	DXS, **MFWS,** TBMF, TGSS	686	0.92
	Chenopodium desertorum	DXS, **MFWS,** TBMF, TGSS, TrGSS	1621	0.87
	Chenopodium nitrariaceum	DXS, MFWS, TBMF, **TGSS,** TrGSS	745	0.93
	Dissocarpus paradoxus	DXS, MFWS, TGSS	1078	0.88
	Einadia hastata	MFWS, TBMF, TGSS, **TrGSS**	2068	0.83
	Einadia nutans	DXS, MFWS, TBMF, **TGSS, TrGSS**	5335	0.84
	Enchylaena tomentosa	DXS, MFWS, TBMF, TGSS, TrGSS	3392	0.85
	Eriochiton sclerolaenoides	DXS, **MFWS,** TGSS	565	0.85
	Maireana georgei	DXS, **MFWS,** TGSS	800	0.80
	Maireana pentatropis	DXS, **MFWS,** TGSS	733	0.92
	Maireana pyramidata	DXS, MFWS, TGSS	895	0.89

Family	Species	Ecoregion	*n*	AUC
	Maireana sedifolia	**DXS,** MFWS, TGSS	377	0.84
	Rhagodia spinescens	**DXS,** MFWS, TBMF, **TGSS,** TrGSS	1716	0.89
	Sclerolaena birchii	MFWS, TBMF, **TGSS,** TrGSS	1062	0.92
	Sclerolaena diacantha	DXS, MFWS, TBMF, TGSS, TrGSS	2143	0.86
	Sclerolaena lanicuspis	**DXS,** MFWS, TGSS	544	0.81
	Sclerolaena limbata	**DXS,** TGSS	55	0.89
	Sclerolaena muricata	DXS, MFWS, TBMF, **TGSS,** TrGSS	2774	0.94
	Sclerolaena obliquicuspis	DXS, **MFWS,** TGSS	886	0.89
	Sclerolaena ventricosa	**DXS,** MFWS, TGSS	247	0.84
Convolvulaceae				
	Dichondra repens	MFWS, MGS, **TBMF,** TGSS, **TrGSS**	6783	0.82
Cupressaceae				
	Callitris endlicheri	MFWS, TBMF, TGSS, **TrGSS**	2184	0.92
	Callitris glaucophylla	DXS, MFWS, TBMF, **TGSS, TrGSS**	3833	0.92
Cyperaceae				
	Cyperus gracilis	TBMF, TGSS, **TrGSS**	2193	0.88
	Lepidosperma laterale	**TBMF,** TGSS, TrGSS	5697	0.78
Dennstaedtiaceae				
	Pteridium esculentum	MGS, **TBMF,** TrGSS	6325	0.85
Dilleniaceae				
	Hibbertia obtusifolia	TBMF, TGSS, **TrGSS**	4085	0.82
Ericaceae				
	Melichrus urceolatus	TBMF, TGSS, **TrGSS**	2842	0.88
Euphorbiaceae				
	Beyeria opaca	**MFWS,** TGSS	257	0.92
	Euphorbia drummondii	DXS, MFWS, TBMF, **TGSS,** TrGSS	2900	0.87
Fabaceae				
	Acacia aneura	**DXS,** MFWS, TGSS, TrGSS	1088	0.83
	Acacia colletioides	DXS, **MFWS,** TGSS, TrGSS	392	0.94
	Acacia deanei	MFWS, MGS, TBMF, TGSS, **TrGSS**	1309	0.90
	Acacia ligulata	**DXS,** MFWS, TBMF, TGSS, TrGSS	171	0.90
	Acacia loderi	**DXS,** MFWS, TGSS	119	0.89
	Acacia pubescens	TBMF	190	0.97
	Acacia ramulosa	**DXS,** MFWS, TGSS	505	0.79
	Acacia stenophylla	DXS, MFWS, TBMF, **TGSS,** TrGSS	718	0.93
	Acacia tetragonophylla	**DXS,** TGSS	592	0.79
	Acacia victoriae	**DXS,** MFWS, TGSS, TrGSS	782	0.80
	Desmodium varians	TBMF, TGSS, **TrGSS**	4754	0.82
	Glycine clandestina	DXS, MFWS, **TBMF,** TGSS, TrGSS	6537	0.80
	Glycine tabacina	TBMF, TGSS, **TrGSS**	3642	0.80
	Hardenbergia violacea	MGS, **TBMF,** TGSS, TrGSS	5013	0.82
	Senna artemisioides	**DXS, MFWS,** TBMF, TGSS, TrGSS	3956	0.83
Junaceae				
	Juncus falcatus	**MGS,** TBMF	166	0.94

Family	Species	Ecoregion	*n*	AUC
Lomandraceae				
	Lomandra filiformis	MGS, TBMF, TGSS, **TrGSS**	6298	0.80
	Lomandra longifolia	MGS, **TBMF,** TGSS, TrGSS	8543	0.82
	Lomandra multiflora	MFWS, **TBMF,** TGSS, **TrGSS**	6574	0.80
Luzuriagaceae				
	Eustrephus latifolius	**TBMF,** TGSS, TrGSS	3623	0.79
Marsileaceae				
	Marsilea drummondii	DXS, MFWS, TBMF, **TGSS,** TrGSS	1487	0.93
Myrtaceae				
	Corymbia gummifera	TBMF	2586	0.90
	Eucalyptus albens	TBMF, TGSS, **TrGSS**	1878	0.93
	Eucalyptus camaldulensis	DXS, MFWS, TBMF, **TGSS,** TrGSS	2734	0.79
	Eucalyptus coolabah	DXS, MFWS, TGSS, **TrGSS**	1122	0.90
	Eucalyptus crebra	TBMF, TGSS, **TrGSS**	3281	0.79
	Eucalyptus dalrympleana	**MGS,** TBMF, TrGSS	1031	0.93
	Eucalyptus delegatensis	**MGS,** TBMF	216	0.92
	Eucalyptus dumosa	**MFWS,** TBMF, TGSS, TrGSS	555	0.94
	Eucalyptus gracilis	**MFWS,** TBMF, TGSS	1139	0.85
	Eucalyptus largiflorens	DXS, MFWS, TBMF, **TGSS,** TrGSS	1243	0.92
	Eucalyptus pauciflora	**MGS,** TBMF, TrGSS	1223	0.91
	Eucalyptus populnea	MFWS, TBMF, **TGSS,** TrGSS	1561	0.92
	Eucalyptus radiata	**MGS,** TBMF	1159	0.90
	Eucalyptus socialis	DXS, **MFWS,** TBMF, TGSS	1814	0.79
Oleaceae				
	Notelaea microcarpa	TBMF, TGSS, **TrGSS**	2082	0.93
Oxalidaceae				
	Oxalis perennans	DXS, MFWS, TBMF, **TGSS, TrGSS**	5773	0.83
Phormiaceae				
	Dianella caerulea	**TBMF,** TrGSS	5792	0.83
Pittosporaceae				
	Bursaria spinosa	MFWS, MGS, **TBMF,** TGSS, TrGSS	4089	0.82
Poaceae				
	Aristida vagans	TBMF, **TrGSS**	3146	0.84
	Austrostipa scabra	DXS, MFWS, TBMF, **TGSS, TrGSS**	5788	0.86
	Austrostipa verticillata	TBMF, TGSS, **TrGSS**	1567	0.91
	Chionochloa frigida	MGS	37	0.99
	Chloris truncata	DXS, MFWS, TBMF, **TGSS,** TrGSS	2845	0.88
	Cymbopogon refractus	DXS, TBMF, TGSS, **TrGSS**	4430	0.87
	Cynodon dactylon	DXS, MFWS, **TBMF,** TGSS, TrGSS	3708	0.84
	Enteropogon acicularis	DXS, MFWS, TBMF, **TGSS,** TrGSS	2262	0.91
	Entolasia stricta	**TBMF,** TGSS, TrGSS	5552	0.84
	Eragrostis dielsii	**DXS,** MFWS, TGSS	672	0.84
	Imperata cylindrica	**TBMF,** TrGSS	4146	0.89
	Microlaena stipoides	MFWS, MGS, **TBMF,** TGSS, **TrGSS**	7330	0.82

Family	Species	Ecoregion	*n*	AUC
	Oplismenus hirtellus	**TBMF,** TrGSS	3916	0.84
	Poa costiniana	**MGS,** TBMF	248	0.97
	Poa ensiformis	**MGS,** TBMF	258	0.87
	Themeda triandra	DXS, MFWS, **TBMF,** TGSS, TrGSS	6252	0.82
	Triodia scariosa	DXS, **MFWS,** TBMF, TGSS, TrGSS	826	0.88
Proteaceae				
	Persoonia linearis	**TBMF,** TrGSS	3966	0.80
Psittosporaceae				
	Pittosporum undulatum	**TBMF,** TrGSS	2769	0.89
Pteridaceae				
	Cheilanthes sieberi	DXS, MFWS, TBMF, TGSS, **TrGSS**	7618	0.86
Ranunculaceae				
	Ranunculus anemoneus	MGS	58	0.98
Rubiaceae				
	Pomax umbellata	TBMF, TGSS, **TrGSS**	3897	0.77
Rutaceae				
	Geijera parviflora	MFWS, TBMF, **TGSS, TrGSS**	2033	0.91
Sapindaceae				
	Alectryon oleifolius	DXS, **MFWS,** TBMF, **TGSS,** TrGSS	1454	0.86
	Dodonaea viscosa	DXS, MFWS, MGS, TBMF, TGSS, TrGSS	4654	0.80
Scrophulariaceae				
	Eremophila glabra	**MFWS,** TGSS	1320	0.83
	Eremophila mitchellii	MFWS, TBMF, **TGSS,** TrGSS	1084	0.92
	Eremophila sturtii	**DXS, MFWS,** TGSS, TrGSS	883	0.89
	Myoporum platycarpum	DXS, **MFWS,** TBMF, TGSS, TrGSS	792	0.89
Solanaceae				
	Solanum sturtianum	**DXS,** TGSS, TrGSS	249	0.79
Violaceae				
	Viola hederacea	MGS, **TBMF,** TrGSS	3189	0.82

Table A2. *Names of 319 threatened species included in this study (81 landscape-managed and 238 site-managed species), along with their common name, number of occurrence records used to fit full models (n); and the average cross-validated test AUC.*

Landscape-management Stream

Family	Species	Common Name	*n*	AUC
Acanthizidae	*Chthonicola sagittata*	Speckled Warbler	6061	0.843
	Hylacola cautus	Shy Heathwren	346	0.897
	Pyrrholaemus brunneus	Redthroat	2972	0.821
Accipitridae	*Circus assimilis*	Spotted Harrier	8439	0.698
	Hieraaetus morphnoides	Little Eagle	11978	0.628
	Lophoictinia isura	Square-tailed Kite	3210	0.734
	Pandion cristatus	Eastern Osprey	4163	0.917
Anatidae	*Oxyura australis*	Blue-billed Duck	2601	0.764
	Stictonetta naevosa	Freckled Duck	2458	0.760
Ardeidae	*Botaurus poiciloptilus*	Australasian Bittern	1077	0.810
	Ixobrychus flavicollis	Black Bittern	1539	0.846
Atrichornithidae	*Atrichornis rufescens*	Rufous Scrub-bird	348	0.949
Burhinidae	*Burhinus grallarius*	Bush Stone-curlew	5811	0.832
Burramyidae	*Cercartetus nanus*	Eastern Pygmy-possum	1007	0.820
Cacatuidae	*Callocephalon fimbriatum*	Gang-gang Cockatoo	5173	0.848
	Calyptorhynchus lathami	Glossy Black-cockatoo	7330	0.785
	Lophochroa leadbeateri	Major Mitchell's Cockatoo	3052	0.887
Campephagidae	*Coracina lineata*	Barred Cuckoo-shrike	943	0.908
Carphodactylidae	*Uvidicolus sphyrurus*	Border Thick-tailed Gecko	53	0.971
Chelidae	*Wollumbinia belli*	Bell's Turtle	24	0.994
Columbidae	*Ptilinopus regina*	Rose-crowned Fruit-dove	2691	0.883
Dasyuridae	*Dasyurus maculatus*	Bindjulang	3396	0.806
	Ningaui yvonneae	Southern Ningaui	422	0.906
	Phascogale tapoatafa tapoatafa	Brush-tailed Phascogale	1713	0.851
	Sminthopsis leucopus	White-footed Dunnart	380	0.876
	Sminthopsis macroura	Stripe-faced Dunnart	1948	0.832
Elapidae	*Hoplocephalus bitorquatus*	Pale-headed Snake	163	0.864
	Hoplocephalus stephensii	Stephens' Banded Snake	288	0.876
	Simoselaps fasciolatus	Narrow-banded Snake	77	0.792
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	1137	0.788
Estrildidae	*Stagonopleura guttata*	Diamond Firetail	6119	0.813
Falconidae	*Falco (Hierofalco) subniger*	Black Falcon	4282	0.713

Hylidae	*Litoria daviesae*	Davies' Tree Frog	126	0.974
	Litoria littlejohni	Littlejohn's Frog	168	0.942
	Litoria olongburensis	Olongburra Frog	196	0.967
	Litoria subglandulosa	Glandular Frog	94	0.966
Jacanidae	*Irediparra gallinacea*	Comb-crested Jacana	3116	0.857
Limnodynastidae	*Heleioporus australiacus*	Giant Burrowing Frog	380	0.885
	Philoria loveridgei	Loveridge's Frog	79	0.967
	Philoria sphagnicola	Sphagnum Frog	203	0.968
Macropodidae	*Notamacropus parma*	Parma wallaby	362	0.920
	Thylogale stigmatica	Red-legged Pademelon	359	0.879
Meliphagidae	*Certhionyx variegatus*	Pied Honeyeater	3776	0.889
	Epthianura albifrons	White-fronted Chat	10261	0.785
	Grantiella picta	Painted Honeyeater	1576	0.806
Menuridae	*Menura alberti*	Albert's Lyrebird	507	0.969
Miniopteridae	*Miniopterus australis*	Little Bentwing-bat	2071	0.792
Myobatrachidae	*Mixophyes balbus*	Stuttering Frog	561	0.907
	Mixophyes iteratus	Giant Barred Frog	602	0.903
	Pseudophryne australis	Red-crowned Toadlet	696	0.931
Neosittidae	*Daphoenositta (Neositta) chrysoptera*	Varied Sittella	17647	0.635
Pachycephalidae	*Pachycephala (Timixos) inornata*	Gilbert's Whistler	2845	0.889
	Pachycephala olivacea	Olive Whistler	3220	0.863
Petauridae	*Petaurus australis australis*	Yellow-bellied Glider	7466	0.833
	Petaurus norfolcensis	Squirrel Glider	2208	0.816
Petroicidae	*Petroica (Littlera) phoenicea*	Flame Robin	10038	0.774
	Petroica boodang	Scarlet Robin	14218	0.777
Podargidae	*Podargus ocellatus*	Marbled Frogmouth	256	0.927
Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	9542	0.749
	Lathamus discolor	Swift Parrot	3213	0.837
	Neophema pulchella	Turquoise Parrot	2071	0.868
	Polytelis swainsonii	Superb Parrot	2146	0.946
Psophodidae	*Cinclosoma (Malleeavis) castanotum*	Chestnut quail-thrush	2616	0.907
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox	3908	0.871
Pygopodidae	*Aprasia inaurita*	Mallee Worm-lizard	270	0.906
	Aprasia parapulchella	Pink-tailed Legless Lizard	65	0.959
	Delma impar	Many-lined Delma	355	0.922
Scincidae	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	82	0.920
	Eulamprus leuraensis	Blue Mountains Swamp-skink	60	0.993
Strigidae	*Ninox (Hieracoglaux) connivens*	Barking Owl	3218	0.788

	Ninox (Rhabdoglaux) strenua	Powerful Owl	6946	0.773
Tytonidae	*Tyto (Megastrix) novaehollandiae*	Masked Owl	3027	0.822
	Tyto (Megastrix) tenebricosa tenebricosa	Sooty Owl	3724	0.866
	Tyto longimembris	Eastern Grass Owl	346	0.904
Varanidae	*Varanus rosenbergi*	Heath Monitor	585	0.885
Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	1560	0.801
	Kerivoula papuensis	Golden-tipped Bat	550	0.870
	Myotis macropus	Southern Myotis	1157	0.795
	Nyctophilus corbeni	Corben's Long-eared Bat	307	0.921
	Scoteanax rueppellii	Greater Broad-nosed Bat	1001	0.763
	Vespadelus troughtoni	Eastern Cave Bat	403	0.786

Site-management stream

Family	Species	Common Name	*n*	AUC
Animals				
Agamidae	*Ctenophorus mirrityana*	Barrier Range Dragon	43	0.991
	Tympanocryptis pinguicolla	Grassland Earless Dragon	31	0.946
Burhinidae	*Esacus magnirostris*	Beach Stone-curlew	1985	0.960
Burramyidae	*Burramys parvus*	Mountain Pygmy-possum	122	0.994
Charadriidae	*Thinornis rubricollis*	Hooded Plover	1403	0.959
Dasyornithidae	*Dasyornis brachypterus*	Eastern Bristlebird	305	0.953
Haematopodidae	*Haematopus longirostris*	pied oystercatcher	8462	0.897
Hylidae	*Litoria aurea*	Green and golden bell frog	658	0.897
	Litoria booroolongensis	Booroolong frog	186	0.924
	Litoria castanea	Yellow-spotted Tree Frog	27	0.945
	Litoria raniformis	Southern Bell Frog	1581	0.814
Laridae	*Sternula albifrons*	Little tern	2169	0.934
Maluridae	*Amytornis barbatus barbatus*	Grey Grasswren	121	0.946
	Amytornis striatus	Striated Grasswren	979	0.917
Meliphagidae	*Anthochaera phrygia*	Regent Honeyeater	1274	0.837
Muridae	*Pseudomys fumeus*	Smoky Mouse	180	0.923
	Pseudomys gracilicaudatus	Eastern Chestnut Mouse	221	0.844
	Pseudomys pilligaensis	Poolkoo	74	0.965
Myobatrachidae	*Crinia sloanei*	Sloane's Froglet	112	0.942
	Mixophyes fleayi	Fleay's Frog	116	0.976
	Pseudophryne pengilleyi	Northern Corroboree Frog	144	0.994
Pachycephalidae	*Pachycephala rufogularis*	Red-lored Whistler	518	0.946
Peramelidae	*Isoodon obesulus obesulus*	Southern Brown Bandicoot (eastern)	1349	0.908

Phaethontidae	*Phaethon rubricauda*	Red-tailed Tropicbird	92	0.815
Potoroidae	*Aepyprymnus rufescens*	Rufous Bettong	1220	0.885
	Potorous tridactylus	Long-nosed Potoroo	771	0.840
Procellariidae	*Ardenna carneipes*	Flesh-footed Shearwater	199	0.957
	Pterodroma leucoptera leucoptera	Gould's Petrel	47	0.958
	Pterodroma nigripennis	Black-winged Petrel	42	0.911
	Pterodroma solandri	Providence Petrel	81	0.953
	Puffinus assimilis	Little Shearwater	22	0.970
Psittacidae	*Pezoporus wallicus wallicus*	Eastern Ground Parrot	816	0.941
	Polytelis anthopeplus monarchoides	Regent Parrot	890	0.958
Sulidae	*Sula dactylatra*	Masked (Blue-faced) Booby	56	0.961
Plants				
Acanthaceae	*Isoglossa eranthemoides*	Isoglossa	25	0.950
Apocynaceae	*Ochrosia moorei*	Southern ochrosia	66	0.963
	Tylophora woollsii	Cryptic forest twiner	48	0.908
Araliaceae	*Astrotricha crassifolia*	Thick-leaf star-hair	28	0.886
	Astrotricha roddii	Rodd's star hair	61	0.982
Asteraceae	*Brachyscome muelleroides*	Claypan daisy	21	0.958
	Calotis glandulosa	Mauve burr-daisy	111	0.973
	Olearia cordata	—	41	0.954
	Olearia flocktoniae	Dorrigo daisy bush	82	0.993
	Ozothamnus vagans	Wollumbin dogwood	28	0.996
	Picris evae	Hawkweed	47	0.961
	Rutidosis leiolepis	Monaro golden daisy	51	0.976
	Rutidosis leptorrhynchoides	Button Wrinklewort	101	0.978
	Senecio spathulatus	Coast Groundsel	178	0.981
Atherospermataceae	*Daphnandra johnsonii*	Illawarra socketwood	59	0.986
Brassicaceae	*Irenepharsus trypherus*	Illawarra Irene	22	0.984
	Lepidium monoplocoides	Winged peppercress	67	0.901
	Lepidium peregrinum	Wandering pepper cress	30	0.906
Casuarinaceae	*Allocasuarina defungens*	Dwarf heath casuarina	64	0.976
	Allocasuarina simulans	Nabiac casuarina	29	0.995
Chenopodiaceae	*Sclerolaena napiformis*	Turnip copperburr	100	0.982
Convolvulaceae	*Wilsonia backhousei*	Narrow-leaf Wilsonia	333	0.928
Cunoniaceae	*Acrophyllum australe*	—	40	0.994
	Davidsonia jerseyana	Davidson's plum	93	0.978
	Davidsonia johnsonii	Smooth Davidson's plum	41	0.966
Cupressaceae	*Callitris baileyi*	Bailey's cypress pine	46	0.947
	Callitris oblonga	Tasmanian cypress pine	70	0.915
Cyperaceae	*Carex raleighii*	Raleigh Sedge	167	0.952

	Eleocharis tetraquetra	Saquare-stemmed Spike-rush	34	0.817
Dilleniaceae	*Hibbertia puberula*	Hibbertia Puberula	24	0.946
	Hibbertia sp. Bankstown	—	937	0.778
	Hibbertia stricta subsp. furcatula	—	42	0.987
	Hibbertia superans	Hibbertia Superans	37	0.994
Droseraceae	*Aldrovanda vesiculosa*	Waterwheel Plant	20	0.914
Ebenaceae	*Diospyros mabacea*	Red-fruited ebony	28	0.944
Elaeocarpaceae	*Elaeocarpus williamsianus*	Hairy quandong	21	0.963
	Tetratheca glandulosa	Tetratheca Glandulosa	409	0.977
Ericaceae	*Epacris hamiltonii*	—	21	0.994
	Epacris purpurascens var. purpurascens	—	179	0.966
	Leucopogon exolasius	Woronora beard-heath	51	0.961
	Leucopogon fletcheri subsp. fletcheri	—	32	0.939
	Melichrus hirsutus	Hairy Melichrus	56	0.970
Euphorbiaceae	*Bertya opponens*	Coolabah vertya	69	0.928
	Chamaesyce psammogeton	Sand spurge	50	0.977
Fabaceae	*Acacia acanthoclada*	Harrow Wattle	74	0.930
	Acacia ausfeldii	Ausfeld's Wattle	190	0.988
	Acacia bakeri	Baker's Wattle	136	0.949
	Acacia bynoeana	Bynoe's wattle	223	0.927
	Acacia carneorum	Needle Wattle	173	0.952
	Acacia courtii	North Brother wattle	21	0.997
	Acacia curranii	Curly-bark Wattle	49	0.946
	Acacia gordonii	Gordon's wattle	36	0.971
	Acacia meiantha	—	22	0.992
	Acacia phasmoides	Phantom wattle	20	0.997
	Acacia pubescens	Downy wattle	207	0.976
	Acacia pubifolia	Velvet wattle	29	0.982
	Acacia terminalis subsp. terminalis	Sunshine wattle	51	0.992
	Archidendron hendersonii	White lace flower	120	0.955
	Bossiaea oligosperma	Few-seeded bossiaea	34	0.992
	Caesalpinia bonduc	Grey-nicker	86	0.884
	Cassia brewsteri var. marksiana	—	73	0.963
	Cullen parvum	Small Scurf-pea	211	0.952
	Desmodium acanthocladum	Thorny pea	126	0.974
	Dillwynia glaucula	Michelago Parrot-pea	33	0.970
	Indigofera baileyi	Bailey's indigo	30	0.908
	Phyllota humifusa	Dwarf phyllota	51	0.995
	Pultenaea glabra	Smooth bush-pea	57	0.971
	Pultenaea maritima	Coast headland pea	35	0.961
	Pultenaea parviflora	—	96	0.991
	Pultenaea pedunculata	Matted Bush-pea	1076	0.929
	Senna acclinis	Rainforest cassia	103	0.854
	Sophora fraseri	Brush sophora	43	0.919
	Sophora tomentosa	Silverbush	60	0.905
	Swainsona plagiotropis	Red darling pea	167	0.972
	Swainsona recta	Small purple-pea	81	0.960

Gentianaceae	*Gentiana wissmannii*	New England gentian	20	0.986
Goodeniaceae	*Dampiera fusca*	Kydra Dampiera	38	0.964
Haloragaceae	*Myriophyllum implicatum*	—	22	0.837
Lamiaceae	*Plectranthus alloplectus*	Narrow-leaved plectranthus	30	0.951
	Prostanthera askania	Tranquility mintbush	22	0.991
	Prostanthera densa	Villous mintbush	47	0.974
	Prostanthera junonis	Somersby mintbush	36	0.986
	Prostanthera stricta	Mount Vincent mintbush	45	0.972
Lauraceae	*Endiandra floydii*	Crystal creek walnut	66	0.962
Linderniaceae	*Lindernia alsinoides*	Noah's false chickweed	32	0.845
	Lindsaea incisa	Slender screw fern	43	0.937
Malvaceae	*Commersonia prostrata*	Dwarf Kerrawang	69	0.958
	Corchorus cunninghamii	Native Jute	35	0.957
	Lasiopetalum joyceae	—	57	0.980
Marsileaceae	*Pilularia novae-hollandiae*	Austral pillwort	122	0.878
Meliaceae	*Owenia cepiodora*	Onion cedar	62	0.924
Menispermaceae	*Tinospora tinosporoides*	Arrow-head vine	185	0.963
Myrtaceae	*Angophora exul*	Gibraltar Rock Apple	26	0.808
	Darwinia biflora	—	141	0.983
	Darwinia glaucophylla	Darwinia Glaucophylla	34	0.995
	Darwinia peduncularis	Darwinia Peduncularis	47	0.913
	Eucalyptus aggregata	Black Gum	201	0.958
	Eucalyptus alligatrix subsp. alligatrix	Silver Stringybark	33	0.990
	Eucalyptus benthamii	Camden white gum	61	0.993
	Eucalyptus camfieldii	Camfield's stringbark	85	0.958
	Eucalyptus camphora subsp. relicta	Warra broad-leaved sally	36	0.939
	Eucalyptus cannonii	Capertee stringybark	202	0.972
	Eucalyptus canobolensis	Silver-leaf candlebark	25	0.999
	Eucalyptus glaucina	Slaty Red Gum	218	0.968
	Eucalyptus kartzoffiana	Araluen gum	54	0.981
	Eucalyptus langleyi	Albatross mallee	38	0.983
	Eucalyptus largeana	Craven grey box	37	0.966
	Eucalyptus macarthurii	Camden woollybutt	142	0.974
	Eucalyptus magnificata	Northern blue box	44	0.957
	Eucalyptus microcodon	Border mallee	48	0.964
	Eucalyptus oresbia	Monkey gum	3370	0.949
	Eucalyptus parvula	Small-leaved gum	53	0.989
	Eucalyptus pulverulenta	Silver-leafed gum	79	0.952
	Eucalyptus rubida subsp. barbigerorum	Blackbutt candlebark	21	0.962
	Eucalyptus saxatilis	Mount Wheeler mallee	31	0.983
	Eucalyptus scoparia	Wallangarra White Gum	30	0.966
	Eucalyptus sp. Cattai	—	88	0.915
	Eucalyptus sturgissiana	Ettrema mallee	51	0.993
	Gossia fragrantissima	Sweet Myrtle	99	0.972
	Kunzea rupestris	—	39	0.983
	Melaleuca biconvexa	Biconvex paperbark	285	0.977

	Melaleuca deanei	Deane's paperbark	138	0.956
	Melaleuca irbyana	Weeping paperbark	95	0.953
	Micromyrtus blakelyi	—	36	0.974
	Micromyrtus minutiflora	—	45	0.984
	Syzygium hodgkinsoniae	Red lilly pilly	224	0.959
	Syzygium moorei	Durobby	243	0.977
	Syzygium paniculatum	Brush cherry	224	0.945
	Triplarina nowraensis	Nowra heath myrtle	26	0.994
	Uromyrtus australis	Peach myrtle	53	0.988
Orchidaceae	*Caladenia arenaria*	Sand-hill spider orchid	73	0.892
	Caladenia concolor	Crimson spider orchid	41	0.945
	Caladenia tessellata	Thick lip spider orchid	78	0.954
	Cryptostylis hunteriana	Leafless Tongue orchid	131	0.966
	Diuris aequalis	Buttercup doubletail	35	0.987
	Diuris arenaria	Sand doubletail	22	0.995
	Diuris pedunculata	Small snake orchid	25	0.896
	Diuris praecox	Rough doubletail	28	0.989
	Genoplesium baueri	Bauer's midge orchid	20	0.925
	Genoplesium littorale	Tuncurry midge orchid	21	0.994
	Phaius australis	Southern swamp orchid	35	0.967
	Prasophyllum affine	Jervis Bay leek orchid	29	0.900
	Pterostylis cobarensis	Greenhood orchid	84	0.958
	Pterostylis despectans	Parna Rustyhood	81	0.981
	Sarcochilus hartmannii	Hartman's sarcochilus	20	0.974
Phyllanthaceae	*Phyllanthus microcladus*	Brush sauropus	86	0.821
Plantaginaceae	*Veronica blakelyi*	Derwentia Blakelyi	49	0.983
Poaceae	*Alexfloydia repens*	Floyd's Grass	27	0.986
	Austrostipa nullanulla	Club Spear-grass	73	0.895
	Dichanthium setosum	Bluegrass	97	0.867
	Digitaria porrecta	Finger panic grass	175	0.948
	Homopholis belsonii	Belson's panic	118	0.971
Polygonaceae	*Persicaria elatior*	Tall knotweed	35	0.898
Proteaceae	*Floydia praealta*	Ball Nut	66	0.942
	Grevillea caleyi	Caley's grevillea	29	0.989
	Grevillea guthrieana	Guthrie's grevillea	30	0.821
	Grevillea hilliana	White yiel yiel	82	0.928
	Grevillea juniperina subsp. juniperina	Juniper-leaved Grevillea	135	0.993
	Grevillea masonii	Mason's grevillea	29	0.983
	Grevillea obtusiflora	—	34	0.991
	Grevillea parviflora subsp. supplicans	Small-flower grevillea	34	0.992
	Grevillea quadricauda	Four-tailed grevillea	36	0.930
	Grevillea renwickiana	Nerriga Grevillea	23	0.984
	Grevillea rhizomatosa	Gibraltar grevillea	20	0.985
	Hakea archaeoides	Big Nellie hakea	24	0.973
	Hakea dohertyi	Kowmung hakea	27	0.976
	Macadamia tetraphylla	Californian nut	275	0.964
	Persoonia acerosa	Needle geebung	76	0.992
	Persoonia bargoensis	Bargo geebung	69	0.996
	Persoonia glaucescens	Mittagong geebung	69	0.991

	Persoonia hindii	—	44	0.997
	Persoonia hirsuta	Hairy geebung	143	0.950
	Persoonia marginata	Clandulla geebung	62	0.971
	Persoonia mollis subsp. maxima	—	36	0.995
	Persoonia nutans	Nodding geebung	82	0.983
Rhamnaceae	*Discaria nitida*	Leafy Anchor Plant	62	0.964
	Pomaderris brunnea	Brown pomaderris	70	0.882
	Pomaderris cocoparrana	Cocoparra pomaderris	30	0.967
	Pomaderris cotoneaster	Cotoneaster pomaderris	45	0.894
	Pomaderris pallida	Pale pomaderris	75	0.978
	Pomaderris parrisiae	Parris' pomaderris	22	0.939
Rubiaceae	*Asperula asthenes*	Trailing woodruff	44	0.918
	Randia moorei	Spiny Gardenia	82	0.972
Rutaceae	*Acronychia littoralis*	Scented acronychia	93	0.969
	Boronia deanei	Deane's Boronia	22	0.984
	Boronia repanda	Granite rose	20	0.989
	Coatesia paniculata	Axe-breaker	95	0.870
	Leionema ralstonii	Ralston's Leionema	49	0.996
	Zieria granulata	Illawarra zieria	82	0.997
	Zieria involucrata	—	54	0.981
	Zieria murphyi	Velvet zieria	23	0.928
	Zieria tuberculata	Warty zieria	21	0.994
Salicaceae	*Xylosma terrae-reginae*	Queensland Xylosma	63	0.806
Sapindaceae	*Diploglottis campbellii*	Small-leaved tamarind	62	0.962
	Dodonaea procumbens	Creeping hop-bush	165	0.966
	Lepiderema pulchella	Fine-leaved tuckeroo	117	0.976
Scrophulariaceae	*Euphrasia ciliolata*	Polblue Eyebright	51	0.979
	Euphrasia scabra	Rough Eyebright	54	0.918
Simaroubaceae	*Quassia sp. Mooney Creek*	Moonee quassia	66	0.971
Solanaceae	*Solanum celatum*	Solanum Celatum	42	0.951
Symplocaceae	*Symplocos baeuerlenii*	Small-leaved hazelwood	87	0.985
Thymelaeaceae	*Pimelea curviflora var. curviflora*	—	102	0.957
	Pimelea spicata	Spiked Rice-flower	79	0.979
Winteraceae	*Tasmannia glaucifolia*	Fragrant pepperbush	54	0.970

Table A3. *Contribution (permutation importance) of each variable to the Maxent model, for each of the threatened species modelled in this study. Variables are: the first three principal components of from a principal components analysis performed on spectral characteristics of soil samples from across Australia (Soil1, Soil2,Soil3); mean diurnal temperature range (MDR); temperature seasonality (the coefficient of variation of weekly mean temperature) (TS); maximum temperature of the warmest month (T_{max}WM); minimum temperature of the coldest month (T_{min}CM); precipitation of the wettest month (PrWM); precipitation of the driest month (PrDM); precipitation seasonality (the coefficient of variation of weekly total precipitation) (PS); Weathering Intensity Index (WII); Topographic Position Index (TPI); Topographic Wetness Index (TWI). See Section 3.2 for additional details.*

Landscape-management stream

Family	Species	Soil1	Soil2	Soil3	MDR	TS	T_{max}WW	T_{min}CM	PrWW	PrDW	PS	WII	TPI	TWI
Acanthizidae	*Chthonicola sagittata*	1.1	0.4	20.7	0.2	4.7	17.4	0.4	25.4	14.4	15.2	0.1	—	—
	Hylacola cautus	1.6	2.3	6.1	5.4	10.1	7.1	4.0	34.4	8.4	13.9	4.7	0.1	2.0
	Pyrrholaemus brunneus	39.0	0.2	10.5	3.7	1.6	0.1	8.0	3.5	8.4	17.6	6.8	0.2	0.4
Accipitridae	*Circus assimilis*	2.4	0.9	10.2	4.0	3.7	0.0	34.3	1.4	6.8	1.7	4.1	0.3	30.1
	Hieraaetus morphnoides	8.2	0.8	18.1	3.2	18.6	0.0	11.7	5.5	15.2	9.2	3.0	1.5	5.2
	Lophoictinia isura	3.2	0.8	24.3	7.4	4.1	0.0	38.5	1.8	11.1	4.5	2.6	0.4	1.2
Accipitridae	*Pandion cristatus*	2.0	0.6	0.6	1.6	2.2	4.2	75.7	0.4	6.9	2.9	1.1	1.2	0.6
Anatidae	*Oxyura australis*	12.1	4.6	4.6	11.5	11.0	7.2	2.4	17.6	8.2	3.0	10.1	2.2	5.5
	Stictonetta naevosa	17.0	2.6	1.8	3.8	4.5	0.1	4.3	1.1	18.5	17.5	9.3	3.3	16.2
Ardeidae	*Botaurus poiciloptilus*	10.3	8.7	8.7	1.1	1.2	0.9	17.4	0.0	2.6	20.9	0.3	0.0	27.9
	Ixobrychus flavicollis	0.7	1.4	1.4	5.1	24.5	22.1	13.8	14.8	9.4	3.0	0.5	0.6	2.8
Atrichornithidae	*Atrichornis rufescens*	1.3	0.1	1.5	43.0	0.5	0.1	29.3	7.1	1.2	9.1	0.7	0.1	6.1
Burhinidae	*Burhinus grallarius*	6.8	0.5	9.5	0.6	1.8	7.1	38.7	16.2	10.8	6.2	1.7	—	—
Burramyidae	*Cercartetus nanus*	3.0	5.2	1.3	42.3	2.6	10.9	11.0	1.2	16.6	0.6	0.5	0.5	4.3
Cacatuidae	*Callocephalon fimbriatum*	4.4	2.7	0.3	4.8	9.3	13.1	38.6	12.6	2.2	7.5	3.1	0.2	1.2
	Calyptorhynchus lathami	1.1	1.2	3.3	17.0	15.0	0.2	10.9	0.3	22.9	14.6	3.7	0.1	9.7
	Lophochroa leadbeateri	8.0	0.4	19.6	2.5	37.5	0.0	1.2	6.4	17.5	7.0	—	—	—
Campephagidae	*Coracina lineata*	0.8	0.9	0.2	6.4	47.9	6.7	13.1	1.6	9.5	7.4	0.7	0.2	4.7
Carphodactylidae	*Uvidicolus sphyrurus*	1.5	0.3	2.9	0.0	7.7	0.0	57.8	14.6	0.0	6.2	3.7	0.1	5.1
Chelidae	*Myuchelys bellii*	0.1	0.9	0.3	0.0	0.0	0.4	53.0	0.0	28.8	4.0	11.2	0.5	0.8
Columbidae	*Ptilinopus regina*	3.7	0.2	0.1	0.5	1.1	0.3	48.5	23.6	3.0	15.0	0.8	0.1	3.1
Dasyuridae	*Dasyurus maculatus*	4.7	0.7	0.3	2.4	25.7	0.1	31.5	1.9	11.2	12.3	9.3	—	—

	Ningaui yvonneae	3.7	0.7	6.5	1.6	4.4	6.0	2.3	46.6	6.4	3.3	17.1	0.5	1.1
	Phascogale tapoatafa	0.4	2.1	18.1	15.4	13.3	12.5	17.9	7.8	3.9	7.1	1.1	0.3	0.0
	Sminthopsis leucopus	1.8	0.2	1.2	21.1	28.1	10.4	10.8	9.4	5.3	2.1	3.4	0.0	6.2
	Sminthopsis macroura	2.4	1.8	5.1	1.1	45.8	0.4	0.5	1.1	23.8	15.4	0.5	0.0	2.2
Elapidae	*Hoplocephalus bitorquatus*	2.1	1.5	5.2	4.4	8.7	13.9	7.0	23.9	6.5	25.7	1.2	—	—
	Hoplocephalus stephensii	4.2	0.1	0.7	0.7	19.5	0.7	3.7	5.1	22.8	28.9	0.8	0.2	12.8
	Simoselaps fasciolatus	2.3	0.6	4.2	6.9	15.0	40.9	21.4	0.7	5.9	0.3	1.8	—	—
Emballonuridae	*Saccolaimus flaviventris*	3.7	1.8	14.4	3.2	0.8	47.9	4.2	0.8	14.5	5.6	1.3	0.0	2.0
Estrildidae	*Stagonopleura guttata*	2.7	1.2	19.6	13.9	7.1	2.1	0.5	36.5	8.1	6.9	1.3	—	—
Falconidae	*Falco subniger*	8.8	0.3	1.3	0.2	1.7	11.0	0.1	8.2	9.3	6.5	5.5	1.6	45.4
Hylidae	*Litoria daviesae*	9.3	0.6	0.6	36.0	26.8	0.6	4.1	15.6	0.8	0.8	3.0	1.7	0.0
	Litoria littlejohni	1.1	1.8	0.3	5.4	1.3	5.2	7.4	47.4	4.4	23.5	1.3	0.1	0.7
	Litoria olongburensis	3.3	0.2	0.5	8.4	0.8	2.7	78.1	0.4	3.7	2.0	—	—	—
	Litoria subglandulosa	0.5	1.4	0.2	0.0	1.8	35.6	50.7	5.2	1.5	0.1	0.6	2.2	0.2
Jacanidae	*Irediparra gallinacea*	1.6	1.4	6.9	7.8	30.0	0.2	21.2	1.9	8.3	15.8	3.7	0.3	1.0
Limnodynastidae	*Heleioporus australiacus*	3.4	1.0	0.2	4.2	12.6	4.1	3.4	47.1	6.1	10.3	4.5	2.2	0.9
	Philoria loveridgei	5.6	0.1	1.6	1.1	63.1	0.1	24.4	1.2	2.8	0.1	—	—	—
	Philoria sphagnicolus	0.5	0.0	1.3	5.2	0.3	64.0	5.6	2.4	2.7	7.8	0.7	0.0	9.4
Macropodidae	*Macropus parma*	1.3	3.5	0.1	14.4	22.1	0.1	8.7	20.3	2.4	18.6	8.5	—	—
	Thylogale stigmatica	5.1	7.9	0.8	0.7	27.0	17.9	1.8	6.6	4.2	8.3	5.6	0.0	14.0
Meliphagidae	*Certhionyx variegatus*	15.9	0.1	5.0	0.2	3.6	6.1	8.8	38.6	7.0	9.5	5.3	—	—
	Epthianura albifrons	4.9	0.4	1.4	7.3	3.9	13.1	0.3	48.7	7.1	1.9	3.4	1.0	6.6
	Grantiella picta	0.9	2.7	13.3	0.6	58.7	0.4	1.9	3.8	8.7	3.2	0.6	0.4	4.9
Menuridae	*Menura alberti*	8.7	0.0	1.0	0.5	26.4	11.8	16.5	23.1	9.1	2.4	0.6	—	—
Miniopteridae	*Miniopterus australis*	2.2	2.2	4.8	8.7	33.5	0.4	23.1	1.2	13.0	7.9	2.2	0.3	0.6
Myobatrachidae	*Mixophyes balbus*	2.3	1.6	1.7	8.8	2.8	1.3	22.2	2.0	13.6	34.4	2.2	2.1	5.1
	Mixophyes iteratus	0.9	1.7	2.7	15.9	23.9	0.7	5.0	19.2	10.6	14.6	0.5	3.6	0.6
	Pseudophryne australis	1.0	0.7	0.0	14.4	11.4	0.7	20.6	25.8	7.2	14.7	1.5	0.4	1.7
Neosittidae	*Daphoenositta chrysoptera*	5.7	0.4	38.6	13.0	3.4	0.5	4.1	0.0	14.5	5.1	2.1	0.0	12.6
Pachycephalidae	*Pachycephala inornata*	1.8	0.9	11.4	8.2	2.4	0.0	0.5	53.0	14.4	2.2	4.5	0.1	0.7
	Pachycephala olivacea	0.9	3.6	1.0	15.1	2.8	32.1	9.9	0.1	3.9	5.0	2.1	1.1	22.6
Petauridae	*Petaurus australis*	0.4	2.1	4.7	8.8	30.3	0.5	6.9	1.0	10.8	3.5	1.0	0.4	29.7
	Petaurus norfolcensis	1.4	2.8	22.1	2.5	9.6	15.6	20.9	1.9	14.6	6.5	1.1	0.2	0.8

	Petroica boodang	1.9	0.6	32.3	8.1	6.8	6.5	4.4	11.1	12.3	13.0	0.6	0.0	2.3
	Petroica phoenicea	0.1	0.1	16.2	4.0	21.3	38.6	1.2	0.2	4.2	10.3	0.8	0.0	2.9
Podargidae	*Podargus ocellatus*	13.7	0.4	0.0	3.4	49.1	20.1	3.9	2.1	3.4	2.4	1.5	—	—
Psittacidae	*Glossopsitta pusilla*	1.9	0.1	36.9	17.4	1.3	12.7	8.3	4.8	10.7	4.0	0.9	0.2	0.7
	Lathamus discolor	1.4	0.0	14.8	4.5	12.9	26.4	13.0	4.0	7.8	9.9	2.5	0.4	2.2
	Neophema pulchella	1.6	0.3	11.7	8.2	35.5	2.6	3.8	9.0	14.2	8.4	4.6	—	—
	Polytelis swainsonii	2.2	0.8	1.8	0.2	34.0	0.0	23.8	0.7	9.6	24.2	2.4	0.0	0.4
Psophodidae	*Cinclosoma castanotum*	8.4	1.2	11.0	5.4	8.2	0.0	0.1	10.6	16.5	16.9	19.1	0.3	2.3
Pteropodidae	*Pteropus poliocephalus*	0.1	0.1	1.7	2.6	3.7	1.0	52.8	30.3	1.0	5.7	0.8	0.1	0.1
Pygopodidae	*Aprasia inaurita*	7.7	0.4	17.0	1.7	0.7	0.0	2.4	38.3	3.9	11.9	15.9	—	—
	Aprasia parapulchella	1.6	1.9	2.7	6.3	11.7	2.7	4.6	46.8	6.8	8.7	2.6	0.1	3.5
	Delma impar	0.5	5.1	2.3	9.5	6.1	9.0	7.4	33.4	16.2	10.6	—	—	—
Scincidae	*Coeranoscincus reticulatus*	1.4	1.7	0.4	2.7	44.2	21.0	6.2	0.6	20.8	0.2	0.8	—	—
	Eulamprus leuraensis	2.9	0.2	0.0	1.9	3.3	11.2	66.0	11.3	1.5	1.0	0.5	—	—
Strigidae	*Ninox connivens*	4.2	0.3	14.6	7.1	0.6	51.6	3.3	6.9	8.1	0.3	1.6	0.0	1.3
	Ninox strenua	1.4	6.0	16.9	9.1	25.5	4.6	4.6	3.1	10.5	1.5	7.4	0.1	9.5
Tytonidae	*Tyto longimembris*	1.7	1.5	2.5	6.1	4.0	8.0	60.0	2.9	2.7	5.7	4.9	—	—
	Tyto novaehollandiae	0.4	1.9	1.2	10.5	43.9	3.0	15.7	4.3	12.3	4.5	0.4	0.0	2.0
	Tyto tenebricosa	0.0	2.9	0.0	4.0	44.5	0.1	8.1	0.5	10.2	1.2	1.7	0.8	25.9
Varanidae	*Varanus rosenbergi*	7.0	4.9	7.1	0.9	0.9	0.2	6.6	16.1	13.6	36.5	3.5	0.2	2.4
Vespertilionidae	*Falsistrellus tasmaniensis*	4.1	0.3	0.9	28.9	9.2	11.4	29.4	1.5	8.5	4.7	1.1	—	—
	Kerivoula papuensis	1.3	3.1	1.8	2.2	9.4	0.7	1.3	9.6	20.3	34.6	1.7	1.0	13.2
	Myotis macropus	2.7	0.2	2.0	8.5	22.5	9.3	5.2	4.7	37.3	2.0	2.1	1.3	2.2
	Nyctophilus corbeni	1.3	0.3	1.3	4.8	1.5	18.8	3.1	28.8	12.7	7.3	11.8	0.4	7.8
	Scoteanax rueppellii	5.7	0.0	2.1	3.5	3.9	15.4	22.5	8.8	21.1	17.1	—	—	—
	Vespadelus troughtoni	1.3	0.2	11.5	6.4	9.8	0.5	13.1	18.4	3.5	22.9	3.5	0.2	8.8
Site-management stream														
Agamidae	*Ctenophorus mirrityana*	0.0	1.9	36.4	39.6	0.0	0.0	0.0	8.2	6.3	0.0	7.5	—	—
	Tympanocryptis pinguicolla	0.0	2.8	0.0	0.0	0.9	2.0	14.6	58.2	5.0	16.5	—	—	—
Burhinidae	*Esacus magnirostris*	0.7	0.4	0.7	15.0	3.3	0.0	70.9	0.8	1.2	3.2	2.6	1.1	0.0
Burramyidae	*Burramys parvus*	0.3	6.3	0.1	0.2	0.2	0.0	91.6	0.2	0.1	1.2	—	—	—
Charadriidae	*Thinornis rubricollis*	1.1	0.1	2.3	1.1	82.3	0.0	3.6	1.5	1.6	2.4	2.6	0.3	1.1

Dasyornithidae	*Dasyornis brachypterus*	4.0	0.2	1.3	0.2	23.0	1.6	1.8	2.3	29.7	18.3	16.9	0.1	0.6
Haematopodidae	*Haematopus longirostris*	1.0	0.5	4.3	22.9	17.8	0.1	23.3	0.2	6.1	15.0	5.0	3.7	0.0
Hylidae	*Litoria aurea*	4.2	6.2	0.9	1.4	28.5	3.7	6.4	9.8	16.2	15.4	0.9	0.4	6.0
	Litoria booroolongensis	0.4	0.9	1.3	5.9	16.9	14.0	10.7	20.2	10.2	11.9	2.4	3.2	2.0
	Litoria castanea	1.7	3.6	0.3	7.3	11.5	0.0	49.8	14.1	0.6	11.1	—	—	—
	Litoria raniformis	3.3	6.5	14.6	12.7	7.5	3.3	12.7	15.8	2.3	12.8	8.4	—	—
Laridae	*Sternula albifrons*	1.4	0.9	1.7	4.8	3.6	0.0	62.9	0.5	5.3	7.8	8.0	2.7	0.4
Maluridae	*Amytornis barbatus barbatus*	7.6	1.8	2.1	1.1	13.3	15.6	0.1	10.0	27.8	18.0	2.6	—	—
Maluridae	*Amytornis striatus*	2.5	0.0	5.4	12.6	1.4	0.0	0.3	6.9	43.5	9.2	13.3	0.1	4.8
Meliphagidae	*Anthochaera phrygia*	1.2	1.5	20.1	18.8	2.2	8.8	4.7	8.2	25.5	4.0	2.6	0.2	2.3
Muridae	*Pseudomys fumeus*	0.2	2.3	0.9	1.5	1.5	15.1	2.4	8.0	36.0	23.8	2.8	0.3	5.2
	Pseudomys gracilicaudatus	6.0	1.1	3.4	7.2	14.1	14.6	17.4	8.7	8.4	15.2	2.2	1.0	0.6
	Pseudomys pilligaensis	11.2	19.1	14.0	0.0	1.7	0.0	0.2	3.3	0.0	3.0	38.5	1.0	8.0
Myobatrachidae	*Crinia sloanei*	2.6	3.5	3.5	9.8	45.6	10.8	20.6	0.4	0.9	2.3	—	—	—
	Mixophyes fleayi	5.9	1.8	0.1	0.4	34.6	32.2	10.4	5.6	2.3	2.9	1.0	1.7	1.1
	Pseudophryne pengilleyi	2.8	1.1	1.0	1.2	24.2	0.2	10.7	51.0	0.9	6.7	—	—	—
Pachycephalidae	*Pachycephala rufogularis*	1.3	2.1	8.6	27.3	18.8	6.3	12.2	0.2	11.2	3.2	8.2	0.1	0.5
Peramelidae	*Isoodon obesulus obesulus*	1.4	0.9	8.4	38.0	26.0	6.2	6.5	0.5	2.1	4.7	2.8	0.0	2.5
Phaethontidae	*Phaethon rubricauda*	0.5	2.0	4.8	15.5	3.8	0.6	8.1	15.7	34.0	15.1	—	—	—
Potoroidae	*Aepyprymnus rufescens*	4.2	6.0	9.4	14.2	6.6	0.0	8.3	11.1	0.5	39.8	—	—	—
Potoroidae	*Potorous tridactylus*	0.9	0.4	0.9	10.4	28.1	7.2	8.9	21.0	5.3	14.1	2.8	—	—
Procellariidae	*Ardenna carneipes*	2.9	0.9	1.3	9.3	14.2	2.7	29.0	12.1	17.4	5.6	1.3	2.6	0.7
	Pterodroma leucoptera leucoptera	2.1	0.4	6.4	31.9	7.2	2.9	30.8	3.1	0.9	14.3	0.2	—	—
	Pterodroma nigripennis	0.0	2.3	19.1	41.2	4.6	17.8	1.9	10.5	0.5	2.2	—	—	—
	Pterodroma solandri	1.3	0.6	3.0	11.1	2.7	0.9	64.7	1.0	3.4	7.7	1.3	0.0	2.2
	Puffinus assimilis	5.8	1.0	2.0	0.0	81.5	0.0	0.0	0.2	8.8	0.0	0.0	0.6	0.0
Psittacidae	*Pezoporus wallicus wallicus*	1.2	0.2	0.2	0.1	23.1	0.4	1.3	38.3	2.1	31.6	1.5	—	—
	Polytelis anthopeplus monarchoides	1.0	1.0	0.8	5.1	3.8	1.4	1.9	0.0	66.1	18.6	0.4	—	—
Sulidae	*Sula dactylatra*	0.1	0.1	0.3	67.3	2.4	23.0	1.1	0.4	0.7	2.7	0.3	0.1	1.4
Acanthaceae	*Isoglossa eranthemoides*	0.6	1.5	2.6	12.0	59.4	0.0	0.0	14.3	0.0	4.2	5.4	—	—
Apocynaceae	*Ochrosia moorei*	4.9	0.2	1.5	9.8	50.3	0.0	2.9	17.3	1.1	11.9	—	—	—

	Tylophora woollsii	1.1	0.1	1.7	19.0	38.4	29.1	2.0	4.7	3.2	0.8	0.0	—	—
Araliaceae	*Astrotricha crassifolia*	11.4	8.6	6.7	16.0	0.0	0.0	27.2	1.8	1.1	9.8	4.0	0.2	13.2
	Astrotricha roddii	0.5	0.0	1.7	0.6	11.5	0.0	2.4	44.9	13.4	15.4	9.0	0.3	0.4
Asteraceae	*Brachyscome muelleroides*	4.1	10.1	18.8	0.0	0.1	0.0	2.2	0.0	50.9	13.9	—	—	—
	Calotis glandulosa	3.9	0.0	0.1	1.4	3.5	0.1	72.7	9.4	0.4	0.6	8.0	—	—
	Olearia cordata	19.1	0.6	0.0	3.0	11.7	15.3	1.7	1.3	35.2	3.2	8.9	—	—
	Olearia flocktoniae	0.4	0.4	0.8	1.3	0.4	0.0	53.1	7.8	30.4	5.4	—	—	—
	Ozothamnus vagans	0.5	0.0	1.1	0.0	84.4	0.4	1.8	0.4	0.0	0.0	10.4	0.0	0.9
	Picris evae	2.4	1.0	0.0	0.0	0.0	8.5	0.0	58.7	3.7	22.5	3.2	—	—
	Rutidosis leiolepis	10.6	1.4	4.7	0.0	20.9	33.2	20.8	2.5	0.0	0.4	5.6	—	—
	Rutidosis leptorrhynchoides	7.4	0.7	10.4	16.5	1.4	6.0	19.3	20.9	7.8	1.6	6.5	0.0	1.4
	Senecio spathulatus	0.3	0.4	0.9	26.9	27.1	11.3	3.1	18.5	5.1	3.8	2.7	—	—
Atherospermataceae	*Daphnandra johnsonii*	0.1	0.2	0.0	8.1	67.1	0.0	0.0	24.3	0.1	0.0	—	—	—
Brassicaceae	*Irenepharsus trypherus*	1.9	0.1	3.2	7.9	35.9	6.1	0.0	31.1	0.1	13.7	—	—	—
	Lepidium monoplocoides	12.6	4.6	1.0	16.2	0.1	0.0	18.0	0.0	30.6	16.9	—	—	—
	Lepidium peregrinum	10.8	0.0	0.1	32.0	21.8	0.0	5.5	0.0	13.3	3.6	12.9	—	—
Casuarinaceae	*Allocasuarina defungens*	0.2	0.1	0.0	4.0	57.6	6.2	1.8	2.4	2.0	19.2	6.5	—	—
	Allocasuarina simulans	0.0	0.0	0.0	2.4	57.5	0.0	1.4	0.0	0.5	36.8	1.4	—	—
Chenopodiaceae	*Sclerolaena napiformis*	2.9	1.3	31.4	13.5	9.8	5.5	3.5	6.8	19.2	2.6	2.1	0.0	1.4
Convolvulaceae	*Wilsonia backhousei*	4.5	1.4	0.5	15.1	22.2	10.1	5.9	6.6	18.0	11.9	3.2	0.3	0.2
Cunoniaceae	*Acrophyllum australe*	0.5	0.8	0.0	6.4	1.1	0.0	18.9	70.7	0.0	0.5	1.1	—	—
	Davidsonia jerseyana	1.3	1.6	0.4	7.1	64.5	0.8	6.2	16.8	0.3	0.4	0.6	—	—
	Davidsonia johnsonii	3.8	0.5	0.5	0.0	7.4	0.4	0.0	69.7	2.3	14.6	0.7	—	—
Cupressaceae	*Callitris baileyi*	29.4	2.9	4.7	1.6	8.8	0.0	5.5	0.7	46.3	0.0	—	—	—
	Callitris oblonga	1.0	2.8	0.3	27.0	8.3	7.9	30.7	2.9	10.3	8.3	0.6	—	—
Cyperaceae	*Carex raleighii*	0.5	0.0	0.0	2.0	0.0	7.6	42.3	36.3	4.6	2.2	2.9	0.1	1.6
	Eleocharis tetraquetra	25.7	0.1	4.2	0.0	0.0	9.9	4.7	17.0	2.9	14.1	6.7	8.6	6.1
Dilleniaceae	*Hibbertia puberula*	39.7	2.7	2.7	10.2	10.8	0.0	5.3	4.6	9.7	0.0	0.0	4.2	10.0
Dilleniaceae	*Hibbertia sp. Bankstown*	2.9	1.9	20.9	5.0	14.5	14.8	1.6	4.0	9.3	12.0	4.9	0.0	8.2
	Hibbertia stricta subsp. furcatula	2.8	0.0	0.2	4.1	1.4	0.0	20.6	33.7	3.8	32.5	0.1	0.6	0.1
	Hibbertia superans	0.6	0.6	4.1	17.2	0.0	15.4	13.2	13.8	26.8	7.0	0.6	0.4	0.0
Droseraceae	*Aldrovanda vesiculosa*	13.3	2.2	0.5	0.1	37.7	24.3	0.0	0.4	3.4	0.0	3.3	2.4	12.2
Ebenaceae	*Diospyros mabacea*	17.6	3.3	0.0	0.0	47.8	5.1	4.0	18.7	3.4	0.0	—	—	—

Elaeocarpaceae	*Elaeocarpus williamsianus*	2.7	1.7	0.0	0.0	45.3	3.1	0.0	39.2	1.7	6.4	—	—	—
	Tetratheca glandulosa	0.3	0.6	0.5	7.0	2.6	8.2	3.7	48.4	13.2	11.2	4.2	—	—
Ericaceae	*Epacris hamiltonii*	1.4	1.9	0.0	12.4	10.8	0.0	66.4	0.2	0.0	7.0	—	—	—
	Epacris purpurascens var. purpurascens	2.4	0.9	1.3	5.0	2.9	0.0	4.5	48.5	15.4	12.6	5.5	0.4	0.6
	Leucopogon exolasius	0.0	0.3	0.4	11.2	22.5	6.0	16.1	13.3	5.1	25.1	—	—	—
	Leucopogon fletcheri subsp. fletcheri	16.6	0.0	1.9	22.8	1.2	0.0	6.0	0.6	25.7	0.0	20.6	4.3	0.2
	Melichrus hirsutus	12.9	0.0	0.7	27.8	0.0	17.0	3.9	5.8	3.3	0.0	14.9	0.7	12.8
Euphorbiaceae	*Bertya opponens*	8.2	5.6	3.7	3.9	11.8	0.6	0.1	1.2	12.4	0.0	17.3	0.6	34.6
	Chamaesyce psammogeton	1.5	0.1	1.5	34.3	39.1	13.7	3.8	0.0	3.8	0.0	2.0	0.3	0.0
Fabaceae	*Acacia acanthoclada*	9.0	4.3	19.7	14.6	0.0	11.9	0.0	11.1	9.9	1.8	12.3	0.0	5.4
	Acacia ausfeldii	8.5	0.2	4.5	2.3	2.6	3.4	10.1	37.3	14.9	16.3	—	—	—
	Acacia bakeri	0.4	1.7	0.9	0.9	12.2	0.1	36.4	35.9	5.9	3.8	1.9	—	—
	Acacia bynoeana	7.2	6.5	3.3	28.0	9.7	1.6	14.5	12.0	13.7	1.0	0.9	1.1	0.5
	Acacia carneorum	4.1	0.2	0.0	20.3	27.4	22.0	18.9	0.1	5.5	0.1	0.4	0.1	0.8
	Acacia courtii	0.2	0.2	0.0	0.0	22.1	0.0	10.2	38.2	2.9	25.8	0.4	—	—
	Acacia curranii	1.2	0.0	30.3	22.0	0.0	6.5	1.3	27.3	1.3	10.1	—	—	—
	Acacia gordonii	0.0	3.3	0.1	0.0	0.1	0.0	8.5	33.5	39.2	3.9	4.9	6.1	0.4
	Acacia meiantha	0.7	0.0	0.0	12.9	4.2	0.0	68.4	0.0	0.1	13.7	—	—	—
	Acacia phasmoides	1.2	20.0	6.6	0.6	29.5	0.0	2.5	0.0	1.5	8.1	29.4	0.2	0.3
	Acacia pubescens	1.9	2.3	0.0	18.7	13.7	0.3	14.5	14.4	25.7	5.2	0.6	0.1	2.6
	Acacia pubifolia	0.3	0.5	1.4	0.0	4.9	0.0	55.7	18.2	4.2	0.3	14.4	—	—
	Acacia terminalis subsp. terminalis	0.1	0.2	0.0	64.6	8.3	0.0	18.1	2.0	4.3	2.2	0.1	—	—
	Archidendron hendersonii	0.8	0.6	0.2	2.9	27.2	1.0	2.6	11.7	9.0	43.0	1.0	—	—
	Bossiaea oligosperma	2.0	0.1	0.0	4.7	13.4	15.7	15.1	33.9	0.9	14.1	—	—	—
	Caesalpinia bonduc	6.1	4.9	5.4	8.9	12.1	0.0	50.6	5.1	5.2	1.8	—	—	—
	Cassia marksiana	0.0	0.1	0.4	0.0	32.1	6.9	4.3	38.1	8.7	8.2	1.1	—	—
	Cullen parvum	2.7	4.4	12.9	1.4	0.6	12.7	18.2	1.0	26.6	4.7	2.1	0.0	12.6
	Desmodium acanthocladum	6.9	0.2	0.9	23.0	37.6	0.0	6.9	9.3	0.0	15.2	—	—	—
	Dillwynia glaucula	0.0	8.7	1.1	0.0	15.6	6.0	35.0	30.4	0.0	3.2	—	—	—
	Indigofera baileyi	9.2	1.2	10.5	6.9	8.2	20.7	0.0	12.5	17.7	0.0	5.4	0.0	7.8
	Phyllota humifusa	0.0	0.1	0.0	11.2	8.3	5.0	39.2	8.2	7.2	6.8	13.7	0.1	0.1

	Pultenaea glabra	0.0	0.2	2.4	0.0	10.2	0.0	48.4	38.5	0.3	0.0	—	—	—
	Pultenaea maritima	0.5	0.8	1.4	7.2	50.0	6.4	2.1	9.0	10.5	10.8	0.0	1.3	0.0
	Pultenaea parviflora	4.8	3.4	5.2	1.9	0.1	0.0	0.9	0.2	77.6	1.1	4.3	0.4	0.2
	Pultenaea pedunculata	3.5	0.3	21.4	18.9	4.8	12.7	16.0	7.5	13.3	0.6	1.0	—	—
	Senna acclinis	3.6	4.0	0.3	10.4	18.4	0.0	19.0	2.6	15.0	14.2	0.8	0.9	10.9
	Sophora fraseri	1.5	1.7	1.2	3.3	36.0	0.0	20.7	2.7	19.1	0.7	13.1	—	—
	Sophora tomentosa	1.7	0.2	0.7	52.1	13.6	3.1	0.0	1.7	2.8	20.4	1.8	2.0	0.0
	Swainsona plagiotropis	4.4	4.5	13.4	1.1	5.8	1.3	8.4	28.6	9.9	13.2	9.4	—	—
	Swainsona recta	9.5	4.8	1.2	2.5	0.3	0.3	16.0	40.7	19.1	3.2	2.3	—	—
Gentianaceae	*Gentiana wissmannii*	1.3	0.1	0.0	0.0	65.7	0.0	29.9	1.6	0.0	0.0	0.8	0.0	0.5
Goodeniaceae	*Dampiera fusca*	0.6	1.1	1.2	0.0	16.1	0.0	78.7	1.4	0.9	0.0	—	—	—
Haloragaceae	*Myriophyllum implicatum*	0.6	0.0	29.3	0.0	0.0	0.0	21.7	31.9	0.0	0.5	3.8	1.1	11.3
Lamiaceae	*Plectranthus alloplectus*	0.4	0.8	0.0	2.5	26.7	0.0	39.5	22.0	2.9	5.2	—	—	—
	Prostanthera askania	1.7	0.1	0.5	0.0	75.3	1.5	0.5	1.1	1.5	5.1	12.5	0.2	0.0
	Prostanthera densa	0.0	0.1	0.1	91.2	0.7	5.5	0.0	0.4	0.6	1.3	—	—	—
	Prostanthera junonis	0.0	0.3	0.6	0.0	22.4	9.0	2.8	52.5	7.1	5.3	—	—	—
	Prostanthera stricta	1.0	6.2	2.8	0.0	23.0	9.1	39.3	16.7	0.2	1.7	—	—	—
Lauraceae	*Endiandra floydii*	1.2	0.0	0.3	3.3	58.6	14.1	6.7	8.1	1.6	1.9	0.5	0.6	3.1
Linderniaceae	*Lindernia alsinoides*	3.4	0.0	0.7	4.9	51.1	0.0	0.0	25.7	0.0	14.3	—	—	—
Lindsaeaceae	*Lindsaea incisa*	3.1	2.8	10.6	41.8	0.0	13.4	24.8	0.4	0.7	0.1	2.5	—	—
Malvaceae	*Commersonia prostrata*	13.5	0.0	3.7	9.8	16.2	1.4	0.2	0.0	1.7	0.6	52.4	0.0	0.4
	Corchorus cunninghamii	12.0	1.6	1.5	25.1	32.5	1.0	0.0	6.7	0.2	0.1	19.3	—	—
	Lasiopetalum joyceae	2.9	5.4	2.9	0.0	0.0	2.9	3.2	47.0	18.7	9.5	5.7	0.2	1.7
Marsileaceae	*Pilularia novae-hollandiae*	5.5	1.0	4.8	14.2	16.4	24.5	10.9	7.9	3.9	1.7	9.1	—	—
Meliaceae	*Owenia cepiodora*	17.7	4.2	0.0	20.0	50.1	6.6	0.0	1.2	0.0	0.2	—	—	—
Menispermaceae	*Tinospora tinosporoides*	10.7	0.1	0.4	7.3	5.9	3.1	14.1	35.6	3.0	19.9	—	—	—
Myrtaceae	*Angophora exul*	13.7	1.7	0.0	0.0	16.0	0.0	3.3	0.0	58.4	0.6	6.3	—	—
	Darwinia biflora	0.3	0.4	0.6	7.0	7.1	4.4	10.3	40.4	16.4	11.2	2.0	—	—
	Darwinia glaucophylla	0.2	0.2	0.6	0.0	36.1	13.8	4.1	28.2	2.7	7.9	5.0	0.0	1.2
	Darwinia peduncularis	4.1	0.1	1.6	0.0	4.2	6.1	0.0	0.0	11.4	0.0	69.6	1.7	1.3
	Eucalyptus aggregata	1.6	2.6	4.5	0.4	0.1	5.2	61.3	10.5	1.8	2.7	0.6	0.1	8.7
	Eucalyptus alligatrix subsp. alligatrix	5.3	2.9	1.9	0.4	3.1	0.0	65.1	5.5	2.4	9.5	3.9	—	—

Eucalyptus benthamii	0.8	0.0	0.0	2.4	21.3	0.0	13.3	16.5	3.2	42.0	0.0	0.0	0.3
Eucalyptus camfieldii	2.1	0.1	0.4	49.3	6.4	0.0	19.4	8.6	3.8	5.1	2.5	0.6	1.8
Eucalyptus camphora subsp. relicta	4.7	0.2	0.2	19.9	16.3	6.6	47.0	0.0	0.0	0.1	1.1	3.8	0.0
Eucalyptus cannonii	2.2	2.4	2.5	0.8	14.4	2.7	54.2	13.0	3.6	4.2	—	—	—
Eucalyptus canobolensis	0.0	0.0	0.0	0.0	5.0	0.0	21.1	42.2	2.2	29.5	0.0	—	—
Eucalyptus glaucina	5.3	0.2	7.6	41.0	10.7	0.0	19.8	2.7	5.4	5.4	1.9	—	—
Eucalyptus kartzoffiana	0.0	0.7	0.0	1.9	27.1	34.1	31.1	0.9	1.5	2.7	—	—	—
Eucalyptus langleyi	13.4	2.5	1.2	5.9	2.1	8.3	0.7	39.6	0.1	26.3	—	—	—
Eucalyptus largeana	0.4	3.7	1.5	24.5	3.3	32.7	21.3	12.4	0.2	0.0	—	—	—
Eucalyptus macarthurii	0.5	0.3	0.1	11.2	3.4	5.1	38.8	26.9	0.0	12.1	0.5	0.0	1.0
Eucalyptus magnificata	0.0	0.6	6.1	7.0	1.8	0.0	41.9	23.6	7.9	11.2	—	—	—
Eucalyptus microcodon	1.7	5.2	0.0	2.5	3.8	55.8	0.0	0.0	4.0	0.1	27.0	—	—
Eucalyptus oresbia	1.5	0.2	1.7	5.1	34.0	0.3	19.0	9.1	1.8	0.6	8.2	0.2	18.4
Eucalyptus parvula	0.1	0.0	0.3	2.8	0.0	16.2	46.4	10.3	23.8	0.0	—	—	—
Eucalyptus pulverulenta	2.1	0.8	0.6	5.5	2.1	0.7	6.1	37.8	0.0	27.2	16.9	—	—
Eucalyptus rubida subsp. barbigerorum	3.3	2.7	2.1	0.0	6.8	6.1	70.2	0.0	0.0	0.3	3.1	0.0	5.3
Eucalyptus saxatilis	4.3	27.9	0.8	0.3	11.4	0.0	37.7	8.3	8.2	0.9	—	—	—
Eucalyptus scoparia	0.0	1.3	0.0	0.0	33.0	0.0	36.7	19.3	2.8	5.9	0.9	—	—
Eucalyptus sp. Cattai	2.4	6.2	0.5	7.2	4.7	0.1	14.2	25.8	32.7	6.2	—	—	—
Eucalyptus sturgissiana	0.4	0.6	1.5	8.9	8.0	16.6	12.7	16.8	0.0	34.4	—	—	—
Gossia fragrantissima	2.0	1.1	0.6	16.8	16.5	0.0	12.9	20.8	6.8	21.0	1.1	0.0	0.5
Kunzea rupestris	0.4	3.2	4.9	0.0	17.9	12.7	6.9	29.7	16.9	6.4	1.1	—	—
Melaleuca biconvexa	4.1	3.0	1.1	8.9	12.4	0.2	22.2	16.5	11.4	15.3	2.0	1.6	1.2
Melaleuca deanei	5.2	4.4	0.2	14.9	10.8	0.4	54.1	3.5	2.5	0.1	1.1	2.1	0.6
Melaleuca irbyana	5.1	1.2	15.0	0.0	28.4	6.6	14.1	0.0	1.8	0.1	27.1	0.1	0.6
Micromyrtus blakelyi	1.0	1.8	0.7	0.0	19.9	19.9	9.7	36.5	6.2	4.4	—	—	—
Micromyrtus minutiflora	1.1	0.3	0.0	1.6	0.0	0.0	1.0	4.0	0.0	92.0	0.0	0.0	0.0
Syzygium hodgkinsoniae	1.3	0.2	0.7	3.6	5.8	0.9	3.2	35.5	6.1	42.7	—	—	—
Syzygium moorei	0.8	0.5	0.2	5.1	21.4	0.0	10.7	42.1	4.1	13.1	1.6	0.2	0.0
Syzygium paniculatum	1.5	0.5	0.1	7.2	5.7	0.0	74.0	1.4	6.3	0.2	3.1	—	—
Triplarina nowraensis	3.6	0.0	0.6	7.8	52.9	10.8	0.0	5.9	0.0	17.6	0.6	0.0	0.1

	Uromyrtus australis	7.7	0.0	6.4	3.4	0.0	0.0	34.3	38.3	0.0	1.3	6.6	0.3	1.8
Orchidaceae	*Caladenia arenaria*	0.5	1.1	24.7	16.6	8.8	0.0	23.2	0.0	10.0	15.0	—	—	—
	Caladenia concolor	0.2	0.8	41.2	0.0	26.4	0.0	11.3	8.2	11.7	0.3	—	—	—
	Caladenia tessellata	0.6	0.4	0.2	2.5	61.3	15.9	6.3	0.4	0.0	10.5	0.3	0.0	1.4
	Cryptostylis hunteriana	0.4	1.3	1.7	0.4	30.9	1.8	3.0	15.5	37.7	6.1	0.9	0.1	0.1
	Diuris aequalis	0.3	0.0	0.0	0.0	0.0	6.3	61.0	7.7	0.0	24.6	—	—	—
	Diuris arenaria	4.1	0.0	0.0	67.7	1.2	24.5	0.0	0.9	0.0	1.5	—	—	—
	Diuris pedunculata	1.0	0.0	5.0	0.0	3.8	31.4	28.7	0.0	1.6	2.4	0.6	0.0	25.5
	Diuris praecox	0.0	0.2	0.0	47.2	6.8	0.1	35.0	2.6	2.1	6.0	—	—	—
	Genoplesium baueri	7.6	4.0	0.1	0.0	0.0	0.0	72.6	6.0	2.5	3.2	0.0	4.1	0.0
	Genoplesium littorale	0.3	0.9	0.0	0.0	46.7	0.0	0.0	21.7	0.3	27.9	2.1	—	—
	Phaius australis	0.0	0.2	0.4	0.0	86.7	2.9	4.2	0.0	0.3	3.1	0.0	0.0	2.1
	Prasophyllum affine	0.9	3.1	0.0	0.0	0.0	2.3	0.4	55.1	33.5	0.3	4.3	—	—
	Pterostylis cobarensis	17.6	3.7	25.7	0.4	0.3	12.4	5.5	11.4	12.1	10.9	—	—	—
	Pterostylis despectans	4.5	1.1	4.6	8.1	5.9	2.7	29.7	0.1	38.6	3.8	0.9	—	—
	Sarcochilus hartmannii	9.8	0.9	48.3	4.5	0.0	12.3	0.0	7.2	1.2	15.8	—	—	—
Phyllanthaceae	*Phyllanthus microcladus*	7.8	1.3	8.5	13.2	11.8	3.3	11.3	13.6	10.0	19.0	—	—	—
Plantaginaceae	*Veronica blakelyi*	0.2	0.0	0.9	12.4	15.4	1.3	49.9	13.4	0.0	6.5	—	—	—
Poaceae	*Alexfloydia repens*	0.3	0.5	0.1	0.0	42.2	17.5	0.8	1.1	22.1	14.3	0.3	0.2	0.8
	Austrostipa nullanulla	0.8	1.2	29.3	0.0	27.4	0.0	0.3	10.4	22.3	1.2	3.7	0.0	3.4
	Dichanthium setosum	1.8	1.1	1.7	0.7	27.9	14.2	0.1	17.8	16.0	15.4	3.3	—	—
	Digitaria porrecta	1.9	2.8	29.2	6.7	6.8	19.6	6.6	7.4	2.3	6.8	6.0	0.0	3.8
	Homopholis belsonii	1.7	2.8	12.0	2.0	1.2	8.7	4.8	29.9	10.8	15.6	10.4	—	—
Polygonaceae	*Persicaria elatior*	2.0	1.1	1.7	0.3	70.9	0.0	2.7	3.1	8.0	0.9	9.5	—	—
Proteaceae	*Floydia praealta*	4.0	0.0	4.8	8.2	50.9	0.0	1.5	20.9	0.9	8.8	—	—	—
	Grevillea caleyi	2.1	0.2	2.5	18.4	0.0	9.6	0.5	45.5	0.0	15.8	3.2	0.1	2.0
	Grevillea guthrieana	3.2	14.1	2.2	1.4	60.1	0.0	0.0	5.3	0.4	13.3	—	—	—
	Grevillea hilliana	1.0	1.4	5.0	4.5	6.8	2.4	54.9	0.7	15.1	1.0	7.1	—	—
	Grevillea juniperina subsp. juniperina	1.4	1.7	0.5	0.0	1.8	0.0	11.4	6.8	72.6	2.2	1.3	0.0	0.3
	Grevillea masonii	0.0	0.1	0.0	17.7	8.9	19.5	21.1	10.6	19.5	2.5	—	—	—
	Grevillea obtusiflora	0.0	2.5	0.6	2.2	22.9	9.4	36.2	18.9	4.6	2.2	0.4	—	—

	Grevillea parviflora subsp. supplicans	0.7	0.2	2.7	0.0	19.0	13.4	6.9	29.9	13.4	7.4	6.4	—	—
	Grevillea quadricauda	20.8	9.9	15.0	0.0	0.0	0.0	4.2	6.3	24.8	0.0	6.0	0.0	13.1
	Grevillea renwickiana	0.1	1.0	0.0	0.0	21.3	8.3	34.3	19.9	15.2	0.0	—	—	—
	Grevillea rhizomatosa	0.8	1.9	0.4	0.0	0.0	0.0	60.0	34.3	0.2	2.4	—	—	—
	Hakea archaeoides	4.6	1.7	1.8	1.3	61.3	0.0	18.7	0.9	0.1	9.5	—	—	—
	Hakea dohertyi	5.4	3.9	3.4	25.8	4.3	0.0	0.0	23.4	19.6	13.8	0.4	—	—
	Macadamia tetraphylla	3.7	0.3	0.4	4.1	37.8	0.1	4.2	31.8	5.9	11.9	—	—	—
	Persoonia acerosa	9.7	0.5	0.2	12.4	0.0	5.2	46.5	19.4	5.3	0.9	—	—	—
	Persoonia bargoensis	1.7	3.1	3.4	5.0	37.6	0.5	6.0	0.7	0.0	40.5	1.2	0.0	0.4
	Persoonia glaucescens	1.2	3.2	0.0	7.5	9.6	0.0	49.8	0.0	2.9	4.1	21.4	0.0	0.3
	Persoonia hindii	29.4	0.0	0.5	3.2	10.4	0.0	30.6	2.1	23.4	0.0	0.0	0.0	0.2
	Persoonia hirsuta	4.7	1.1	2.8	20.4	3.0	1.0	18.5	15.6	24.5	2.6	4.7	1.1	0.1
	Persoonia marginata	0.0	9.8	1.7	1.6	4.6	0.0	50.3	7.1	7.4	10.3	5.9	0.7	0.6
	Persoonia mollis subsp. maxima	1.7	0.1	0.8	8.0	0.0	10.1	0.0	39.1	20.5	19.7	—	—	—
	Persoonia nutans	4.2	23.8	3.5	19.0	0.2	0.0	1.0	11.8	0.2	36.3	—	—	—
Rhamnaceae	*Discaria nitida*	9.0	3.3	0.7	2.4	19.4	43.5	7.3	7.5	2.1	4.8	—	—	—
	Pomaderris brunnea	0.0	0.1	0.1	3.7	31.5	26.4	21.0	2.3	4.7	9.1	1.3	—	—
	Pomaderris cocoparrana	0.0	0.5	18.8	5.1	2.1	0.0	24.0	18.0	30.5	0.2	0.7	—	—
	Pomaderris cotoneaster	0.0	5.8	0.0	1.5	13.8	0.0	58.0	12.7	0.6	1.6	5.9	—	—
	Pomaderris pallida	8.6	1.0	3.3	4.2	0.3	3.0	34.0	40.3	0.2	0.9	1.4	0.2	2.7
	Pomaderris parrisiae	0.8	3.6	3.1	0.0	19.5	28.3	0.0	6.9	12.4	16.2	9.3	—	—
Rubiaceae	*Asperula asthenes*	1.0	2.1	0.1	7.9	48.5	9.6	7.6	0.0	15.9	7.2	—	—	—
	Randia moorei	1.4	0.3	0.4	0.0	22.9	5.3	2.9	37.4	8.0	19.6	0.0	0.1	1.7
Rutaceae	*Acronychia littoralis*	1.1	0.7	0.4	0.2	59.0	1.6	4.2	17.1	1.4	10.8	3.6	—	—
	Boronia deanei	5.6	0.0	0.1	2.4	13.8	0.0	45.3	0.0	26.5	0.0	0.4	0.0	5.8
	Boronia repanda	22.9	1.3	0.1	13.7	0.0	0.0	44.6	9.3	7.5	0.4	0.0	—	—
	Coatesia paniculata	10.9	2.8	0.4	14.9	33.9	0.4	2.1	0.3	8.7	19.9	5.5	—	—
	Leionema ralstonii	1.0	0.0	0.4	31.9	41.3	0.0	11.3	0.0	9.7	0.6	3.8	—	—
	Zieria granulata	0.0	0.1	0.0	2.5	78.6	0.0	1.4	17.2	0.2	0.0	—	—	—
	Zieria involucrata	0.4	5.8	0.0	0.5	0.0	3.0	0.9	53.5	29.8	6.2	—	—	—
	Zieria murphyi	11.5	0.6	0.0	0.4	6.6	0.0	36.4	22.5	10.9	11.1	—	—	—
	Zieria tuberculata	21.0	0.2	0.0	6.0	49.7	17.9	0.0	3.8	0.0	0.0	1.4	—	—

Salicaceae	*Xylosma terrae-reginae*	0.2	4.1	5.2	13.0	64.1	5.1	0.0	3.6	0.0	4.7	0.0	—	—
Sapindaceae	*Diploglottis campbellii*	6.1	1.0	1.3	0.0	45.1	4.9	4.4	32.0	1.8	3.4	—	—	—
	Dodonaea procumbens	2.5	0.1	11.4	0.1	5.3	0.9	33.2	11.2	24.1	7.1	2.5	0.1	1.6
	Lepiderema pulchella	1.4	0.1	0.5	0.4	16.0	1.6	6.3	51.5	5.2	11.9	4.4	0.0	0.6
Scrophulariaceae	*Euphrasia ciliolata*	0.0	0.3	0.0	66.0	8.0	0.0	18.5	7.2	0.0	0.0	—	—	—
	Euphrasia scabra	1.6	0.0	2.0	1.7	0.0	6.9	43.8	7.6	9.9	17.7	2.5	1.2	4.9
Simaroubaceae	*Quassia sp. Moonee Creek*	1.4	0.2	0.8	49.5	0.0	32.0	15.1	0.1	0.9	0.1	—	—	—
Solanaceae	*Solanum celatum*	13.7	0.1	4.9	2.2	9.9	4.5	1.7	24.2	3.8	30.2	4.7	—	—
Symplocaceae	*Symplocos baeuerlenii*	0.4	0.7	3.1	3.0	2.7	23.9	45.4	17.3	0.3	3.2	—	—	—
Thymelaeaceae	*Pimelea curviflora var. curviflora*	0.7	1.4	0.5	2.2	0.4	9.1	3.5	50.7	19.1	8.1	4.1	—	—
	Pimelea spicata	2.0	20.6	3.6	0.0	12.7	6.0	2.6	0.0	14.4	16.4	20.7	0.7	0.2
Winteraceae	*Tasmannia glaucifolia*	0.3	0.2	1.6	2.9	39.5	0.0	52.9	2.1	0.0	0.4	—	—	—

Table A4. *Proportion of occupied current habitat (see Box 2 in main body of report) that is projected to remain climatically suitable until 2070, for each landscape- and site-managed species. These areas are classified as internal refugia and comprise grid cells that are suitable in 2000, 2030, and 2070. NB: our definition of occupied current habitat prevented identification of internal refugia for Myriophyllum implicatum.*

Stream	Species	Status	Hotter / Wetter	Hotter / Little change	Warmer / Drier	Warmer / Wetter
Landscape						
	Aprasia inaurita	EN	41%	75%	77%	43%
	Aprasia parapulchella	V	12%	51%	67%	13%
	Atrichornis rufescens	V	30%	98%	54%	50%
	Botaurus poiciloptilus	EN	33%	18%	41%	58%
	Burhinus grallarius	EN	89%	96%	98%	88%
	Callocephalon fimbriatum	V	81%	58%	54%	63%
	Calyptorhynchus lathami	V	36%	33%	26%	70%
	Cercartetus nanus	V	54%	28%	22%	59%
	Certhionyx variegatus	V	94%	99%	99%	93%
	Chthonicola sagittata	V	89%	96%	94%	85%
	Cinclosoma castanotum	V	1%	12%	14%	25%
	Circus assimilis	V	98%	98%	100%	99%
	Coeranoscincus reticulatus	V	1%	37%	23%	3%
	Coracina lineata	V	20%	81%	90%	72%
	Daphoenositta chrysoptera	V	88%	98%	99%	93%
	Dasyurus maculatus	V	46%	35%	36%	62%
	Delma impar	V	0%	0%	0%	0%
	Epthianura albifrons	V	14%	30%	57%	37%
	Eulamprus leuraensis	EN	0%	0%	0%	0%
	Falco subniger	V	94%	97%	99%	95%
	Falsistrellus tasmaniensis	V	73%	52%	40%	66%
	Glossopsitta pusilla	V	95%	96%	98%	95%
	Grantiella picta	V	100%	100%	98%	99%
	Heleioporus australiacus	V	30%	44%	51%	61%
	Hieraaetus morphnoides	V	94%	98%	99%	94%
	Hoplocephalus bitorquatus	V	61%	90%	100%	88%
	Hoplocephalus stephensii	V	7%	18%	3%	34%
	Hylacola cautus	V	0%	2%	14%	2%
	Irediparra gallinacea	V	52%	93%	98%	80%
	Ixobrychus flavicollis	V	90%	86%	76%	95%
	Kerivoula papuensis	V	18%	14%	6%	35%
	Lathamus discolor	EN	42%	60%	57%	66%
	Litoria daviesae	V	97%	93%	55%	90%
	Litoria littlejohni	V	25%	34%	14%	20%
	Litoria olongburensis	V	20%	2%	28%	24%
	Litoria subglandulosa	V	10%	38%	18%	41%
	Lophochroa leadbeateri	V	100%	100%	96%	99%
	Lophoictinia isura	V	95%	99%	98%	99%
	Menura alberti	V	1%	0%	6%	1%
	Miniopterus australis	V	53%	61%	66%	86%
	Mixophyes balbus	EN	28%	17%	5%	40%
	Mixophyes iteratus	EN	6%	37%	3%	68%
	Myotis macropus	V	69%	50%	44%	76%
	Neophema pulchella	V	92%	91%	92%	84%
	Ningaui yvonneae	V	1%	3%	5%	3%
	Ninox connivens	V	99%	100%	95%	99%
	Ninox strenua	V	51%	40%	47%	85%
	Notamacropus parma	V	61%	82%	20%	79%
	Nyctophilus corbeni	V	34%	52%	81%	40%
	Oxyura australis	V	59%	55%	71%	60%

	Pachycephala inornata	V	2%	15%	51%	22%
	Pachycephala olivacea	V	16%	11%	15%	24%
	Pandion cristatus	V	81%	55%	67%	86%
	Petaurus australis australis	V	18%	19%	24%	67%
	Petaurus norfolcensis	V	96%	97%	92%	96%
	Petroica boodang	V	65%	81%	90%	64%
	Petroica phoenicea	V	39%	31%	43%	33%
	Phascogale tapoatafa tapoatafa	V	56%	49%	73%	85%
	Philoria loveridgei	EN	0%	5%	1%	0%
	Philoria sphagnicola	V	1%	40%	16%	35%
	Podargus ocellatus	V	1%	44%	11%	15%
	Polytelis swainsonii	V	7%	4%	16%	1%
	Pseudophryne australis	V	36%	32%	26%	65%
	Pteropus poliocephalus	V	97%	94%	82%	96%
	Ptilinopus regina	V	65%	92%	76%	99%
	Pyrrholaemus brunneus	V	68%	82%	85%	95%
	Saccolaimus flaviventris	V	94%	99%	98%	98%
	Scoteanax rueppellii	V	27%	17%	13%	46%
	Simoselaps fasciolatus	V	82%	79%	74%	80%
	Sminthopsis leucopus	V	6%	1%	5%	11%
	Sminthopsis macroura	V	100%	100%	96%	97%
	Stagonopleura guttata	V	45%	57%	87%	50%
	Stictonetta naevosa	V	87%	90%	88%	90%
	Thylogale stigmatica	V	13%	64%	42%	65%
	Tyto longimembris	V	72%	60%	77%	83%
	Tyto novaehollandiae	V	33%	23%	16%	80%
	Tyto tenebricosa tenebricosa	V	28%	17%	12%	73%
	Uvidicolus sphyrurus	V	44%	17%	52%	8%
	Varanus rosenbergi	V	18%	6%	13%	49%
	Vespadelus troughtoni	V	66%	84%	96%	65%
	Wollumbinia belli	EN	0%	0%	52%	0%
Site						
	Acacia acanthoclada	EN	0%	4%	9%	0%
	Acacia ausfeldii	V	0%	0%	0%	0%
	Acacia bakeri	V	9%	94%	47%	6%
	Acacia bynoeana	EN	93%	98%	66%	61%
	Acacia carneorum	V	9%	0%	19%	0%
	Acacia courtii	V	0%	0%	0%	41%
	Acacia curranii	V	100%	98%	62%	59%
	Acacia gordonii	EN	94%	100%	49%	76%
	Acacia meiantha	EN	0%	0%	0%	0%
	Acacia phasmoides	V	39%	100%	19%	60%
	Acacia pubescens	V	64%	94%	36%	40%
	Acacia pubifolia	EN	0%	0%	33%	0%
	Acacia terminalis subsp. terminalis	EN	0%	0%	0%	0%
	Acronychia littoralis	EN	0%	0%	8%	28%
	Acrophyllum australe	V	3%	7%	0%	16%
	Aepyprymnus rufescens	V	61%	100%	88%	83%
	Aldrovanda vesiculosa	EN	21%	34%	45%	57%
	Alexfloydia repens	EN	6%	5%	0%	36%
	Allocasuarina defungens	EN	0%	0%	0%	0%
	Allocasuarina simulans	V	0%	0%	0%	0%
	Amytornis barbatus barbatus	EN	11%	76%	65%	40%
	Amytornis striatus	V	5%	85%	48%	50%
	Angophora exul	EN	33%	88%	98%	51%
	Anthochaera phrygia	CE	71%	71%	73%	75%
	Archidendron hendersonii	V	0%	15%	21%	42%
	Ardenna carneipes	V	17%	2%	29%	65%
	Asperula asthenes	V	0%	0%	0%	26%
	Astrotricha crassifolia	V	34%	22%	32%	71%

Astrotricha roddii	EN	0%	0%	1%	0%
Austrostipa nullanulla	EN	0%	0%	0%	15%
Bertya opponens	V	99%	100%	97%	98%
Boronia deanei	V	0%	0%	0%	0%
Boronia repanda	EN	0%	0%	0%	0%
Bossiaea oligosperma	V	4%	20%	95%	23%
Brachyscome muelleroides	V	0%	1%	26%	9%
Burramys parvus	EN	17%	61%	2%	32%
Caesalpinia bonduc	EN	100%	0%	0%	67%
Caladenia arenaria	EN	85%	100%	100%	100%
Caladenia concolor	EN	86%	100%	100%	100%
Caladenia tessellata	EN	0%	0%	0%	2%
Callitris baileyi	EN	0%	99%	100%	1%
Callitris oblonga	V	56%	73%	85%	68%
Calotis glandulosa	V	33%	44%	26%	9%
Carex raleighii	EN	24%	31%	29%	26%
Cassia brewsteri var. marksiana	EN	16%	100%	49%	58%
Chamaesyce psammogeton	EN	41%	23%	48%	81%
Coatesia paniculata	EN	0%	3%	54%	0%
Commersonia prostrata	EN	4%	3%	28%	30%
Corchorus cunninghamii	EN	0%	0%	10%	1%
Crinia sloanei	V	66%	49%	56%	85%
Cryptostylis hunteriana	V	0%	0%	0%	0%
Ctenophorus mirrityana	EN	0%	0%	0%	0%
Cullen parvum	EN	0%	0%	0%	0%
Dampiera fusca	EN	0%	0%	1%	0%
Daphnandra johnsonii	EN	0%	0%	0%	48%
Darwinia biflora	V	40%	72%	70%	6%
Darwinia glaucophylla	V	64%	32%	68%	100%
Darwinia peduncularis	V	95%	81%	66%	93%
Dasyornis brachypterus	EN	1%	18%	23%	14%
Davidsonia jerseyana	EN	0%	0%	21%	0%
Davidsonia johnsonii	EN	65%	53%	9%	94%
Desmodium acanthocladum	V	0%	0%	1%	36%
Dichanthium setosum	V	24%	62%	37%	44%
Digitaria porrecta	EN	10%	3%	4%	16%
Dillwynia glaucula	EN	1%	23%	62%	30%
Diospyros mabacea	EN	20%	100%	48%	55%
Diploglottis campbellii	EN	60%	97%	82%	80%
Discaria nitida	V	0%	10%	4%	3%
Diuris aequalis	EN	0%	0%	0%	0%
Diuris arenaria	EN	100%	100%	100%	100%
Diuris pedunculata	EN	32%	52%	46%	51%
Diuris praecox	V	87%	87%	3%	21%
Dodonaea procumbens	V	55%	78%	97%	80%
Elaeocarpus williamsianus	EN	85%	99%	62%	99%
Eleocharis tetraquetra	EN	100%	82%	78%	100%
Endiandra floydii	EN	36%	77%	99%	89%
Epacris hamiltonii	EN	0%	0%	0%	0%
Epacris purpurascens var. purpurascens	V	17%	6%	15%	15%
Esacus magnirostris	CE	100%	96%	94%	100%
Eucalyptus aggregata	V	3%	6%	7%	6%
Eucalyptus alligatrix subsp. alligatrix	V	0%	0%	0%	0%
Eucalyptus benthamii	V	0%	0%	0%	0%
Eucalyptus camfieldii	V	75%	34%	49%	58%
Eucalyptus camphora subsp. relicta	EN	51%	38%	49%	35%
Eucalyptus cannonii	V	0%	0%	0%	0%
Eucalyptus canobolensis	V	0%	0%	0%	0%
Eucalyptus glaucina	V	0%	0%	5%	13%
Eucalyptus kartzoffiana	V	0%	0%	0%	0%

Eucalyptus langleyi	V	0%	0%	0%	0%
Eucalyptus largeana	EN	98%	100%	91%	69%
Eucalyptus macarthurii	EN	1%	3%	1%	4%
Eucalyptus magnificata	EN	1%	47%	79%	23%
Eucalyptus microcodon	EN	0%	15%	27%	39%
Eucalyptus oresbia	V	0%	0%	0%	1%
Eucalyptus parvula	EN	0%	0%	1%	0%
Eucalyptus pulverulenta	V	8%	54%	81%	34%
Eucalyptus rubida subsp. barbigerorum	V	0%	0%	1%	0%
Eucalyptus saxatilis	EN	2%	3%	77%	56%
Eucalyptus scoparia	EN	0%	0%	1%	0%
Eucalyptus sp. Cattai	CE	13%	66%	34%	41%
Eucalyptus sturgissiana	V	0%	0%	0%	0%
Euphrasia ciliolata	V	97%	94%	40%	65%
Euphrasia scabra	EN	0%	1%	3%	0%
Floydia praealta	V	0%	13%	33%	77%
Genoplesium baueri	EN	100%	98%	79%	100%
Genoplesium littorale	CE	0%	0%	0%	0%
Gentiana wissmannii	V	0%	0%	0%	0%
Gossia fragrantissima	EN	0%	0%	0%	9%
Grevillea caleyi	CE	21%	1%	2%	100%
Grevillea guthrieana	EN	2%	25%	94%	37%
Grevillea hilliana	EN	80%	18%	25%	70%
Grevillea juniperina subsp. juniperina	V	22%	100%	64%	60%
Grevillea masonii	EN	96%	100%	35%	0%
Grevillea obtusiflora	EN	0%	0%	0%	0%
Grevillea parviflora subsp. supplicans	EN	54%	4%	9%	44%
Grevillea quadricauda	V	47%	100%	98%	71%
Grevillea renwickiana	EN	0%	0%	0%	0%
Grevillea rhizomatosa	V	0%	0%	0%	0%
Haematopus longirostris	EN	58%	51%	91%	82%
Hakea archaeoides	V	0%	0%	4%	2%
Hakea dohertyi	EN	0%	0%	0%	0%
Hibbertia puberula	EN	0%	0%	0%	0%
Hibbertia sp. Bankstown	CE	73%	86%	94%	73%
Hibbertia stricta subsp. furcatula	EN	0%	0%	0%	0%
Hibbertia superans	EN	84%	100%	64%	41%
Homopholis belsonii	EN	0%	0%	0%	0%
Indigofera baileyi	EN	0%	5%	47%	8%
Irenepharsus trypherus	EN	0%	0%	0%	12%
Isoglossa eranthemoides	EN	0%	4%	26%	87%
Isoodon obesulus obesulus	EN	66%	54%	54%	40%
Kunzea rupestris	V	29%	19%	20%	0%
Lasiopetalum joyceae	V	62%	60%	62%	66%
Leionema ralstonii	V	0%	0%	1%	0%
Lepiderema pulchella	V	6%	90%	0%	11%
Lepidium monoplocoides	EN	3%	2%	22%	2%
Lepidium peregrinum	EN	19%	100%	55%	99%
Leucopogon exolasius	V	0%	0%	0%	0%
Leucopogon fletcheri subsp. fletcheri	EN	33%	91%	74%	8%
Lindernia alsinoides	EN	0%	0%	11%	11%
Lindsaea incisa	EN	100%	99%	67%	98%
Litoria aurea	EN	12%	4%	12%	56%
Litoria booroolongensis	EN	8%	4%	15%	4%
Litoria castanea	CE	45%	65%	60%	37%
Litoria raniformis	EN	2%	10%	39%	35%
Macadamia tetraphylla	V	0%	12%	0%	46%
Melaleuca biconvexa	V	1%	0%	6%	0%
Melaleuca deanei	V	60%	50%	52%	41%
Melaleuca irbyana	EN	53%	71%	87%	39%

Melichrus hirsutus	EN	13%	0%	12%	0%
Micromyrtus blakelyi	V	95%	24%	14%	87%
Micromyrtus minutiflora	EN	0%	0%	2%	0%
Mixophyes fleayi	EN	0%	0%	4%	2%
Myriophyllum implicatum	CE	—	—	—	—
Ochrosia moorei	EN	0%	0%	0%	30%
Olearia cordata	V	10%	75%	96%	33%
Olearia flocktoniae	EN	0%	0%	0%	0%
Owenia cepiodora	V	0%	0%	17%	48%
Ozothamnus vagans	EN	0%	1%	0%	38%
Pachycephala rufogularis	CE	0%	2%	35%	12%
Persicaria elatior	V	13%	20%	65%	25%
Persoonia acerosa	V	12%	26%	35%	13%
Persoonia bargoensis	EN	0%	0%	0%	0%
Persoonia glaucescens	EN	0%	1%	33%	5%
Persoonia hindii	EN	0%	0%	0%	0%
Persoonia hirsuta	EN	13%	24%	37%	5%
Persoonia marginata	V	0%	0%	9%	0%
Persoonia mollis subsp. maxima	EN	0%	0%	0%	0%
Persoonia nutans	EN	7%	0%	59%	0%
Pezoporus wallicus wallicus	V	16%	7%	30%	61%
Phaethon rubricauda	V	19%	7%	11%	37%
Phaius australis	EN	0%	0%	17%	25%
Phyllanthus microcladus	EN	96%	88%	97%	92%
Phyllota humifusa	V	0%	0%	0%	0%
Picris evae	V	0%	0%	5%	0%
Pilularia novae-hollandiae	EN	0%	0%	1%	2%
Pimelea curviflora var. curviflora	V	55%	68%	44%	55%
Pimelea spicata	EN	3%	5%	21%	7%
Plectranthus alloplectus	EN	0%	0%	0%	0%
Polytelis anthopeplus monarchoides	EN	0%	0%	0%	0%
Pomaderris brunnea	EN	1%	0%	0%	0%
Pomaderris cocoparrana	EN	0%	0%	0%	0%
Pomaderris cotoneaster	EN	11%	10%	30%	21%
Pomaderris pallida	V	0%	58%	51%	1%
Pomaderris parrisiae	V	16%	2%	24%	8%
Potorous tridactylus	V	53%	70%	60%	90%
Prasophyllum affine	EN	0%	0%	0%	0%
Prostanthera askania	EN	36%	34%	2%	43%
Prostanthera densa	V	36%	24%	95%	62%
Prostanthera junonis	EN	100%	100%	12%	100%
Prostanthera stricta	V	0%	0%	0%	0%
Pseudomys fumeus	CE	0%	0%	2%	17%
Pseudomys gracilicaudatus	V	11%	71%	64%	29%
Pseudomys pilligaensis	V	100%	89%	82%	91%
Pseudophryne pengilleyi	CE	32%	79%	6%	4%
Pterodroma leucoptera leucoptera	V	39%	5%	49%	76%
Pterodroma nigripennis	V	100%	46%	64%	79%
Pterodroma solandri	V	34%	1%	5%	81%
Pterostylis cobarensis	V	80%	49%	47%	36%
Pterostylis despectans	CE	0%	0%	0%	0%
Puffinus assimilis	V	8%	2%	11%	37%
Pultenaea glabra	V	0%	0%	1%	0%
Pultenaea maritima	V	4%	1%	3%	14%
Pultenaea parviflora	EN	12%	100%	73%	0%
Pultenaea pedunculata	EN	29%	98%	76%	29%
Quassia sp. Mooney Creek	EN	93%	56%	32%	25%
Randia moorei	EN	16%	88%	40%	57%
Rutidosis leiolepis	V	47%	87%	50%	35%
Rutidosis leptorrhynchoides	EN	0%	24%	25%	0%

Sarcochilus hartmannii	V	8%	100%	71%	44%
Sclerolaena napiformis	EN	75%	22%	0%	18%
Senecio spathulatus	EN	0%	0%	28%	1%
Senna acclinis	EN	25%	29%	25%	60%
Solanum celatum	EN	0%	0%	3%	23%
Sophora fraseri	V	0%	37%	82%	12%
Sophora tomentosa	EN	72%	51%	94%	93%
Sternula albifrons	EN	64%	33%	64%	83%
Sula dactylatra	V	98%	68%	84%	92%
Swainsona plagiotropis	V	0%	0%	0%	0%
Swainsona recta	EN	0%	1%	1%	0%
Symplocos baeuerlenii	V	0%	0%	0%	0%
Syzygium hodgkinsoniae	V	19%	41%	15%	98%
Syzygium moorei	V	5%	99%	41%	35%
Syzygium paniculatum	EN	42%	5%	18%	85%
Tasmannia glaucifolia	V	0%	0%	0%	6%
Tetratheca glandulosa	V	66%	90%	47%	71%
Thinornis rubricollis	CE	13%	1%	66%	52%
Tinospora tinosporoides	V	0%	1%	1%	13%
Triplarina nowraensis	EN	0%	0%	0%	19%
Tylophora woollsii	EN	0%	0%	0%	21%
Tympanocryptis pinguicolla	EN	0%	23%	29%	26%
Uromyrtus australis	EN	37%	14%	13%	88%
Veronica blakelyi	V	0%	0%	0%	0%
Wilsonia backhousei	V	17%	27%	70%	41%
Xylosma terrae-reginae	EN	0%	0%	74%	11%
Zieria granulata	EN	0%	0%	1%	55%
Zieria involucrata	EN	8%	47%	11%	0%
Zieria murphyi	V	13%	8%	19%	33%
Zieria tuberculata	V	0%	0%	0%	0%

Table A5. *For each landscape- and site-managed species, we calculated the size of current occupied and unoccupied habitat (see Box 2 in main body of report) and a) the percent of occupied habitat classified as an area with consensus for internal refugia and b) the percent of unoccupied habitat classified as an area with consensus for translocation. That is, these grid cells are projected to be suitable now, as well as in 2030 and in 2070, under all climate scenario. Species are separated into landscape and site-managed streams. In addition, we placed species into one of four categories, depending on whether these areas spanned < 20% or ≥ 20% of current occupied or unoccupied habitat, respectively. 'a' = limited regions with consensus for internal refugia AND limited regions with consensus for translocation, 'b' = some regions with consensus for internal refugia but limited regions with consensus for translocation, 'c' = limited regions with consensus for internal refugia but some regions with consensus for translocation, 'd' some regions with consensus for internal refugia and some regions with consensus for translocation.*

NB: our definition of occupied current habitat prevented identification of internal refugia for Myriophyllum implicatum.

			Consensus for Internal Refugia			Consensus for Translocation		
Species	**Status**	**Current *occupied* habitat (km²)**	**2030**	**2070**	**Current *unoccupied* habitat (km²)**	**2030**	**2070**	**Risk category**
Landscape								
Aprasia inaurita	EN	12,244	58%	31%	90,054	1%	0%	b
Aprasia parapulchella	V	31,940	21%	5%	48,568	31%	3%	a
Atrichornis rufescens	V	14,013	30%	24%	9,180	28%	23%	d
Botaurus poiciloptilus	EN	217,443	17%	15%	36,062	5%	4%	a
Burhinus grallarius	EN	103,196	80%	79%	8,497	49%	48%	d
Callocephalon fimbriatum	V	115,855	74%	47%	40,495	47%	17%	b
Calyptorhynchus lathami	V	151,800	35%	12%	4,533	3%	2%	a
Cercartetus nanus	V	71,307	30%	17%	11,912	21%	11%	a
Certhionyx variegatus	V	254,744	92%	88%	6,888	88%	86%	d
Chthonicola sagittata	V	287,922	80%	78%	2,258	20%	10%	b
Cinclosoma castanotum	V	61,717	1%	1%	9,046	0%	0%	a
Circus assimilis	V	582,574	97%	97%	7,881	99%	99%	d
Coeranoscincus reticulatus	V	2,501	5%	1%	6,838	45%	29%	c
Coracina lineata	V	9,845	23%	17%	2,185	40%	34%	c
Daphoenositta chrysoptera	V	393,643	89%	86%	2,838	28%	26%	d
Dasyurus maculatus	V	135,878	55%	30%	6,954	48%	35%	d
Delma impar	V	10,775	0%	0%	66,187	0%	0%	a
Epthianura albifrons	V	297,812	41%	14%	8,796	21%	5%	a
Eulamprus leuraensis	EN	714	0%	0%	18,965	11%	5%	a
Falco subniger	V	591,842	94%	93%	17,073	93%	92%	d
Falsistrellus tasmaniensis	V	134,157	60%	38%	8,895	51%	38%	d
Glossopsitta pusilla	V	226,895	91%	91%	14,652	90%	90%	d
Grantiella picta	V	525,059	98%	98%	74,818	93%	93%	d
Heleioporus australiacus	V	22,399	23%	16%	20,640	6%	4%	a
Hieraaetus morphnoides	V	638,447	91%	90%	9,081	94%	94%	d
Hoplocephalus bitorquatus	V	71,730	77%	60%	110,088	84%	48%	d
Hoplocephalus stephensii	V	35,875	5%	2%	11,011	3%	1%	a
Hylacola cautus	V	93,159	0%	0%	42,609	0%	0%	a

Irediparra gallinacea	V	11,732	49%	48%	84	58%	55%	d
Ixobrychus flavicollis	V	26,947	71%	69%	704	68%	61%	d
Kerivoula papuensis	V	46,208	10%	3%	13,488	2%	0%	a
Lathamus discolor	EN	39,770	39%	31%	18,827	44%	37%	d
Litoria daviesae	V	7,686	56%	54%	11,456	64%	55%	d
Litoria littlejohni	V	7,159	9%	5%	21,088	27%	14%	a
Litoria olongburensis	V	1,625	3%	0%	558	29%	19%	a
Litoria subglandulosa	V	9,437	35%	8%	10,846	20%	3%	a
Lophochroa leadbeateri	V	388,190	95%	95%	27,770	91%	91%	d
Lophoictinia isura	V	52,531	93%	93%	8,680	94%	93%	d
Menura alberti	V	6,101	1%	0%	9,249	37%	14%	a
Miniopterus australis	V	46,901	51%	44%	5,928	63%	56%	d
Mixophyes balbus	EN	35,479	11%	3%	8,503	1%	0%	a
Mixophyes iteratus	EN	27,949	4%	1%	3,077	3%	1%	a
Myotis macropus	V	80,021	46%	37%	11,046	5%	4%	b
Neophema pulchella	V	181,778	85%	80%	14,570	65%	59%	d
Ningaui yvonneae	V	34,712	3%	0%	21,922	1%	0%	a
Ninox connivens	V	350,385	94%	94%	28,003	91%	91%	d
Ninox strenua	V	142,345	53%	35%	7,406	29%	24%	d
Notamacropus parma	V	31,938	20%	19%	7,946	15%	15%	a
Nyctophilus corbeni	V	187,113	34%	22%	78,102	12%	7%	b
Oxyura australis	V	366,078	56%	47%	19,256	30%	24%	d
Pachycephala inornata	V	210,825	7%	2%	47,658	0%	0%	a
Pachycephala olivacea	V	44,818	15%	10%	5,074	6%	2%	a
Pandion cristatus	V	14,050	52%	51%	635	70%	69%	d
Petaurus australis australis	V	104,071	35%	10%	7,853	2%	0%	a
Petaurus norfolcensis	V	147,716	88%	87%	23,748	93%	93%	d
Petroica boodang	V	141,465	81%	58%	1,007	60%	21%	d
Petroica phoenicea	V	198,700	38%	25%	18,450	0%	0%	b
Phascogale tapoatafa tapoatafa	V	47,577	40%	37%	26,827	33%	30%	d
Philoria loveridgei	EN	1,738	1%	0%	9,207	36%	13%	a
Philoria sphagnicola	V	7,559	5%	1%	6,331	31%	21%	c
Podargus ocellatus	V	5,702	3%	1%	3,533	29%	11%	a
Polytelis swainsonii	V	227,088	11%	0%	6,866	0%	0%	a
Pseudophryne australis	V	12,094	23%	5%	12,027	22%	18%	a
Pteropus poliocephalus	V	59,602	78%	78%	926	54%	53%	d
Ptilinopus regina	V	15,577	57%	56%	352	37%	36%	d
Pyrrholaemus brunneus	V	62,763	68%	61%	102,520	61%	56%	d
Saccolaimus flaviventris	V	304,904	93%	92%	32,572	91%	91%	d
Scoteanax rueppellii	V	91,315	12%	4%	4,501	25%	20%	a
Simoselaps fasciolatus	V	35,851	76%	53%	56,640	42%	20%	d
Sminthopsis leucopus	V	12,413	1%	1%	6,881	1%	0%	a
Sminthopsis macroura	V	103,984	96%	94%	53,679	91%	88%	d
Stagonopleura guttata	V	343,745	56%	39%	1,139	17%	12%	b
Stictonetta naevosa	V	479,804	85%	81%	38,403	84%	80%	d
Thylogale stigmatica	V	18,969	20%	10%	10,360	27%	20%	a
Tyto longimembris	V	9,876	55%	51%	3,673	49%	48%	d
Tyto novaehollandiae	V	109,331	42%	11%	10,510	1%	0%	a
Tyto tenebricosa tenebricosa	V	76,284	34%	9%	3,654	8%	2%	a
Uvidicolus sphyrurus	V	21,963	58%	8%	52,467	46%	14%	a
Varanus rosenbergi	V	15,732	3%	1%	26,426	1%	0%	a

Vespadelus troughtoni	V	64,744	56%	54%	58,836	78%	76%	d
Wollumbinia belli	EN	3,187	28%	0%	61,369	21%	8%	a
Site								
Acacia acanthoclada	EN	17,965	2%	0%	3,193	0%	0%	a
Acacia ausfeldii	V	7,480	0%	0%	3,262	0%	0%	a
Acacia bakeri	V	965	74%	0%	80	15%	0%	a
Acacia bynoeana	EN	10,379	57%	34%	6,348	23%	8%	b
Acacia carneorum	V	32,329	0%	0%	16,284	0%	0%	a
Acacia courtii	V	109	0%	0%	2,016	2%	0%	a
Acacia curranii	V	28,941	62%	52%	12,090	71%	56%	d
Acacia gordonii	EN	3,789	44%	43%	13,914	17%	12%	b
Acacia meiantha	EN	1,248	0%	0%	349	0%	0%	a
Acacia phasmoides	V	433	37%	18%	2,201	27%	18%	a
Acacia pubescens	V	3,828	22%	11%	208,369	24%	20%	a
Acacia pubifolia	EN	3,681	0%	0%	24,504	9%	8%	a
Acacia terminalis subsp. terminalis	EN	203	0%	0%	216	0%	0%	a
Acronychia littoralis	EN	3,228	0%	0%	2,257	1%	1%	a
Acrophyllum australe	V	1,156	0%	0%	21,713	33%	23%	c
Aepyprymnus rufescens	V	48,122	64%	57%	22,862	17%	11%	b
Aldrovanda vesiculosa	EN	3,191	34%	17%	17,923	29%	16%	a
Alexfloydia repens	EN	890	0%	0%	257	0%	0%	a
Allocasuarina defungens	EN	2,649	0%	0%	13,355	0%	0%	a
Allocasuarina simulans	V	522	0%	0%	12,993	0%	0%	a
Amytornis barbatus barbatus	EN	6,353	11%	11%	497	4%	4%	a
Amytornis striatus	V	8,967	45%	5%	14,384	14%	0%	a
Angophora exul	EN	19,936	48%	21%	172,939	31%	23%	d
Anthochaera phrygia	CE	198,185	64%	61%	27,972	17%	14%	b
Archidendron hendersonii	V	1,745	0%	0%	5,361	3%	2%	a
Ardenna carneipes	V	10,160	2%	1%	828	8%	7%	a
Asperula asthenes	V	7,466	0%	0%	15,541	0%	0%	a
Astrotricha crassifolia	V	8,449	22%	20%	19,397	36%	33%	d
Astrotricha roddii	EN	3,564	0%	0%	2,469	0%	0%	a
Austrostipa nullanulla	EN	10,314	0%	0%	25,030	0%	0%	a
Bertya opponens	V	11,530	95%	94%	20,702	90%	84%	d
Boronia deanei	V	1,310	0%	0%	1,593	0%	0%	a
Boronia repanda	EN	30	0%	0%	35,549	11%	0%	a
Bossiaea oligosperma	V	1,382	20%	2%	56,338	4%	1%	a
Brachyscome muelleroides	V	14,647	0%	0%	33,383	0%	0%	a
Burramys parvus	EN	1,770	19%	2%	258	0%	0%	a
Caesalpinia bonduc	EN	3	0%	0%	482	35%	34%	c
Caladenia arenaria	EN	30,292	87%	85%	138,424	92%	88%	d
Caladenia concolor	EN	7,970	86%	86%	3,828	41%	40%	d
Caladenia tessellata	EN	197	0%	0%	1,534	0%	0%	a
Callitris baileyi	EN	155	6%	0%	931	10%	0%	a
Callitris oblonga	V	12,819	73%	50%	31,117	52%	20%	d
Calotis glandulosa	V	10,703	53%	9%	1,587	19%	0%	a
Carex raleighii	EN	4,600	37%	16%	5,121	4%	0%	a
Cassia brewsteri var. marksiana	EN	1,449	51%	3%	159	13%	0%	a
Chamaesyce psammogeton	EN	4,020	23%	20%	1,060	35%	31%	d
Coatesia paniculata	EN	3,577	0%	0%	4,281	4%	2%	a

Commersonia prostrata	EN	5,858	6%	3%	9,448	4%	1%	a
Corchorus cunninghamii	EN	2,839	0%	0%	5,301	6%	0%	a
Crinia sloanei	V	46,017	34%	34%	38,086	1%	0%	b
Cryptostylis hunteriana	V	6,993	0%	0%	3,178	0%	0%	a
Ctenophorus mirrityana	EN	2,070	0%	0%	10	0%	0%	a
Cullen parvum	EN	4,386	2%	0%	7,942	6%	0%	a
Dampiera fusca	EN	6,699	11%	0%	2,179	0%	0%	a
Daphnandra johnsonii	EN	678	0%	0%	26,283	14%	8%	a
Darwinia biflora	V	1,179	5%	1%	2,474	21%	5%	a
Darwinia glaucophylla	V	249	81%	29%	9,456	71%	70%	d
Darwinia peduncularis	V	8,565	86%	62%	53,250	46%	40%	d
Dasyornis brachypterus	EN	5,967	4%	1%	2,154	0%	0%	a
Davidsonia jerseyana	EN	1,338	0%	0%	617	1%	0%	a
Davidsonia johnsonii	EN	2,041	8%	7%	161,637	0%	0%	a
Desmodium acanthocladum	V	3,004	0%	0%	2,106	0%	0%	a
Dichanthium setosum	V	46,662	40%	21%	90,885	36%	18%	b
Digitaria porrecta	EN	50,570	1%	1%	203,100	3%	2%	a
Dillwynia glaucula	EN	6,926	1%	1%	5,062	0%	0%	a
Diospyros mabacea	EN	2,281	25%	14%	628	48%	40%	c
Diploglottis campbellii	EN	2,831	65%	55%	703	71%	62%	d
Discaria nitida	V	7,254	5%	0%	2,210	0%	0%	a
Diuris aequalis	EN	6,270	0%	0%	487	0%	0%	a
Diuris arenaria	EN	274	100%	100%	2,897	36%	35%	d
Diuris pedunculata	EN	32,669	64%	29%	30,716	42%	8%	b
Diuris praecox	V	1,553	1%	1%	824	0%	0%	a
Dodonaea procumbens	V	6,261	59%	52%	18,343	7%	1%	b
Elaeocarpus williamsianus	EN	1,682	61%	61%	150	52%	52%	d
Eleocharis tetraquetra	EN	6,619	76%	76%	408,484	95%	94%	d
Endiandra floydii	EN	1,793	37%	32%	217	18%	1%	b
Epacris hamiltonii	EN	104	11%	0%	10,401	20%	0%	a
Epacris purpurascens var. purpurascens	V	3,454	2%	0%	14,867	2%	0%	a
Esacus magnirostris	CE	2,445	92%	92%	353	98%	98%	d
Eucalyptus aggregata	V	25,217	5%	1%	9,223	1%	0%	a
Eucalyptus alligatrix subsp. alligatrix	V	31	0%	0%	23,855	6%	2%	a
Eucalyptus benthamii	V	1,244	0%	0%	24,763	0%	0%	a
Eucalyptus camfieldii	V	3,638	61%	14%	1,796	35%	17%	a
Eucalyptus camphora subsp. relicta	EN	10,837	78%	33%	44,520	69%	38%	d
Eucalyptus cannonii	V	5,722	7%	0%	11,998	1%	0%	a
Eucalyptus canobolensis	V	80	0%	0%	296	85%	26%	c
Eucalyptus glaucina	V	14,881	0%	0%	3,263	0%	0%	a
Eucalyptus kartzoffiana	V	464	0%	0%	141	0%	0%	a
Eucalyptus langleyi	V	693	0%	0%	2,098	0%	0%	a
Eucalyptus largeana	EN	7,135	89%	63%	269,100	38%	10%	b
Eucalyptus macarthurii	EN	1,705	1%	1%	1,505	20%	5%	a
Eucalyptus magnificata	EN	9,635	37%	1%	5,005	23%	0%	a
Eucalyptus microcodon	EN	2,929	14%	0%	12,361	9%	2%	a
Eucalyptus oresbia	V	6,128	0%	0%	175	0%	0%	a
Eucalyptus parvula	EN	2,614	0%	0%	12,318	0%	0%	a
Eucalyptus pulverulenta	V	8,101	11%	6%	22,319	2%	0%	a

Eucalyptus rubida subsp. barbigerorum	V	8,128	52%	0%	42,375	20%	9%	a
Eucalyptus saxatilis	EN	863	10%	1%	1,326	0%	0%	a
Eucalyptus scoparia	EN	1,854	0%	0%	63,716	3%	3%	a
Eucalyptus sp. Cattai	CE	21,107	11%	2%	13,448	12%	4%	a
Eucalyptus sturgissiana	V	949	0%	0%	29,063	0%	0%	a
Euphrasia ciliolata	V	3,627	43%	39%	10,159	72%	60%	d
Euphrasia scabra	EN	4,605	0%	0%	14,797	3%	1%	a
Floydia praealta	V	3,050	8%	0%	3,421	0%	0%	a
Genoplesium baueri	EN	2,217	79%	79%	10,312	82%	82%	d
Genoplesium littorale	CE	116	0%	0%	7,995	1%	0%	a
Gentiana wissmannii	V	347	0%	0%	6,862	0%	0%	a
Gossia fragrantissima	EN	3,577	0%	0%	149,557	1%	0%	a
Grevillea caleyi	CE	301	21%	0%	5,682	39%	16%	a
Grevillea guthrieana	EN	4,702	4%	2%	14,334	3%	1%	a
Grevillea hilliana	EN	1,183	15%	11%	2,047	11%	3%	a
Grevillea juniperina subsp. juniperina	V	705	18%	18%	13,041	79%	58%	c
Grevillea masonii	EN	482	32%	0%	256,367	32%	3%	a
Grevillea obtusiflora	EN	925	0%	0%	10,095	0%	0%	a
Grevillea parviflora subsp. supplicans	EN	623	23%	0%	3,325	11%	9%	a
Grevillea quadricauda	V	3,494	46%	42%	6,222	27%	14%	b
Grevillea renwickiana	EN	1,001	0%	0%	310	0%	0%	a
Grevillea rhizomatosa	V	474	0%	0%	2,252	29%	14%	a
Haematopus longirostris	EN	8,713	46%	46%	588	81%	81%	d
Hakea archaeoides	V	3,038	0%	0%	1,053	14%	4%	a
Hakea dohertyi	EN	413	0%	0%	19,252	0%	0%	a
Hibbertia puberula	EN	1,344	0%	0%	3,573	1%	0%	a
Hibbertia sp. Bankstown	CE	35,220	65%	62%	39,004	72%	68%	d
Hibbertia stricta subsp. furcatula	EN	1,107	0%	0%	902	0%	0%	a
Hibbertia superans	EN	857	61%	30%	8,723	7%	3%	b
Homopholis belsonii	EN	17,259	0%	0%	5,314	0%	0%	a
Indigofera baileyi	EN	4,502	8%	0%	20,963	12%	2%	a
Irenepharsus trypherus	EN	1,280	0%	0%	7,877	3%	3%	a
Isoglossa eranthemoides	EN	2,652	0%	0%	2,556	0%	0%	a
Isoodon obesulus obesulus	EN	6,667	70%	31%	1,430	26%	12%	b
Kunzea rupestris	V	996	1%	0%	5,976	1%	0%	a
Lasiopetalum joyceae	V	1,455	35%	33%	3,198	44%	26%	d
Leionema ralstonii	V	403	0%	0%	141	0%	0%	a
Lepiderema pulchella	V	1,514	0%	0%	1,226	3%	0%	a
Lepidium monoplocoides	EN	113,141	21%	1%	104,451	12%	1%	a
Lepidium peregrinum	EN	666	55%	17%	145,453	85%	84%	c
Leucopogon exolasius	V	1,972	0%	0%	8,953	5%	1%	a
Leucopogon fletcheri subsp. fletcheri	EN	2,158	31%	5%	22,476	40%	22%	c
Lindernia alsinoides	EN	7,467	0%	0%	17,293	5%	5%	a
Lindsaea incisa	EN	4,721	67%	67%	43,444	89%	88%	d
Litoria aurea	EN	21,568	10%	3%	46,625	50%	15%	a
Litoria booroolongensis	EN	69,928	3%	1%	25,981	1%	0%	a
Litoria castanea	CE	28,859	73%	36%	40,946	57%	6%	b
Litoria raniformis	EN	54,588	4%	1%	46,238	2%	0%	a
Macadamia tetraphylla	V	3,763	0%	0%	2,667	1%	0%	a

Melaleuca biconvexa	V	4,594	0%	0%	1,463	29%	18%	a
Melaleuca deanei	V	6,793	32%	16%	8,688	15%	9%	a
Melaleuca irbyana	EN	3,532	65%	33%	1,461	21%	5%	b
Melichrus hirsutus	EN	1,280	0%	0%	11,198	44%	41%	c
Micromyrtus blakelyi	V	1,082	15%	6%	15,967	34%	29%	c
Micromyrtus minutiflora	EN	349	0%	0%	17,589	9%	6%	a
Mixophyes fleayi	EN	1,647	1%	0%	8,117	40%	13%	a
Myriophyllum implicatum	CE	0	0%	0%	80,455	35%	35%	c
Ochrosia moorei	EN	3,678	0%	0%	5,672	0%	0%	a
Olearia cordata	V	5,613	10%	9%	34,287	28%	20%	c
Olearia flocktoniae	EN	1,177	0%	0%	2,039	14%	9%	a
Owenia cepiodora	V	6,876	0%	0%	6,425	1%	0%	a
Ozothamnus vagans	EN	112	0%	0%	195	0%	0%	a
Pachycephala rufogularis	CE	27,398	2%	0%	48,393	1%	0%	a
Persicaria elatior	V	16,870	19%	8%	4,033	12%	5%	a
Persoonia acerosa	V	917	22%	10%	10,537	18%	2%	a
Persoonia bargoensis	EN	342	0%	0%	2,840	0%	0%	a
Persoonia glaucescens	EN	1,214	25%	0%	12,584	36%	10%	a
Persoonia hindii	EN	119	0%	0%	499	0%	0%	a
Persoonia hirsuta	EN	8,659	13%	5%	21,422	16%	6%	a
Persoonia marginata	V	4,016	5%	0%	31,473	3%	0%	a
Persoonia mollis subsp. maxima	EN	282	0%	0%	17,500	2%	1%	a
Persoonia nutans	EN	844	0%	0%	232,509	75%	67%	c
Pezoporus wallicus wallicus	V	6,152	8%	5%	3,264	16%	13%	a
Phaethon rubricauda	V	8,803	7%	3%	8,596	3%	1%	a
Phaius australis	EN	4,187	0%	0%	5,963	11%	8%	a
Phyllanthus microcladus	EN	13,095	83%	79%	12,345	23%	23%	d
Phyllota humifusa	V	646	0%	0%	57	4%	0%	a
Picris evae	V	3,529	0%	0%	2,614	0%	0%	a
Pilularia novae-hollandiae	EN	38,195	0%	0%	81,545	0%	0%	a
Pimelea curviflora var. curviflora	V	3,376	20%	14%	20,231	6%	2%	a
Pimelea spicata	EN	2,012	13%	2%	7,865	10%	5%	a
Plectranthus alloplectus	EN	764	0%	0%	10,184	2%	0%	a
Polytelis anthopeplus monarchoides	EN	26,297	0%	0%	7,959	0%	0%	a
Pomaderris brunnea	EN	6,943	0%	0%	28,154	0%	0%	a
Pomaderris cocoparrana	EN	403	0%	0%	17,404	0%	0%	a
Pomaderris cotoneaster	EN	30,860	18%	5%	64,356	21%	8%	a
Pomaderris pallida	V	5,793	0%	0%	3,938	0%	0%	a
Pomaderris parrisiae	V	4,879	2%	0%	21,184	2%	0%	a
Potorous tridactylus	V	57,770	55%	37%	12,513	34%	29%	d
Prasophyllum affine	EN	785	0%	0%	175,230	78%	66%	c
Prostanthera askania	EN	555	2%	2%	7,033	12%	12%	a
Prostanthera densa	V	1,554	20%	20%	4,663	21%	21%	c
Prostanthera junonis	EN	252	12%	12%	15,037	56%	56%	c
Prostanthera stricta	V	4,139	0%	0%	20,626	3%	2%	a
Pseudomys fumeus	CE	10,370	0%	0%	39,775	1%	0%	a
Pseudomys gracilicaudatus	V	22,787	18%	8%	74,330	57%	31%	c
Pseudomys pilligaensis	V	5,539	80%	77%	9,011	8%	7%	b
Pseudophryne pengilleyi	CE	1,793	7%	2%	17	0%	0%	a
Pterodroma leucoptera leucoptera	V	5,167	5%	5%	2,222	10%	10%	a

Pterodroma nigripennis	V	843	42%	42%	1,277	74%	74%	d
Pterodroma solandri	V	1,961	1%	0%	61,362	0%	0%	a
Pterostylis cobarensis	V	27,141	64%	27%	15,284	40%	27%	d
Pterostylis despectans	CE	55	0%	0%	39	0%	0%	a
Puffinus assimilis	V	4,643	2%	2%	2,022	3%	2%	a
Pultenaea glabra	V	1,054	8%	0%	18,475	21%	2%	a
Pultenaea maritima	V	1,690	0%	0%	1,105	1%	1%	a
Pultenaea parviflora	EN	728	11%	0%	613	34%	7%	a
Pultenaea pedunculata	EN	894	21%	13%	2,299	50%	42%	c
Quassia sp. Mooney Creek	EN	1,644	32%	8%	121,963	61%	35%	c
Randia moorei	EN	1,668	32%	2%	1,063	1%	0%	a
Rutidosis leiolepis	V	4,685	74%	32%	7,563	4%	0%	b
Rutidosis leptorrhynchoides	EN	5,210	0%	0%	2,882	0%	0%	a
Sarcochilus hartmannii	V	3,494	9%	5%	943	5%	2%	a
Sclerolaena napiformis	EN	7,436	9%	0%	39,533	15%	2%	a
Senecio spathulatus	EN	973	0%	0%	957	1%	0%	a
Senna acclinis	EN	34,563	26%	13%	9,421	14%	6%	a
Solanum celatum	EN	2,351	0%	0%	86,212	13%	4%	a
Sophora fraseri	V	4,270	1%	0%	11,133	20%	11%	a
Sophora tomentosa	EN	2,576	47%	47%	8,741	72%	70%	d
Sternula albifrons	EN	10,599	33%	33%	749	56%	56%	d
Sula dactylatra	V	2,970	68%	68%	1,820	59%	59%	d
Swainsona plagiotropis	V	16,348	4%	0%	24,481	4%	0%	a
Swainsona recta	EN	24,588	0%	0%	7,572	0%	0%	a
Symplocos baeuerlenii	V	578	0%	0%	3,095	0%	0%	a
Syzygium hodgkinsoniae	V	3,272	11%	3%	1,732	3%	1%	a
Syzygium moorei	V	2,246	21%	1%	79	6%	0%	a
Syzygium paniculatum	EN	18,848	4%	2%	13,601	2%	1%	a
Tasmannia glaucifolia	V	1,012	0%	0%	521	0%	0%	a
Tetratheca glandulosa	V	3,579	40%	31%	6,399	15%	2%	b
Thinornis rubricollis	CE	1,238	1%	1%	786	2%	2%	a
Tinospora tinosporoides	V	4,143	0%	0%	188,500	1%	0%	a
Triplarina nowraensis	EN	582	0%	0%	22,325	7%	6%	a
Tylophora woollsii	EN	14,655	1%	0%	24,635	0%	0%	a
Tympanocryptis pinguicolla	EN	9,472	4%	0%	13,365	2%	1%	a
Uromyrtus australis	EN	468	14%	13%	4,749	13%	12%	a
Veronica blakelyi	V	422	0%	0%	19,089	5%	0%	a
Wilsonia backhousei	V	1,965	5%	4%	47,173	39%	24%	c
Xylosma terrae-reginae	EN	6,283	1%	0%	18,676	2%	2%	a
Zieria granulata	EN	402	1%	0%	9,462	0%	0%	a
Zieria involucrata	EN	2,722	0%	0%	15,924	0%	0%	a
Zieria murphyi	V	6,597	12%	3%	13,932	30%	16%	a
Zieria tuberculata	V	218	0%	0%	671	0%	0%	a

Figures A1.1 to 1.6 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the (1.1) Deserts and Xeric Shrublands ecoregion (1.2) Mediterranean Forests, Woodlands & Scrub ecoregion, (1.3) Montane Grasslands and Shrublands ecoregion, (1.4) Temperate Broadleaf and Mixed Forest ecoregion, (1.5) Temperate Grasslands, Savannas and Shrublands ecoregion, and (1.6) Tropical/Subtropical Grasslands, Savannas and Shrublands ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

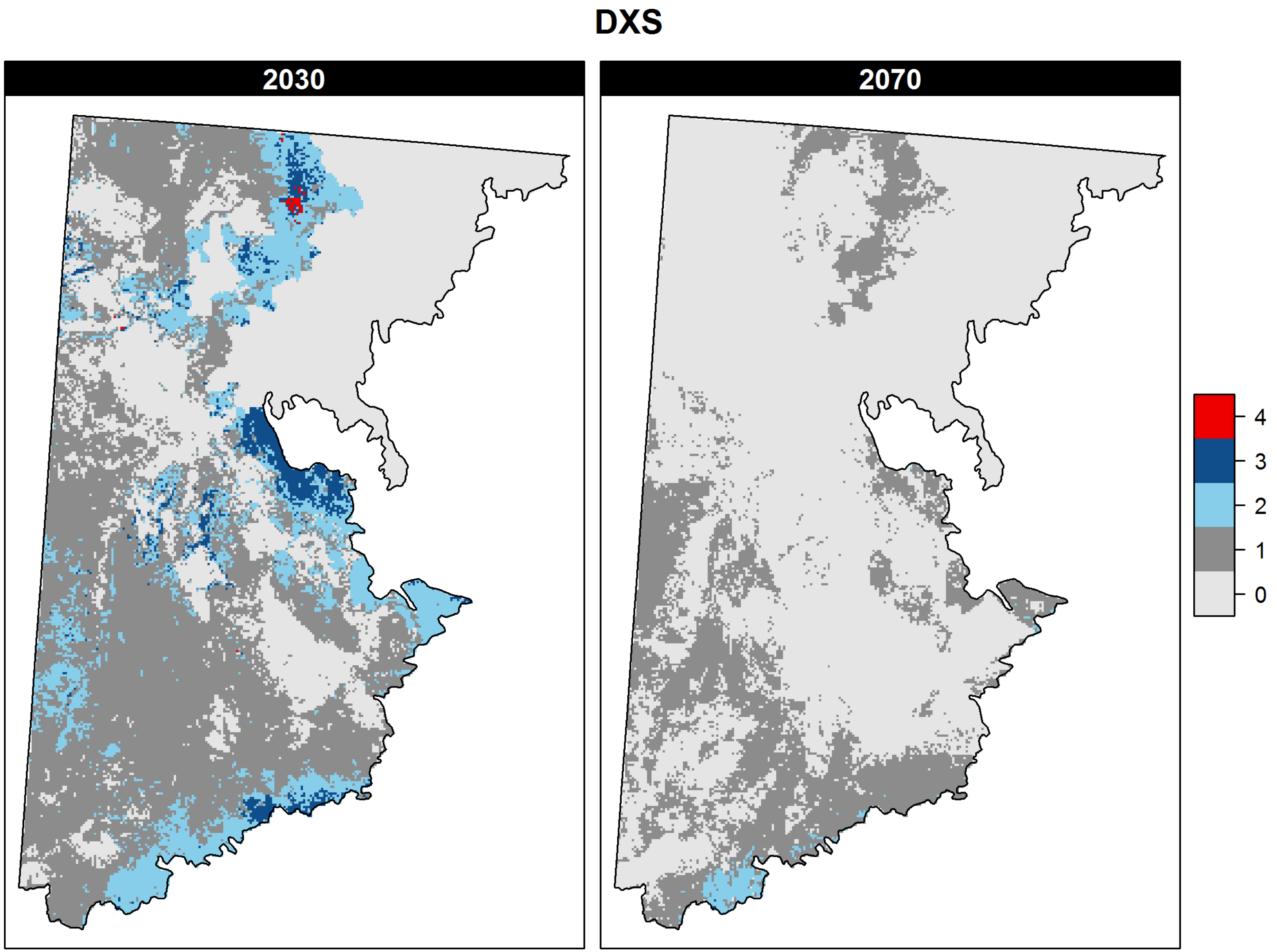

DXS
2030
2070
4
3
2
1
0

Figure A1.1 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Deserts and Xeric Shrublands ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

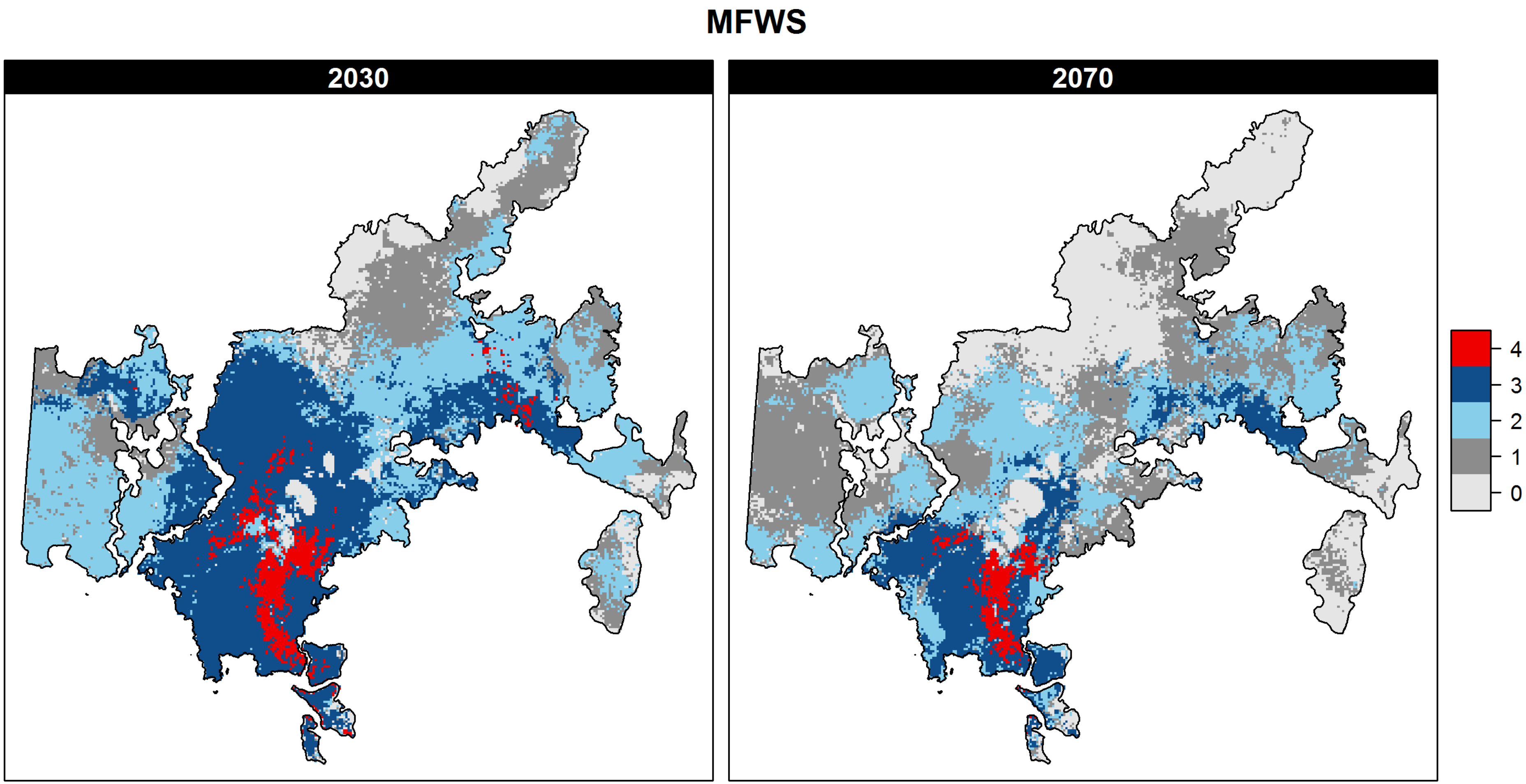


Figure A1.2 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Mediterranean Forests, Woodlands & Scrub ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

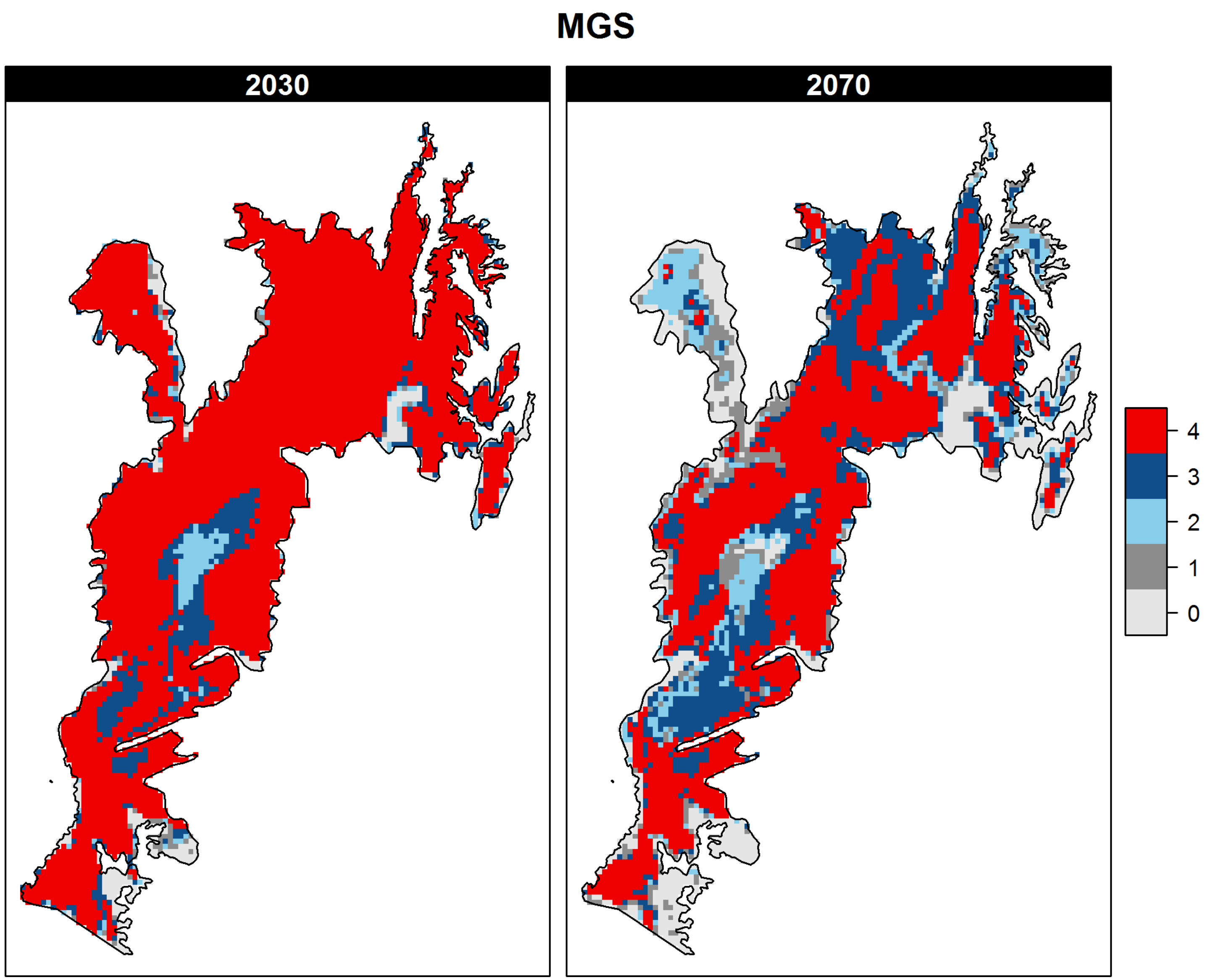
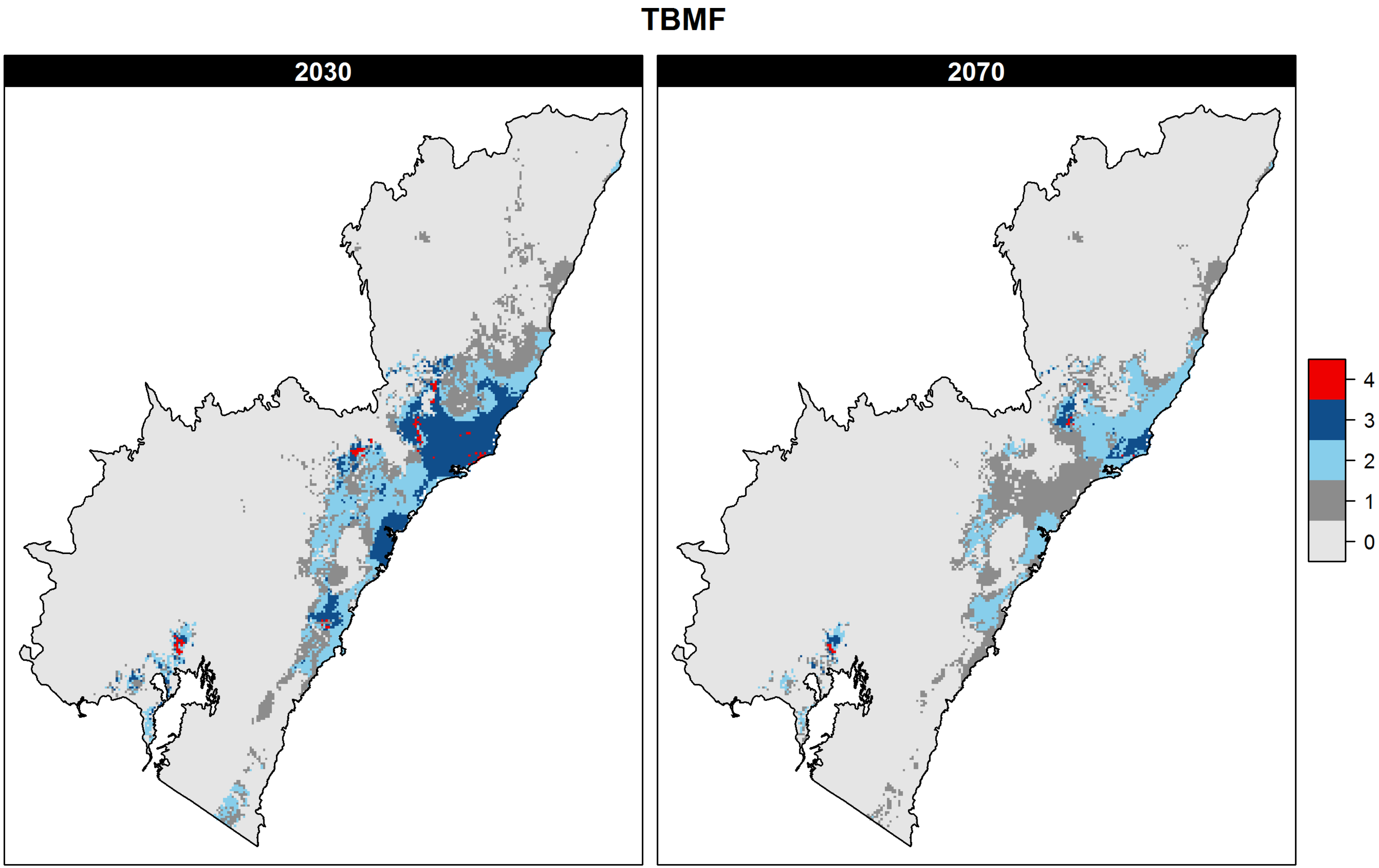


Figure A1.3 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Montane Grasslands and Shrublands ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*



TBMF
2030
2070
4
3
2
1
0

Figure A1.4 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Temperate Broadleaf and Mixed Forest ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

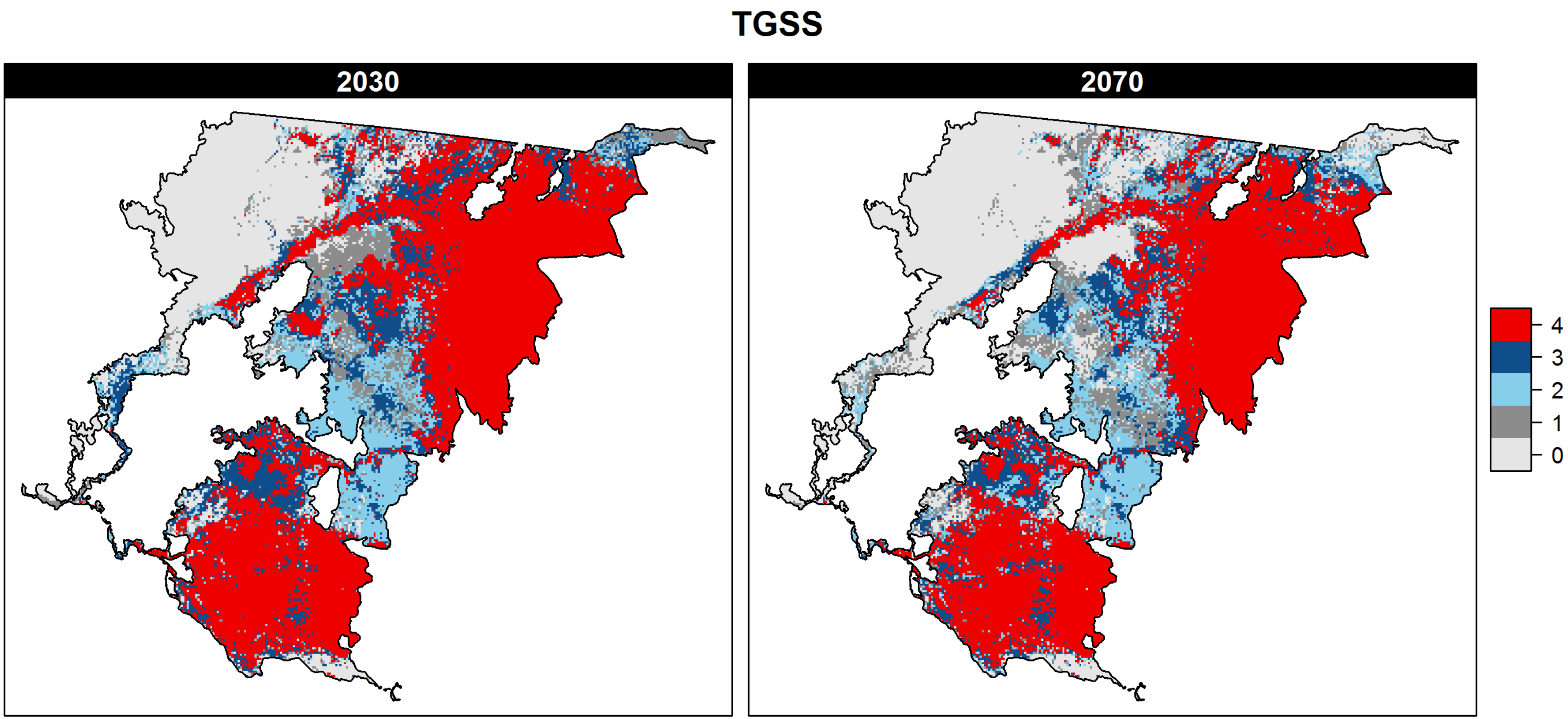


Figure A1.5 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Temperate Grasslands, Savannas and Shrublands ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

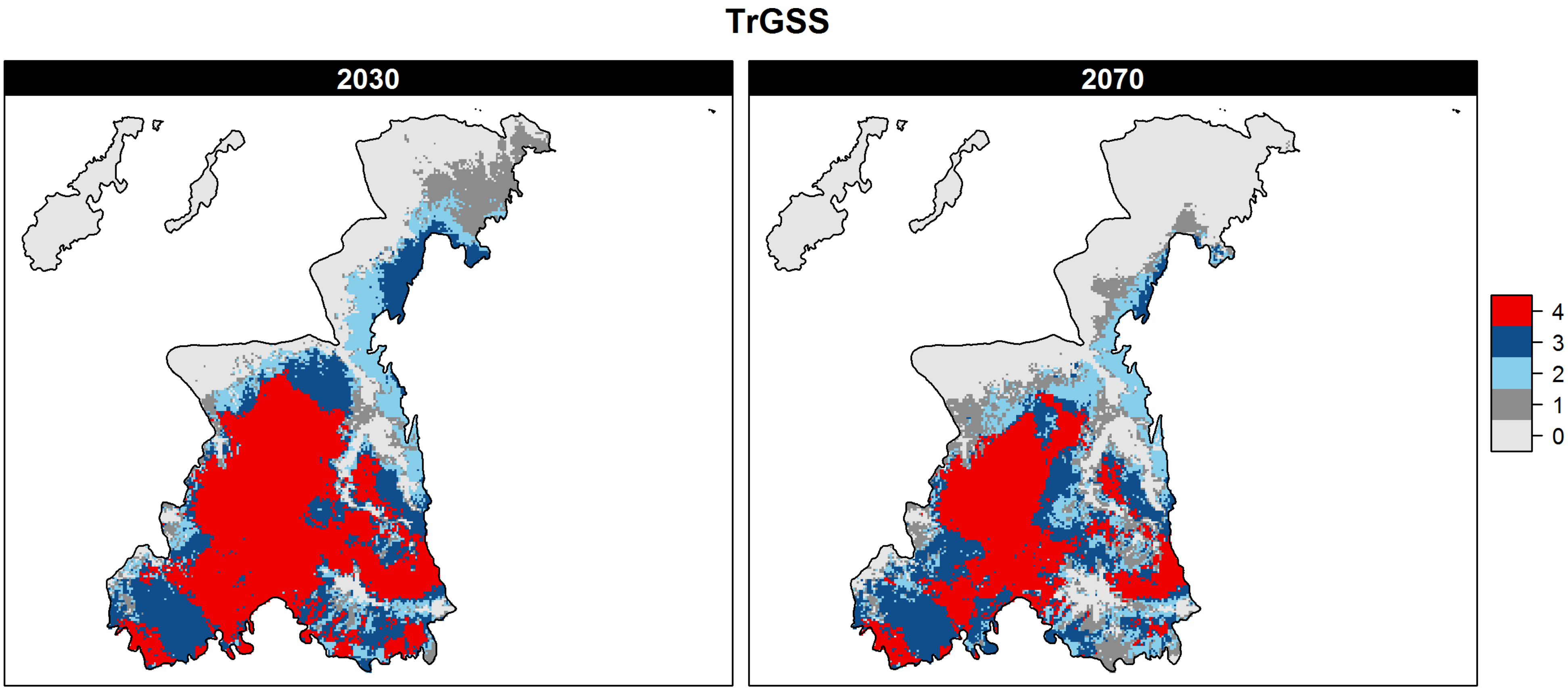


Figure A1.6 *Agreement across four GCMs about the distribution of in situ climate refugia that are continuously suitable for at least 50% of species representative of the Tropical/Subtropical Grasslands, Savannas and Shrublands ecoregion. The legend indicates the number of future climate scenarios under which a given cell is projected to meet this criterion.*

Figure A1. *Climate refugia and areas of vulnerability in the Deserts & Xeric Shrublands (DXS) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure 4.5 in the main text.*

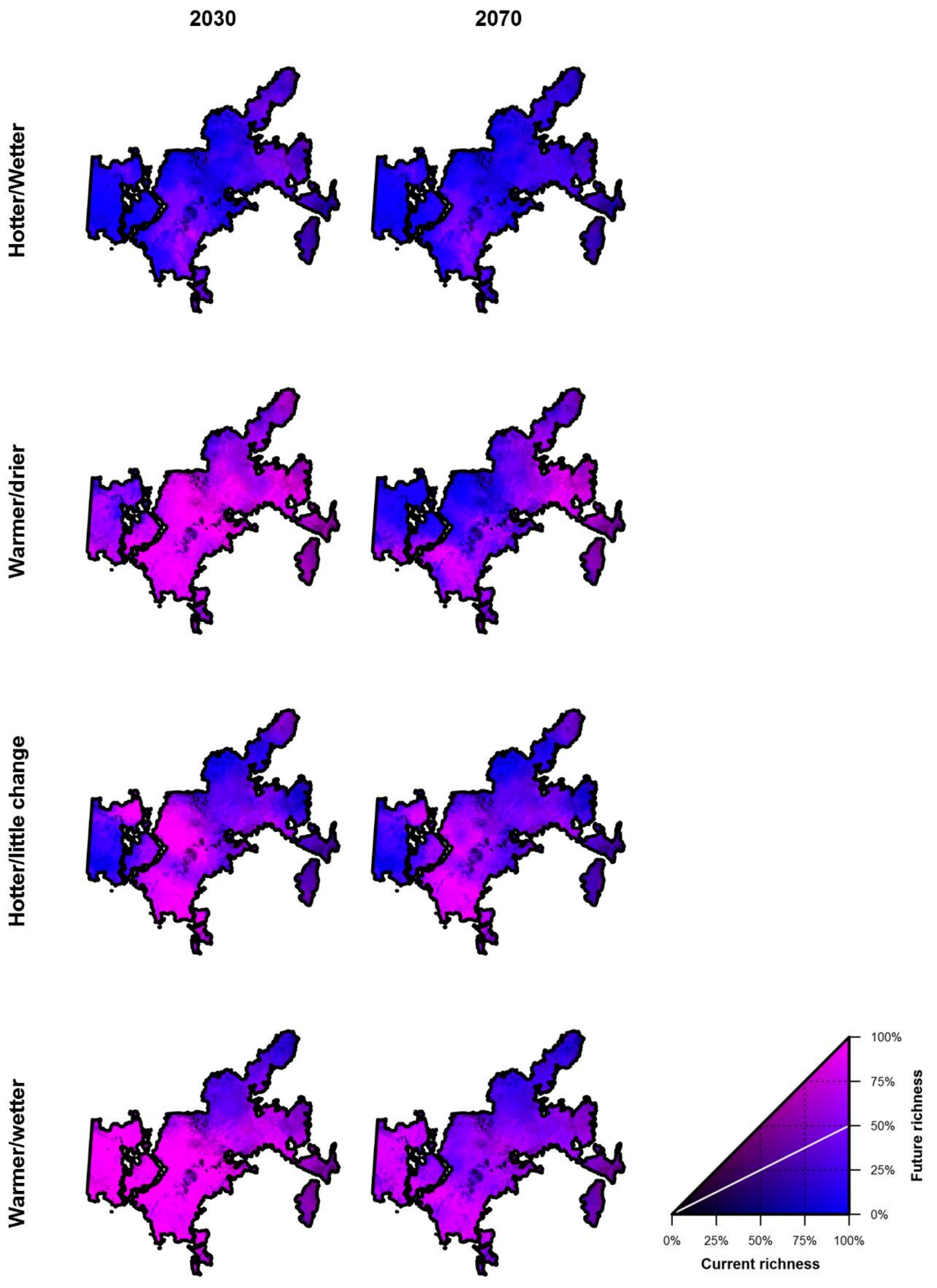


Figure A2.2. *Climate refugia and areas of vulnerability in the Mediterranean Forests Woodlands & Scrub (MFWS) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure 4.5 in the main text.*

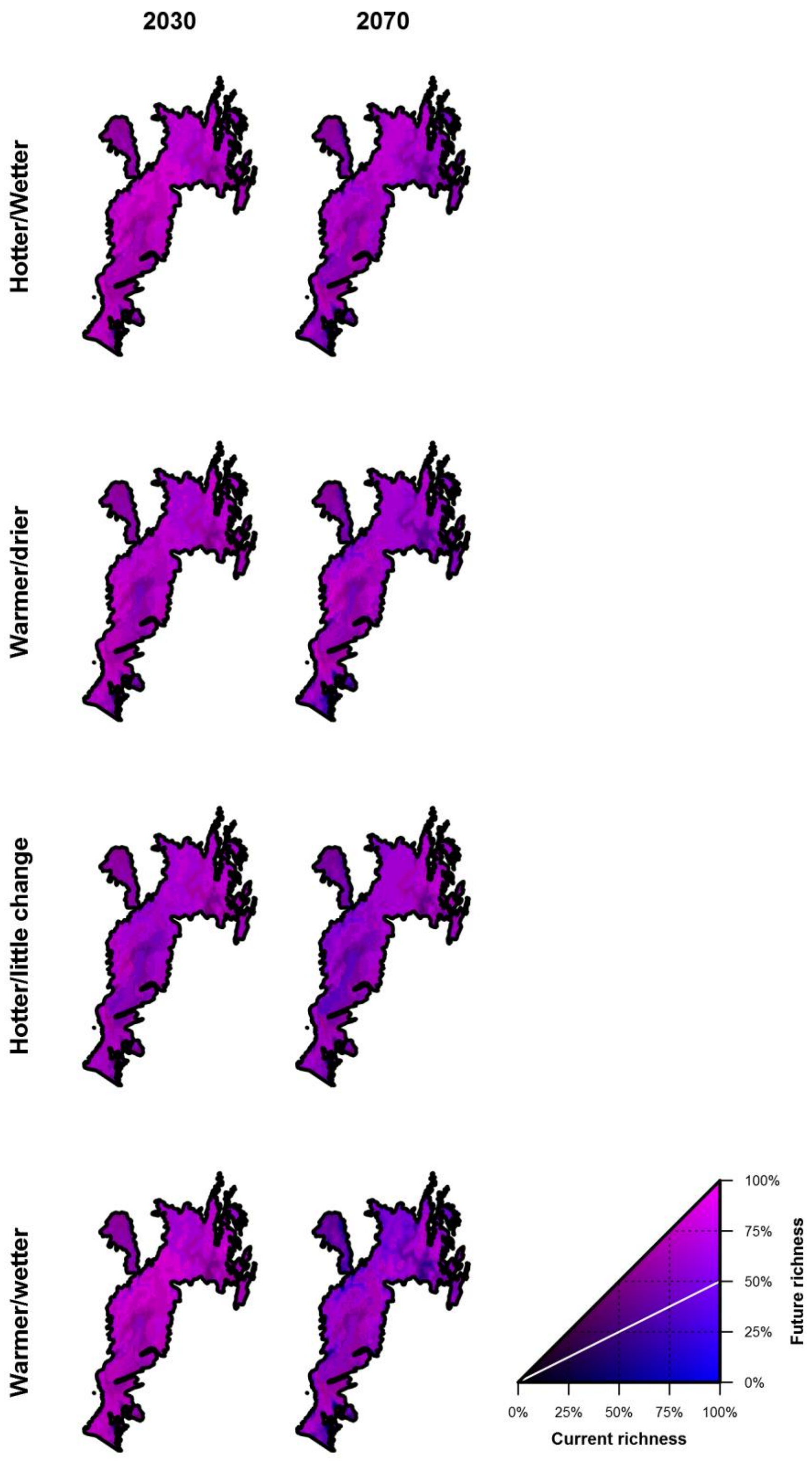


Figure A2. *Climate refugia and areas of vulnerability in the Montane Grasslands & Shrublands (MGS) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure* 4.5 *in the main text.*

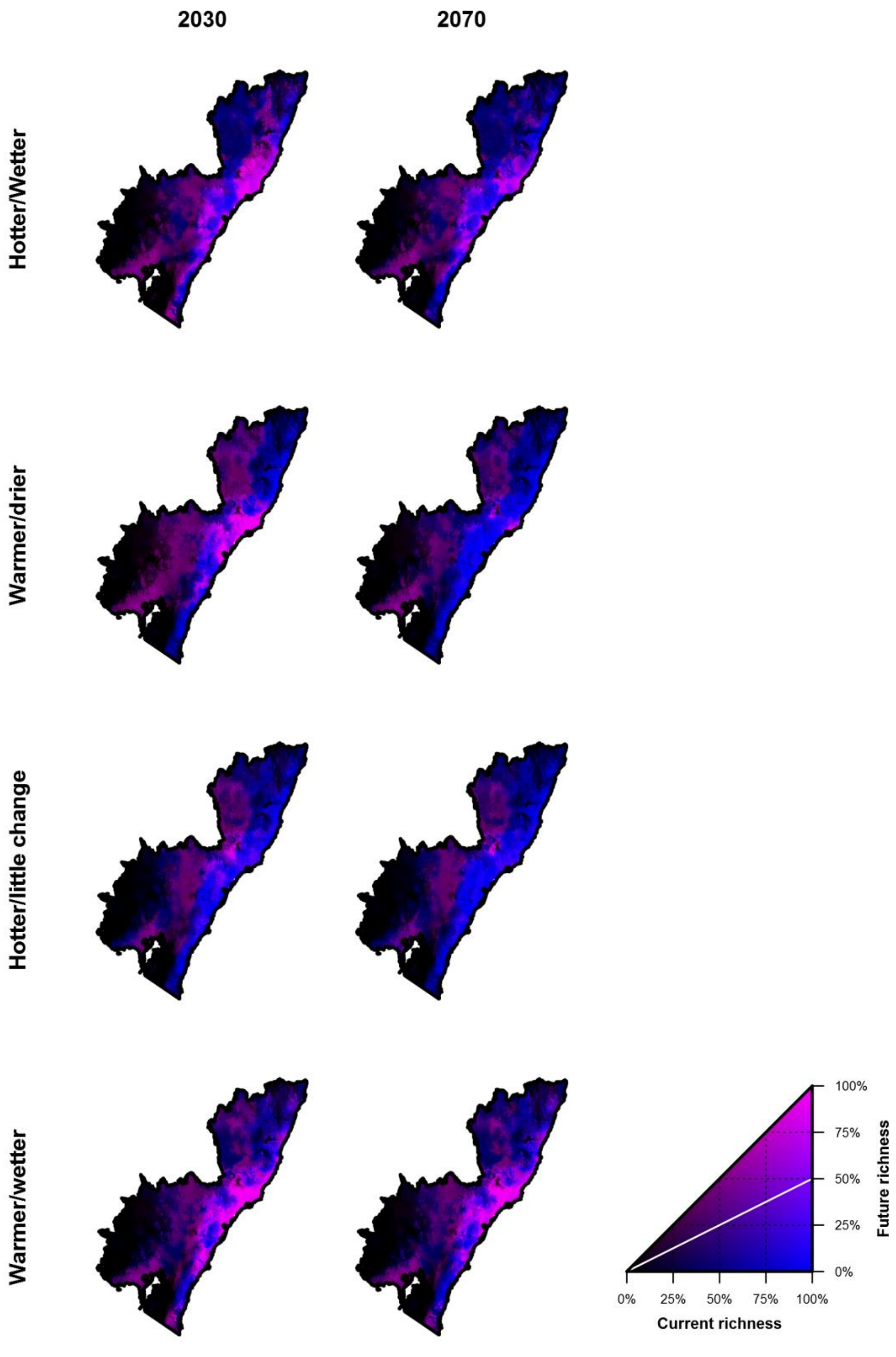


Figure A3. *Climate refugia and areas of vulnerability in the Temperate Broadleaf & Mixed Forests (TBMF) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure* 4.5 *in the main text.*

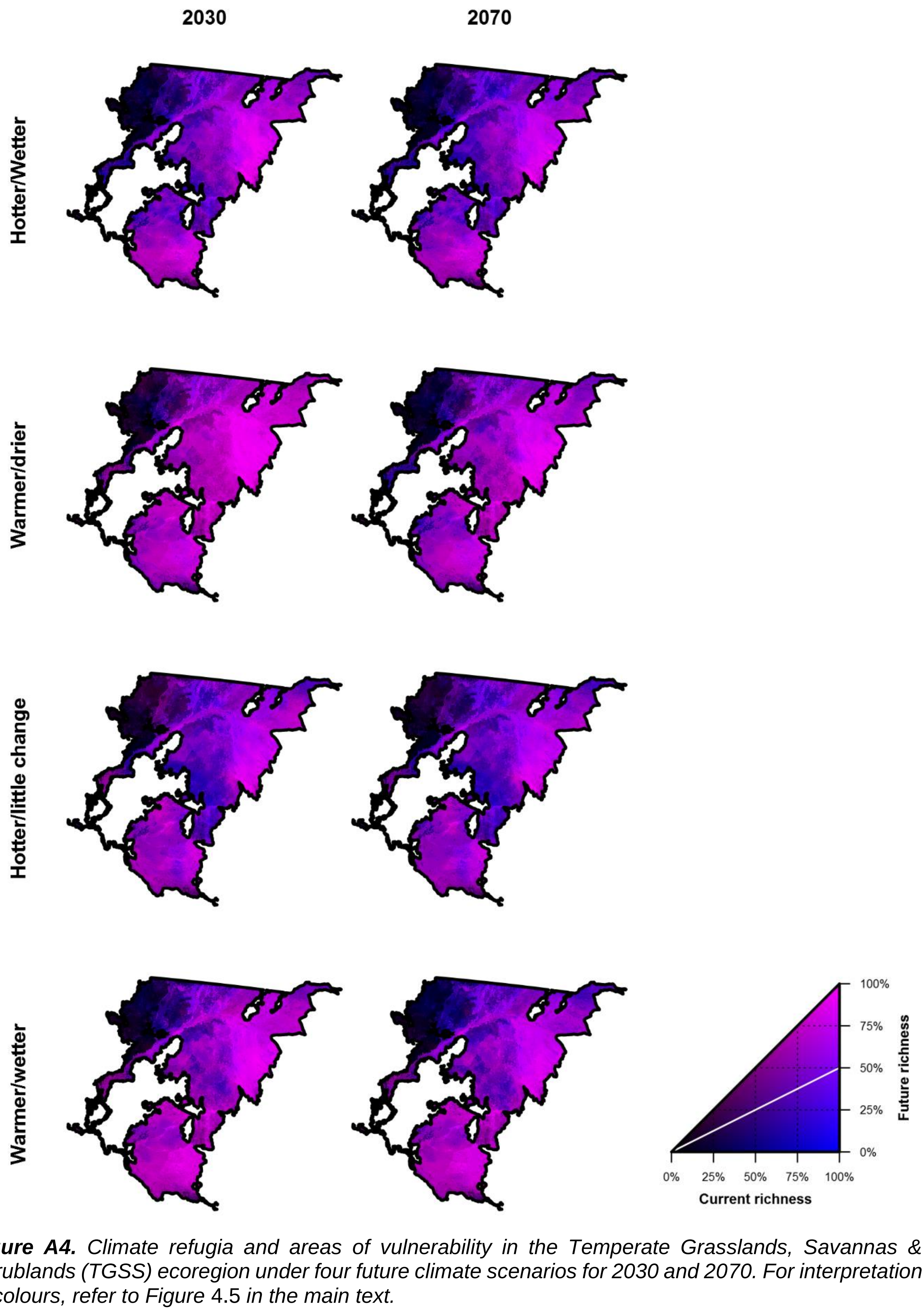


Figure A4. *Climate refugia and areas of vulnerability in the Temperate Grasslands, Savannas & Shrublands (TGSS) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure* 4.5 *in the main text.*

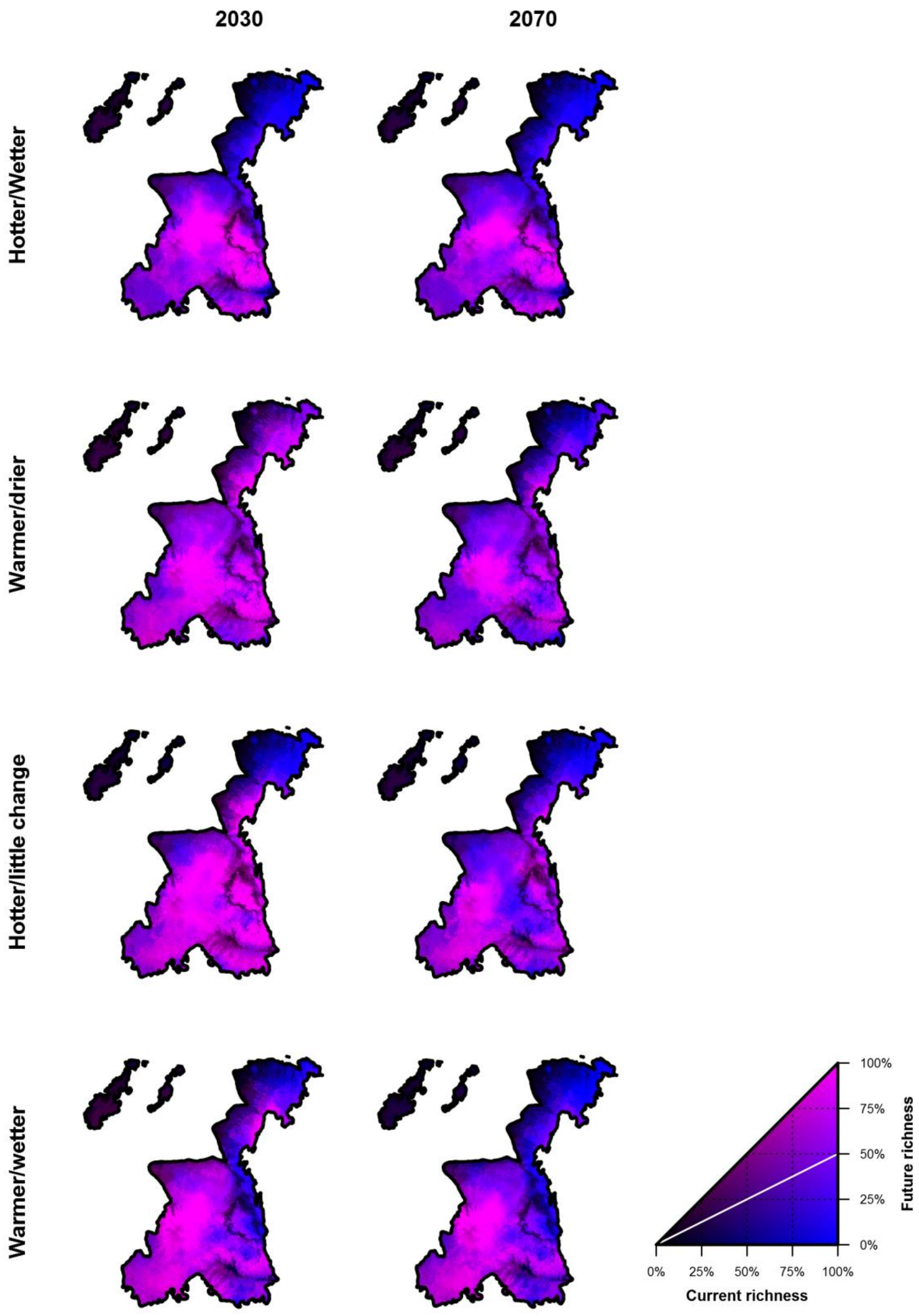


Figure A5. *Climate refugia and areas of vulnerability in the Tropical/Subtropical Grasslands, Savannas & Shrublands (TrGSS) ecoregion under four future climate scenarios for 2030 and 2070. For interpretation of colours, refer to Figure 4.5 in the main text.*