Threatened Species Recovery Hub

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Threatened bird conservation in Murray-Darling Basin wetland and floodplain habitat: Final report

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THE UNIVERSITY OF MELBOURNE

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Cover image: Floodplain-dependent yellow rosella.Image: Rowan Mott

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Red-rumped parrot. Image: Rowan Mott

Executive summary

The Murray-Darling Basin (MDB) provides vital habitat for many species, including terrestrial species that depend on floodplain forests and woodlands. The ecological condition of floodplain forests and woodlands in the MDB is in decline due to an array of threats, including increasing frequency and severity of droughts, changed hydrologic regimes, and pressures from invasive species. Maintaining and enhancing ecosystem condition will depend on informed management decisions. We aimed to provide decision support for MDB managers by identifying priority areas for floodplain-associated terrestrial bird species. Our findings can be used to efficiently allocate management resources (e.g. environmental water) so that conservation outcomes for these species are optimised.

We used the spatial prioritisation tool Zonation to create maps of hierarchically ranked (0-100) priorities within MDB floodplains in terms of value to terrestrial birds that are commonly associated with floodplain vegetation. Prioritisation was based upon temporally-specific habitat suitability predictions over a 21-year study period (1998-2018). Spatial priorities were identified for three separate subsets of terrestrial bird species: threatened species, species for which floodplains represent core habitat, and all species commonly associated with MDB floodplain habitats.

We found that the priorities identified were scenario-dependent. When the focus was to identify priorities for management of core habitat of threatened species, floodplains along the western reaches of the Murray River had the highest priority. Conversely, when non-threatened species were also included in the prioritisation process, the highest priority sites were concentrated in the north of the MDB to the east of Cunnamulla and east of Lightning Ridge.

Background

Floodplain ecosystems in south-eastern Australia's Murray-Darling Basin (MDB) are under stress from multiple threatening processes including changes to the hydrologic regimes, grazing from stock and feral herbivores, and vegetation clearing (Robertson and Rowling 2000, Mac Nally et al. 2011). Despite the negative impacts of these threats on ecosystem integrity, floodplain ecosystems remain one of the most important components in the habitat network of terrestrial woodland birds, and represent some of the largest contiguous stretches of habitat (McGinness et al. 2010). Floodplain ecosystems tend to have higher productivity than surrounding non-floodplain habitats, and a microclimate that is moderated from temperature extremes by the presence of water in the main channel (Taylor et al. 1990, Brosofske et al. 1997, Schindler and Smits 2017). Despite the habitat values floodplains provide to terrestrial species such as birds, floodplain research, policy and management seldom focus on achieving management outcomes for terrestrial fauna (McGinness et al. 2010). Climate change-induced increases in the frequency and severity of drought in the MDB (CSIRO 2008, CSIRO and Bureau of Meteorology 2015) will likely enhance the importance of the region's floodplains for the terrestrial bird assemblages they support. The benefits floodplains provide to terrestrial birds mean they become important refuges during times of drought (Selwood et al. 2015, Nimmo et al. 2016, Selwood et al. 2018). They also enhance resilience by supporting post-drought recovery and recolonization of non-floodplain habitats (Selwood et al. 2019).

South-east Australia's woodland bird assemblage has undergone sustained declines since European colonization (Ford et al. 2001, Fraser et al. 2019). Three terrestrial bird species that are commonly associated with MDB floodplain habitats (painted honeyeater *Grantiella picta*, regent parrot *Polytelis anthopeplus monarchoides*, and superb parrot *P. swainsonii*) are classified as threatened taxa under the Australian Federal Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Identifying effective and efficient actions for these, and other floodplain-associated terrestrial bird species, is critical for maximising the benefits of limited conservation resources (Halpern et al. 2013). In this project, we use a spatial prioritisation approach based on modelled habitat suitability for 108 terrestrial bird species to identify floodplain areas that consistently provide habitat with high suitability under varying rainfall scenarios. The outputs from these analyses are intended to provide managers with information on where management actions (e.g., environmental water allocations, invasive species control, additions to the protected area network) aimed at environmental protection and enhancing habitat quality are likely to result in the greatest benefit for floodplain-associated terrestrial birds.

Approach

Systematic conservation planning and spatial prioritisation

Conservation managers must make decisions about how and where to allocate management resources. Systematic conservation planning facilitates this decision-making process to deliver adequate protection of a representative proportion of biodiversity (Margules and Pressey 2000). This approach uses clearly defined management objectives and information on the distribution of biodiversity, to identify locations that provide complementary and comprehensive representation of key biodiversity values.

Identifying which locations should be highest priority for protection and/or conservation management is a core component of systematic conservation planning. Several methods (e.g., Marxan (Ball et al. 2009), ConsNet (Ciarleglio et al. 2009), Zonation (Moilanen et al. 2005)) for spatial prioritisation have been developed, predominantly for the identification of optimal protected area networks and for assessing the potential impacts of land-use scenarios. These methods evaluate landscape value across a management region according to the principles of complementarity, comprehensiveness, and irreplaceability based on a set of mapped biodiversity components (Kukkala and Moilanen 2013).

We use the spatial prioritisation software Zonation (Moilanen et al. 2005) to identify priority areas for terrestrial bird conservation in the MDB. Zonation uses spatial data on biodiversity values to generate a hierarchical (0-100) ranking of the conservation value of all sites (raster grid cells) in a landscape (Moilanen et al. 2014). We use information on the distribution of threatened and other floodplain-associated terrestrial birds to determine conservation value.

Specifically, we address three different scenarios for prioritising habitat for terrestrial species in the MDB:

1. Identify priority areas that maximise core habitat for threatened terrestrial bird species (painted honeyeater *Grantiella picta*, regent parrot *Polytelis anthopeplus monarchoides*, and superb parrot *P. swainsonii*)
2. Identify priority areas that maximise the habitat for all floodplain-dependent terrestrial bird species
3. Identify priority areas that maximise the habitat for all floodplain-associated terrestrial bird species

Bird presence data

Our study focused on 108 bird species that have been identified by McGinness et al. (2010) as being commonly associated with floodplain vegetation types in the MDB (see Appendix 1 for species names). We compiled a database of 4,555,939 presence records for these species collected between 1998 and 2018 from existing data sources (Table 1) in order to build individual habitat suitability models.

We produced spatial prioritisation grids based on the entire species pool as well as two subsets of these bird species. The first subset was comprised of species listed as threatened under the EPBC Act: painted honeyeater, regent parrot and superb parrot. The second subset consisted of 50 floodplain-dependent species. These were species for which MDB floodplains represented the core habitat for the species during either the breeding or non-breeding season (see "Mapping habitat suitability" below for further details and Appendix 3 for a complete description of the method).

Table 1. Data sources for presence points along with the number of records of floodplain-associated species (or subspecies) contributed by each source.

Source	Time span	N
BirdLife Australia's Birdata database[a]	1998-2018	2,174,865
eBird[b]	1998-2018	733,508
Atlas of Living Australia[c]	1998-2018	1,646,954
The Living Murray Project	2001-2018	543
The South Australian Regent Parrot Recovery Team	2006-2017	69

[a] Barrett (2003);[b] eBird (2019);[c] Newman et al. (2019).

Mapping habitat suitability

Species presence points were used to build individual habitat suitability models for each species using boosted regression trees (BRTs). Separate models were built for the breeding season and non-breeding season for each species (September to January and February to August, respectively; Ford 1989).

Habitat suitability models were developed by modelling the relationship between species occurrence and a set of environmental predictor variables that past research has found to affect terrestrial bird occurrence (Appendix 2). Predictor variables included proxies for habitat extent (e.g., percent tree cover) and condition (e.g., Normalised Difference Vegetation Index), as well as variables that affect bird distribution through their effects on physiology (e.g., longest run of consecutive hot and dry days). Some variables were constant across years (e.g., elevation), whereas other variables were dynamic across years (e.g., cumulative rainfall). Detailed methods for the habitat modelling are provided in Appendix 3.

Of the resultant 216 models (108 species in breeding and non-breeding seasons), we retained 132, which were considered to have good model fit (mean AUC value of >0.7) (Hosmer et al. 2013) (Table 2 and Appendix 1). These retained models covered 72 species, including all three of the threatened species and 50 floodplain-dependent species (Table 2 and Appendix 1).

Species with models that did not have good fit, and hence were excluded from the prioritisations (AUC value ≤ 0.7), were typically abundant, widespread species (e.g., Australian Magpie and Striated Pardalote). Model performance for species with widespread occurrence is often poor, reflecting their weak habitat affinities (Elith et al. 2006, Andrew and Fox 2020).

We used the retained models to produce maps of habitat suitability in each year from 1998-2018 for each species (across its distribution) in both the breeding and non-breeding season using environmental variables from each year-by-season combination.

To identify species considered floodplain dependent, we evaluated whether MDB floodplains as defined by the Murray Darling Basin Authority (MDBA 2008) represented core habitat for each species in either the breeding or non-breeding season. A species was considered floodplain-dependent in its breeding or non-breeding season if the median habitat suitability value of grid cells within MDB floodplains was greater than the median habitat suitability value outside these areas in at least one year. To avoid including large areas of unoccupied habitat in these comparisons, we limited the predicted habitat suitability grid for each species to within its distribution defined by the Handbook of Birds of the World spatial dataset (BirdLife International and Handbook of the Birds of the World 2018).

Table 2. Species included in this research. Columns indicate which scenarios each species contributed to. 'Both seasons' indicates that habitat suitability predictions from the breeding season and the non-breeding season for that species were used in a particular spatial prioritisation scenario. 'Breeding' indicates that habitat suitability predictions from only the breeding season were used, whereas 'Non-breeding' indicates only non-breeding season habitat suitability predictions were used. A blank cell indicates that that species did not meet the criteria for inclusion in that particular scenario. A dash (-) indicates that model performance was poor for that species (AUC ≤ 0.7) and hence the species was excluded from that particular scenario.

Species	Scenario 1	Scenario 2	Scenario 3
Apostlebird		Both seasons	Both seasons
Australasian pipit			Non-breeding
Australian hobby		-	-
Australian magpie		-	-
Australian pratincole			Both seasons
Australian raven		-	-
Australian ringneck		Non-breeding	Both seasons
Banded lapwing		Both seasons	Both seasons
Barking owl		Non-breeding	Both seasons
Black-chinned honeyeater		Non-breeding	Both seasons
Black-faced cuckoo-shrike		-	-
Black-faced woodswallow			Both seasons
Black honeyeater			Both seasons
Black kite		Both seasons	Both seasons
Black-shouldered kite		Both seasons	Both seasons
Black-tailed native-hen		Both seasons	Both seasons
Blue bonnet		Both seasons	Both seasons
Brown falcon		-	-
Brown-headed honeyeater			Both seasons
Brown songlark		Both seasons	Both seasons
Brown treecreeper		Both seasons	Both seasons
Budgerigar			Both seasons
Buff-rumped thornbill			Both seasons
Bush stone-curlew			Both seasons
Chestnut-crowned babbler		Non-breeding	Non-breeding
Chestnut-rumped thornbill		Both seasons	Both seasons
Chirruping wedgebill			Both seasons
Cockatiel		Both seasons	Both seasons
Collared sparrowhawk		-	-
Common bronzewing		-	-
Crested pigeon		-	-
Crested shrike-tit		Non-breeding	Both seasons
Crimson chat			Both seasons
Diamond dove			Both seasons
Diamond firetail		Both seasons	Both seasons
Dusky woodswallow		-	-
Eastern rosella		-	-
Emu		Both seasons	Both seasons
Fairy martin		Non-breeding	Non-breeding
Galah		-	-
Golden whistler			Both seasons
Grey butcherbird		-	-
Grey-crowned babbler		Both seasons	Both seasons
Grey currawong		-	-
Grey fantail		Breeding	Breeding

Species	Scenario 1	Scenario 2	Scenario 3
Grey shrike-thrush		-	-
Ground cuckoo-shrike		Both seasons	Both seasons
Hooded robin		Both seasons	Both seasons
Horsfield's bronze-cuckoo		-	-
Jacky winter		Both seasons	Both seasons
Laughing kookaburra		-	-
Little corella		Non-breeding	Non-breeding
Little eagle		-	-
Little friarbird		Non-breeding	Both seasons
Little raven		Non-breeding	Non-breeding
Magpie-lark		-	-
Major Mitchell's cockatoo		Both seasons	Both seasons
Mallee ringneck		Both seasons	Both seasons
Masked woodswallow		Breeding	Both seasons
Mistletoebird		-	-
Nankeen kestrel		-	-
Noisy friarbird		-	-
Noisy miner		-	-
Olive-backed oriole		-	-
Painted button-quail			Both seasons
Painted honeyeater	Both seasons	Both seasons	Both seasons
Pallid cuckoo			Non-breeding
Peaceful dove		Both seasons	Both seasons
Pied butcherbird		-	-
Pied currawong			Breeding
Rainbow bee-eater			Non-breeding
Red-backed kingfisher			Both seasons
Red-browed pardalote			Both seasons
Red-capped robin		Both seasons	Both seasons
Red-rumped parrot		Breeding	Breeding
Regent parrot	Both seasons	Both seasons	Both seasons
Restless flycatcher		Both seasons	Both seasons
Rufous songlark		Both seasons	Both seasons
Rufous whistler		-	-
Sacred kingfisher		Non-breeding	Non-breeding
Scarlet robin			Both seasons
Southern boobook		-	-
Southern whiteface		Both seasons	Both seasons
Spiny-cheeked honeyeater		Both seasons	Both seasons
Striated pardalote		-	-
Sulphur-crested cockatoo		-	-
Superb fairy-wren		-	-
Superb parrot	Both seasons	Non-breeding	Both seasons
Tawny frogmouth		-	-
Tree martin		-	-

Species	Scenario 1	Scenario 2	Scenario 3
Varied sittella		-	-
Variegated fairy-wren		-	-
Wedge-tailed eagle		-	-
Weebill		Both seasons	Both seasons
Whistling kite		Both seasons	Both seasons
White-breasted woodswallow		Both seasons	Both seasons
White-browed babbler			Both seasons
White-browed woodswallow		Both seasons	Both seasons
White-plumed honeyeater		Both seasons	Both seasons
White-winged chough		Both seasons	Both seasons
White-winged fairy-wren		Both seasons	Both seasons
White-winged triller			Non-breeding
Willie wagtail		-	-
Yellow rosella		Both seasons	Both seasons
Yellow-rumped thornbill		-	-
Yellow thornbill		-	-
Yellow-throated miner		Non-breeding	Both seasons
Zebra finch			Both seasons

Zonation settings

We used Zonation (Moilanen et al. 2005) to identify the most important areas within the MDB floodplains for the three scenarios: scenario 1) threatened species (painted honeyeater, regent parrot, and superb parrot); scenario 2) floodplain-dependent species; and scenario 3) all floodplain-associated species.

We conducted separate prioritisations for each of these species-sets. Prioritisations for threatened species and floodplain-associated species included habitat suitability maps for each species in each year (1998-2018) for both breeding and non-breeding seasons (where models had been assessed as having good fit). For floodplain-dependent species, habitat suitability maps were included only for seasons (breeding or non-breeding) where the species was found to be floodplain-dependent in at least one year (Table 2 and Appendix 1). For these species-by-season combinations, all years were included in the prioritisation.

We conducted a two-staged prioritisation process for each of these three prioritisation scenarios. First, the relevant species habitat suitability predictions for each year were used to identify priority areas in a) the breeding season and b) the non-breeding season for each year, resulting in 42 prioritisation layers (one for each season in each of 21 years). The second stage used these 42 prioritised layers to determine the overall priority areas for the entire 21-year study period. A boundary length penalty was applied to each prioritisation to ensure connectivity and cohesiveness of high priority areas (Lehtomäki and Moilanen 2013). This was considered important because management planning and actions, including environmental watering, are typically carried out at landscape scales (e.g., Swirepik et al. 2016).

For scenario 1 (threatened species), we used Zonation's 'core area Zonation' algorithm so that core habitat for each of the three threatened species was prioritised (Moilanen 2007). For scenarios 2 and 3 (floodplain-dependent and floodplain-associated, respectively), we used Zonation's 'additive benefit function' to prioritise species-rich floodplains (Moilanen 2007). During each Zonation run, the prioritisation was constrained to grid cells that intersected Murray-Darling Basin Authority-defined floodplains (MDBA 2008) via the use a hierarchical removal mask. This mask meant that floodplain grid cells were ranked prior to ranking non-floodplain grid cells (Moilanen et al. 2014). As a result, landscape context information from surrounding non-floodplain areas influenced the value of floodplain grid cells (e.g., a large area of high conservation value non-floodplain habitat adjacent to a floodplain grid cell meant that floodplain grid cell received a higher priority than a similar site that was isolated from other nearby habitat).

Further details on the specifications used in each prioritisation are presented in Appendix 3.

Findings

Habitat suitability maps

Mean predicted habitat suitability maps are presented for each species in Appendix 4. Most species had seasonal habitat suitability predictions that varied little throughout the 21-year study period, i.e. there was high correlation between years (median Pearson's correlation coefficient > 0.9 between years for 78.5% of species-season combinations). This included the regent parrot, superb parrot (median Pearson's r > 0.97 in breeding and non-breeding seasons for both species) and painted honeyeater (median Pearson's r > 0.91 in breeding and non-breeding seasons). For some taxa, there was appreciable variation in the predicted habitat suitability from year to year (e.g., median Pearson's r < 0.8 for little friarbird and barking owl during non-breeding seasons).

Spatial conservation prioritisation

Within each scenario, spatial priorities for individual years (outputs from stage one of the prioritisation process) varied only slightly among years. Median Pearson's r was > 0.95 among years for both breeding and non-breeding seasons in all three scenarios.

1. Threatened terrestrial bird species
   Prioritisations based on incorporating core habitat for the three threatened taxa (scenario 1) indicated that floodplains along the Murray River from Swan Hill westward were identified as high priorities (Figure 1). Under this scenario, there were also high priority floodplains along the eastern reaches of the Murrumbidgee River, and Yanco, Billabong and Tuppal Creeks east of Deniliquin (Figure 1).
2. Floodplain-dependent terrestrial bird species
   Floodplains along the Barwon, Boomi, and Macintyre Rivers east of Lightning Ridge were ranked as high priorities for floodplain-dependent taxa (scenario 2) (Figure 2). Similarly, floodplains extending west from the Nebine Creek east of Cunnamulla, and floodplains along scattered creeks west of Menindee also ranked highly in this scenario (Figure 2).
3. Floodplain-associated terrestrial bird species
   Floodplains east of Cunnamulla along the Mungallala, Paterson, and Widgeegoara Creeks, and floodplains in the headwaters of the Warrego and Paroo Rivers were ranked as high priorities for all floodplain-associated taxa (scenario 3) (Figure 3).

Irrespective of the scenario, floodplains along the Darling River between Bourke and Menindee were never ranked as high priorities (Figures 1-3). Floodplains in the very south of the MDB, such as those along the Murray River from Swan Hill eastward, were also consistently ranked as lower priorities except when prioritising to maintain the core areas of threatened taxa (Figures 1-3).

For all three scenarios, only a small percentage of cells ranked in the top 10% of priorities occurred within a protected area as defined by the World Database on Protected Areas (UNEP-WCMC and IUCN 2020). This database includes protected areas such as state and federally managed reserves, Indigenous Protected Areas, and Ramsar Wetlands of International Importance (UNEP-WCMC and IUCN 2020). For threatened taxa, only 15.3% of the highest priority areas (top 10% rankings) occurred within protected areas. These protected areas included the Murray Valley National Park, Barmah National Park, and Hattah-Kulkyne National Park, as well as the NSW Central Murray State Forests Ramsar site, Barmah Forest Ramsar Site, and Riverland Ramsar Site. When prioritisation included non-threatened taxa (scenarios 2 and 3), <1.5% of the highest priority areas (top 10% rankings) occurred in protected areas, with the Currawinya National Park (and the Currawinya Lakes Ramsar Site within), along with Paroo-Darling National Park (and the Paroo River Ramsar Site within) encompassing cells in the top 10% of priorities. Some Ramsar wetlands (e.g., Barmah Forest Ramsar Site and Hattah Lakes Ramsar Site) were entirely, or almost entirely, ranked within the top 10% of priorities under scenario 1 (threatened species) (Figure 4). Conversely, only very small areas of individual Ramsar sites were represented in the top 10% of priorities under scenarios 2 and 3 (floodplain-dependent species and floodplain-associated species) (Figures 5 and 6).

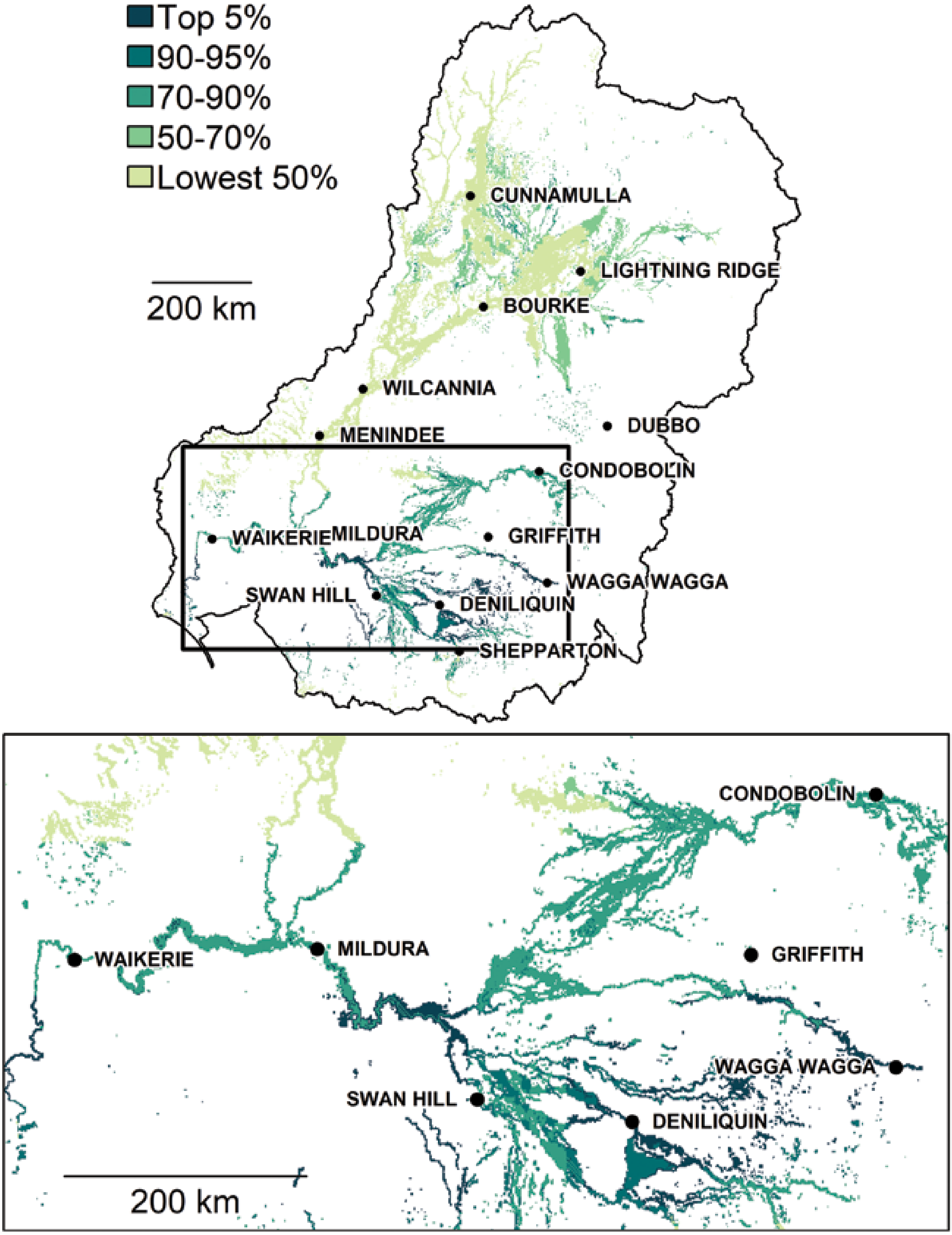

Figure 1. Murray-Darling Basin floodplain spatial priorities when managing core habitat for threatened species is the management objective. The main map shows priorities for the entire MDB, whereas the rectangular insets show enlargements of the corresponding regions indicated by the black rectangles on the main map. Darker colours indicate higher priorities.

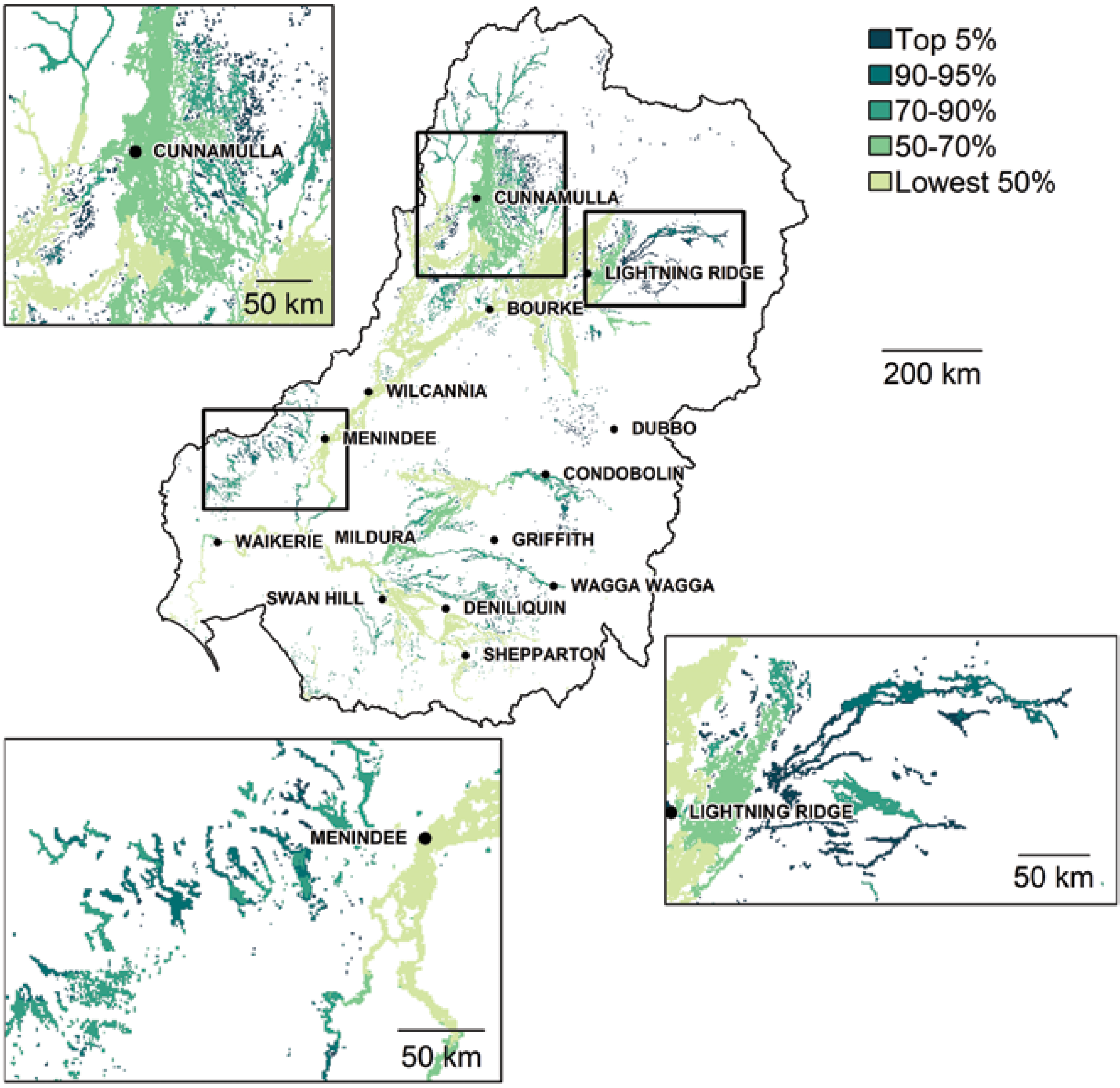

Figure 2. Murray-Darling Basin floodplain spatial priorities when the management objective is to manage habitat for floodplain-dependent species. The main map shows priorities for the entire MDB, whereas the rectangular insets show enlargements of the corresponding regions indicated by the black rectangles on the main map. Darker colours indicate higher priorities.

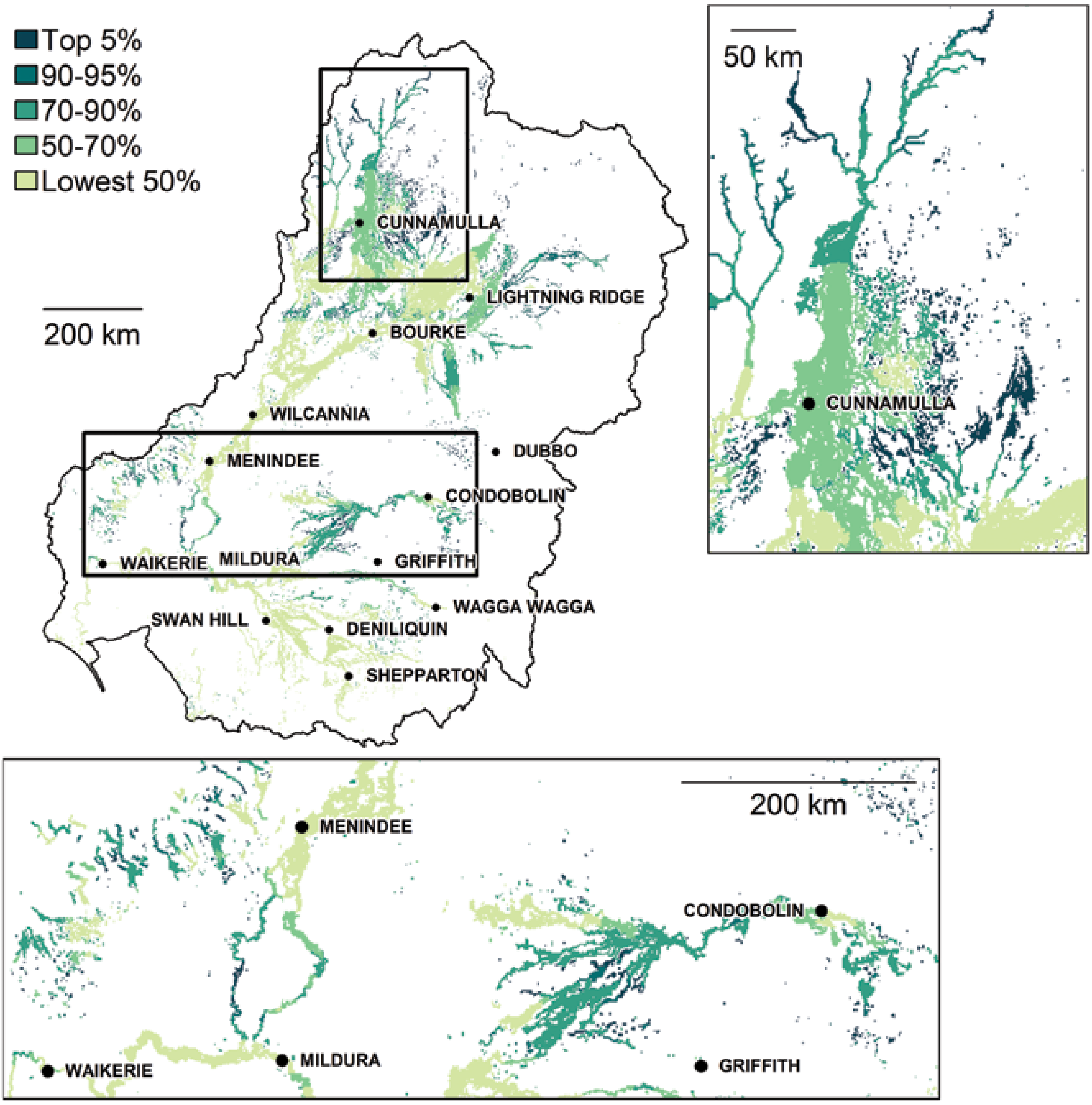

Figure 3. Murray-Darling Basin floodplain spatial priorities when the management objective is to manage habitat for all floodplain-associated species. The main map shows priorities for the entire MDB, whereas the rectangular insets show enlargements of the corresponding regions indicated by the black rectangles on the main map. Darker colours indicate higher priorities.

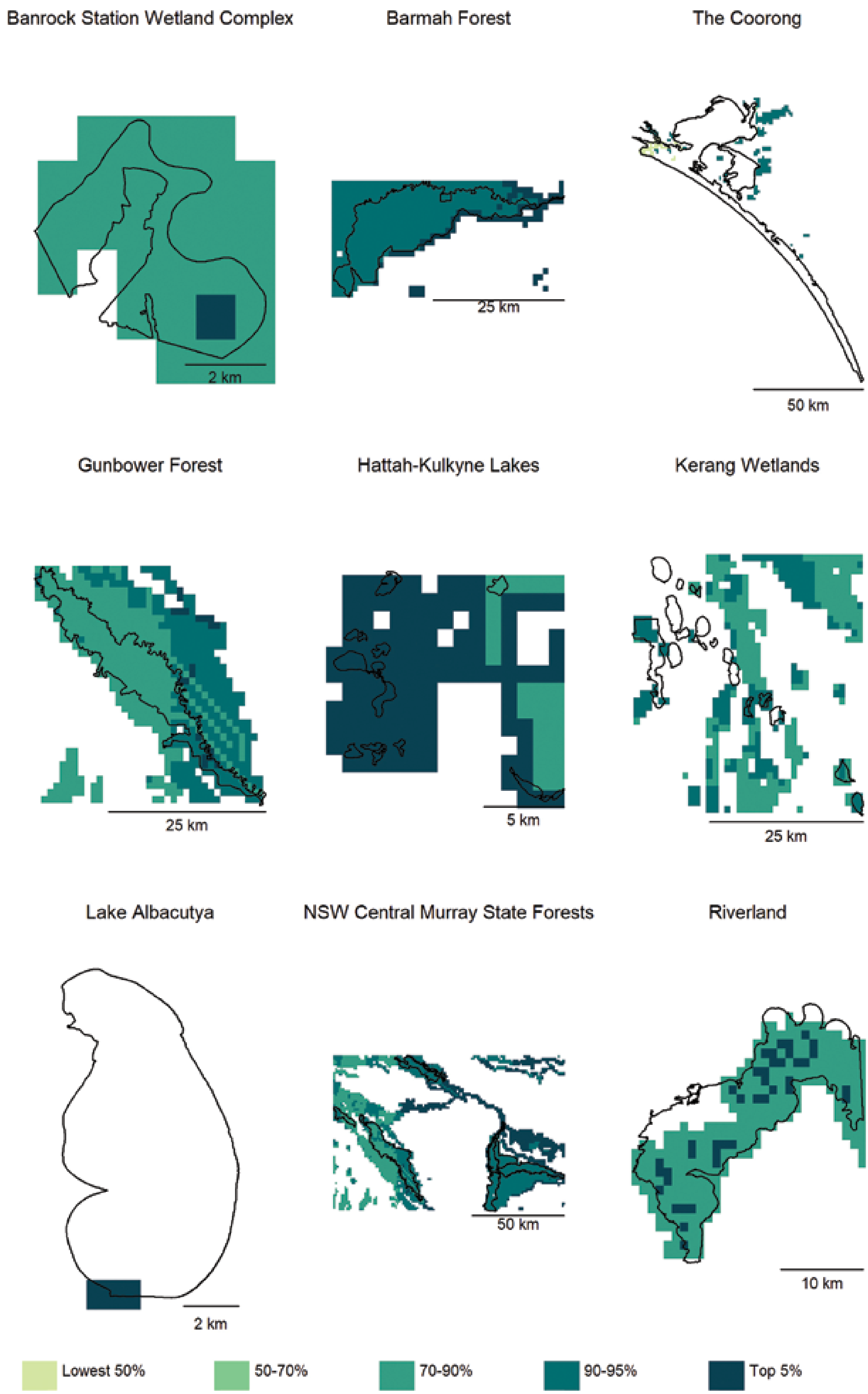

Figure 4. Spatial priorities for threatened species (scenario 1) in relation to Ramsar Wetlands of International Importance. Each Ramsar site that intersected with cells ranked within the top 10% of spatial priorities for this scenario is shown in its own panel (See Appendix 6 for all Ramsar sites irrespective of their priority ranking). Note the differing scale in each panel.

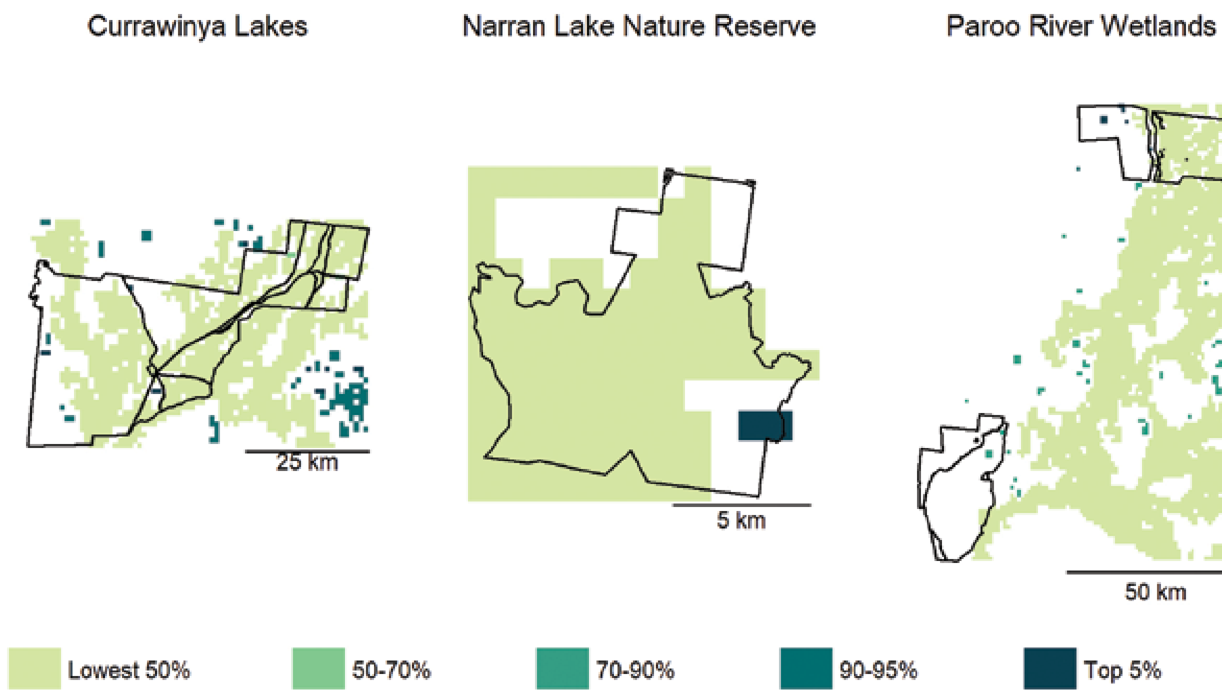

Figure 5. Spatial priorities for floodplain-dependent species (scenario 2) in relation to Ramsar Wetlands of International Importance. Each Ramsar site that intersected with cells ranked within the top 10% of spatial priorities for this scenario is shown in its own panel (See Appendix 6 for all Ramsar sites irrespective of their priority ranking). Note the differing scale in each panel.

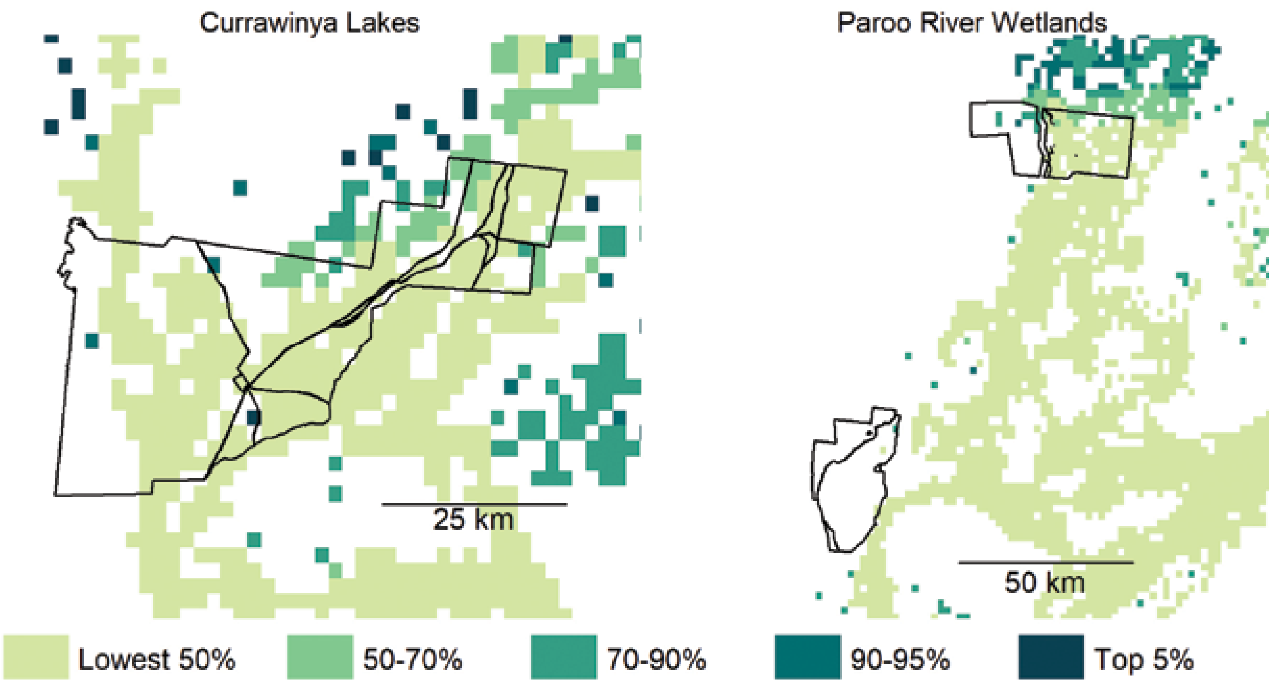

Figure 6. Spatial priorities for floodplain-associated species (scenario 3) in relation to Ramsar Wetlands of International Importance. Each Ramsar site that intersected with cells ranked within the top 10% of spatial priorities for this scenario is shown in its own panel (See Appendix 6 for all Ramsar sites irrespective of their priority ranking). Note the differing scale in each panel.

Discussion

The outputs of spatial prioritisations using different subsets of terrestrial bird species commonly associated with floodplain vegetation in the MDB highlighted the complexities facing floodplain managers. When prioritising with a focus on core areas for the three threatened species, floodplains along the Murray River west of Swan Hill were the highest priorities. However, floodplains in the northern MDB east of Cunnamulla or Lightning Ridge were most important when prioritisations sought to identify management priorities for up to 72 threatened and non-threatened species. These differences emphasise the need for management objectives to be clearly articulated before allocating resources because resource allocation targeted towards one component of the biota will not necessarily be optimal for the entire assemblage.

The high priorities in the western reaches of the Murray River when prioritising core areas for each threatened species were strongly influenced by regent parrots. Regent parrots have a very restricted range with high habitat suitability predicted in floodplain cells relative to non-floodplain cells. Hence these floodplain cells have high irreplaceability for this species, which led to them being retained as core areas. Conversely, superb parrots and painted honeyeaters have wider distributions and areas with high habitat suitability were often predicted in non-floodplain areas for both species. Therefore, both species had a weaker influence on core area Zonation outputs because the many highly suitable areas in the wider landscape reduced the necessity to retain floodplain areas for these species.

All spatial prioritisations indicated floodplains along the Darling River and floodplains in the very south of the MDB were ranked lower for floodplain-associated terrestrial birds. This is not to say that these areas have low value to terrestrial birds per se. The spatial prioritisation process ranks all areas within a defined study area (in this case, the MDB floodplains); it does not represent an absolute rating of the conservation value of any individual location, but a relative value within the study area. That is, areas in the top and bottom 10% each represent exactly 10% of the spatial extent of the study area and so their rankings need to be considered holistically. Lower ranked areas are still likely to be of high conservation value, particularly given the relative importance of floodplains compared to other areas (McGinness et al. 2010, Selwood et al. 2015, Selwood et al. 2019). Furthermore, the top ranked areas (e.g. top 10%) are unlikely to represent the area needed to maintain viable populations of terrestrial birds, particularly given these species have already experienced widespread habitat loss (Fraser et al. 2019, Simmonds et al. 2019).

Only a very small percentage of top ranked areas (<15.3% for the top 10%) occurred within protected areas. This suggests that management actions on unreserved and private lands are likely to be important for the long-term conservation of floodplain-associated terrestrial birds in the MDB. Therefore, the works of organisations, such as catchment management authorities and local land services, that work with and provide incentives to landholders to carry out conservation works will have a key role in ensuring high priority areas are suitably managed. Consideration of the top ranked areas might also feed into future decision-making and assessments on the designation of protected areas (e.g., Ramsar sites).

Habitat suitability predictions for many of the species modelled varied little across time. This led to limited inter-annual (stage one) variation in the location of spatial priorities within each of the three prioritisation scenarios. Spatial stability of priorities is beneficial to decision-making because it removes the challenge of scheduling management actions to coincide with time periods when a particular site has high priority status (Reside et al. 2019). There are several reasons why habitat suitability predictions varied so little in most cases. Temporally-variable habitat features such as NDVI and recent rainfall can influence habitat suitability at the local scale (Andrew and Fox 2020). However, at larger spatial scales, such as the entire MDB, coarse climatic variables (e.g. precipitation seasonality), typically govern species distribution predictions (Pearson and Dawson 2003, Reside et al. 2012, Kent et al. 2014). Furthermore, the lack of spatial variability observed for many species likely reflects long-term ecological processes rather than short-term responses to prevailing weather conditions. For example, 63.1% of bird species in eastern Australia have been classified as sedentary (Griffioen and Clarke 2002), and dispersal of many woodland bird species is limited by habitat fragmentation (Amos et al. 2014). Species that had appreciable variability in habitat suitability predictions across time (e.g., non-breeding little friarbirds) are likely to benefit less relative to sedentary species from management of a fixed set of high priority sites (Dickman et al. 1995, Runge et al. 2016). However, management actions may also contribute to these fixed sites maintaining high habitat suitability for dispersive species in a greater proportion of years.

The priority areas identified in this study might be used to maximise the benefits of management actions for terrestrial birds. For example, targeting environmental watering to maintain or improve the habitat quality of top-ranked floodplains for threatened species (scenario 1) is likely to help maximise the persistence of these species. Similarly, targeting environmental watering to the areas identified as high priority in scenarios 2 and 3 will maximise the benefits of such actions to a large set of species. Because scenarios 2 and 3 prioritise species rich locations, management actions that benefit multiple species are expected to yield the most efficient conservation return and be most appropriate for implementing at the top-ranked sites in these scenarios. Although species-specific actions (e.g., installing nest boxes tailored for a focal species) may well produce species-specific benefits at these sites, conservation return is likely to be maximised when management actions benefit the floodplain-associated terrestrial bird community more generally. For example, increasing habitat condition through environmental watering, fencing to improve understorey regeneration, or targeted additions to the protected area network will provide benefits to multiple species and would be among the most appropriate management actions for these species-rich, high priority sites.

This study made hindcast habitat suitability predictions to identify important floodplains for the period of 1998-2018. Climate change predictions suggest that the frequency and severity of droughts are likely to increase in the MDB (CSIRO 2008, CSIRO and Bureau of Meteorology 2015). It is unclear how the habitat suitability predictions made here for recent decades will compare to habitat suitability under a future, more extreme climate. However, the study period did encompass the Millennium Drought (1998-2009), one of the longest and most severe droughts in Australia's recorded history, as well as several years of low rainfall (2013, 2017, 2018; Jones et al. 2009). Therefore, floodplains identified as priorities for management in this study are likely to remain important under drought conditions in the future.

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Appendix 1. Species list and model fit data

Taxa included in habitat suitability modelling and spatial prioritisation. Taxonomy follows the BirdLife Australia Working List (version 2.1). Whether model performance was satisfactory for inclusion in any Zonation spatial prioritisation process is indicated (AUC > 0.7), as is whether each species was classified as dependent on MDB floodplain habitats during the breeding or non-breeding seasons. The Zonation weight indicates how the contribution of each species was scaled according to IUCN and EPBC Act conservation status in Zonation runs where weighting was applied.

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Apostlebird	*Struthidea cinerea*	Breeding	0.79	Yes	Yes	2
		Non-breeding	0.77	Yes	Yes	
Australasian pipit	*Anthus novaeseelandiae*	Breeding	0.69	No	NA	2
		Non-breeding	0.71	Yes	No	
Australian hobby	*Falco longipennis*	Breeding	0.68	No	NA	1
		Non-breeding	0.69	No	NA	
Australian magpie	*Gymnorhina tibicen*	Breeding	0.63	No	NA	1
		Non-breeding	0.62	No	NA	
Australian pratincole	*Stiltia isabella*	Breeding	0.86	Yes	No	2
		Non-breeding	0.88	Yes	No	
Australian raven	*Corvus coronoides*	Breeding	0.54	No	NA	1
		NA	NA	NA	NA	
Australian ringneck	*Barnardius zonarius*	Breeding	0.76	Yes	No	1
		Non-breeding	0.77	Yes	Yes	
Banded lapwing	*Vanellus tricolor*	Breeding	0.71	Yes	Yes	2
		Non-breeding	0.74	Yes	Yes	
Barking owl	*Ninox connivens*	Breeding	0.73	Yes	No	3
		Non-breeding	0.75	Yes	Yes	
Black-chinned honeyeater	*Melithreptus gularis*	Breeding	0.77	Yes	No	2
		Non-breeding	0.76	Yes	Yes	
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	Breeding	0.57	No	NA	3
		Non-breeding	0.59	No	NA	
Black-faced woodswallow	*Artamus cinereus*	Breeding	0.84	Yes	No	1
		Non-breeding	0.85	Yes	No	
Black honeyeater	*Sugomel niger*	Breeding	0.80	Yes	No	3
		Non-breeding	0.84	Yes	No	
Black kite	*Milvus migrans*	Breeding	0.75	Yes	Yes	2
		Non-breeding	0.78	Yes	Yes	
Black-shouldered kite	*Elanus axillaris*	Breeding	0.71	Yes	Yes	1
		Non-breeding	0.72	Yes	Yes	
Black-tailed native-hen	*Tribonyx ventralis*	Breeding	0.75	Yes	Yes	2
		Non-breeding	0.77	Yes	Yes	
Blue bonnet	*Northiella haematogaster*	Breeding	0.81	Yes	Yes	3
		Non-breeding	0.82	Yes	Yes	

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Brown falcon	*Falco berigora*	Breeding	0.65	No	NA	3
		Non-breeding	0.66	No	NA	
Brown-headed honeyeater	*Melithreptus brevirostris*	Breeding	0.73	Yes	No	2
		Non-breeding	0.74	Yes	No	
Brown songlark	*Cincloramphus cruralis*	Breeding	0.75	Yes	Yes	2
		Non-breeding	0.82	Yes	Yes	
Brown treecreeper	*Climacteris picumnus*	Breeding	0.75	Yes	Yes	3
		Non-breeding	0.75	Yes	Yes	
Budgerigar	*Melopsittacus undulatus*	Breeding	0.84	Yes	No	1
		Non-breeding	0.89	Yes	No	
Buff-rumped thornbill	*Acanthiza reguloides*	Breeding	0.77	Yes	No	3
		Non-breeding	0.79	Yes	No	
Bush stone-curlew	*Burhinus grallarius*	Breeding	0.75	Yes	No	3
		Non-breeding	0.77	Yes	No	
Chestnut-crowned babbler	*Pomatostomus ruficeps*	Breeding	0.68	No	NA	2
		Non-breeding	0.75	Yes	Yes	
Chestnut-rumped thornbill	*Acanthiza uropygialis*	Breeding	0.85	Yes	Yes	3
		Non-breeding	0.81	Yes	Yes	
Chirruping wedgebill	*Psophodes cristatus*	Breeding	0.79	Yes	No	2
		Non-breeding	0.81	Yes	No	
Cockatiel	*Nymphicus hollandicus*	Breeding	0.77	Yes	Yes	2
		Non-breeding	0.80	Yes	Yes	
Collared sparrowhawk	*Accipiter cirrocephalus*	Breeding	0.60	No	NA	3
		Non-breeding	0.64	No	NA	
Common bronzewing	*Phaps chalcoptera*	Breeding	0.66	No	NA	2
		Non-breeding	0.64	No	NA	
Crested pigeon	*Ocyphaps lophotes*	Breeding	0.66	No	NA	1
		Non-breeding	0.64	No	NA	
Crested shrike-tit	*Falcunculus frontatus*	Breeding	0.72	Yes	No	3
		Non-breeding	0.72	Yes	Yes	
Crimson chat	*Epthianura tricolor*	Breeding	0.82	Yes	No	2
		Non-breeding	0.83	Yes	No	
Diamond dove	*Geopelia cuneata*	Breeding	0.88	Yes	No	2
		Non-breeding	0.86	Yes	No	
Diamond firetail	*Stagonopleura guttata*	Breeding	0.79	Yes	Yes	3
		Non-breeding	0.77	Yes	Yes	
Dusky woodswallow	*Artamus cyanopterus*	Breeding	0.69	No	NA	3
		Non-breeding	0.69	No	NA	

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Eastern rosella	*Platycercus eximius*	Breeding	0.64	No	NA	1
		Non-breeding	0.61	No	NA	
Emu	*Dromaius novaehollandiae*	Breeding	0.74	Yes	Yes	2
		Non-breeding	0.73	Yes	Yes	
Fairy martin	*Petrochelidon ariel*	Breeding	0.70	No	NA	1
		Non-breeding	0.71	Yes	Yes	
Galah	*Eolophus roseicapilla*	Breeding	0.61	No	NA	1
		Non-breeding	0.62	No	NA	
Golden whistler	*Pachycephala pectoralis*	Breeding	0.77	Yes	No	2
		Non-breeding	0.74	Yes	No	
Grey butcherbird	*Cracticus torquatus*	Breeding	0.65	No	NA	2
		Non-breeding	0.62	No	NA	
Grey-crowned babbler	*Pomatostomus temporalis*	Breeding	0.75	Yes	Yes	3
		Non-breeding	0.75	Yes	Yes	
Grey currawong	*Strepera versicolor*	Breeding	0.67	No	NA	2
		Non-breeding	0.64	No	NA	
Grey fantail	*Rhipidura fuliginosa*	Breeding	0.70	Yes	Yes	2
		Non-breeding	0.68	No	NA	
Grey shrike-thrush	*Colluricincla harmonica*	Breeding	0.64	No	NA	3
		Non-breeding	0.64	No	NA	
Ground cuckoo-shrike	*Coracina maxima*	Breeding	0.76	Yes	Yes	3
		Non-breeding	0.77	Yes	Yes	
Hooded robin	*Melanodryas cucullata*	Breeding	0.74	Yes	Yes	3
		Non-breeding	0.76	Yes	Yes	
Horsfield's bronze-cuckoo	*Chalcites basalis*	Breeding	0.58	No	NA	2
		Non-breeding	0.62	No	NA	
Jacky winter	*Microeca fascinans*	Breeding	0.75	Yes	Yes	3
		Non-breeding	0.71	Yes	Yes	
Laughing kookaburra	*Dacelo novaeguineae*	Breeding	0.66	No	NA	2
		Non-breeding	0.68	No	NA	
Little corella	*Cacatua sanguinea*	Breeding	0.68	No	NA	1
		Non-breeding	0.71	Yes	Yes	
Little eagle	*Hieraaetus morphnoides*	Breeding	0.61	No	NA	2
		Non-breeding	NA	NA	NA	
Little friarbird	*Philemon citreogularis*	Breeding	0.74	Yes	No	2
		Non-breeding	0.73	Yes	Yes	
Little raven	*Corvus mellori*	Breeding	0.58	No	NA	1
		Non-breeding	0.70	Yes	Yes	
Magpie-lark	*Grallina cyanoleuca*	Breeding	0.66	No	NA	1
		Non-breeding	0.66	No	NA	

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Major Mitchell's cockatoo	*Cacatua leadbeateri*	Breeding	0.79	Yes	Yes	2
		Non-breeding	0.84	Yes	Yes	
Mallee ringneck	*Barnardius zonarius barnardi*	Breeding	0.80	Yes	Yes	2*
		Non-breeding	0.79	Yes	Yes	
Masked woodswallow	*Artamus personatus*	Breeding	0.78	Yes	Yes	2
		Non-breeding	0.84	Yes	No	
Mistletoebird	*Dicaeum hirundinaceum*	Breeding	0.63	No	NA	2
		Non-breeding	0.57	No	NA	
Nankeen kestrel	*Falco cenchroides*	Breeding	0.66	No	NA	1
		Non-breeding	0.67	No	NA	
Noisy friarbird	*Philemon corniculatus*	Breeding	0.65	No	NA	2
		Non-breeding	0.61	No	NA	
Noisy miner	*Manorina melanocephala*	Breeding	0.65	No	NA	1
		Non-breeding	0.65	No	NA	
Olive-backed oriole	*Oriolus sagittatus*	Breeding	0.67	No	NA	3
		Non-breeding	0.68	No	NA	
Painted button-quail	*Turnix varius*	Breeding	0.75	Yes	No	3
		Non-breeding	0.75	Yes	No	
Painted honeyeater	*Grantiella picta*	Breeding	0.80	Yes	Yes	4
		Non-breeding	0.74	Yes	Yes	
Pallid cuckoo	*Heteroscenes pallidus*	Breeding	0.62	No	NA	1
		Non-breeding	0.71	Yes	No	
Peaceful dove	*Geopelia placida*	Breeding	0.72	Yes	Yes	2
		Non-breeding	0.73	Yes	Yes	
Pied butcherbird	*Cracticus nigrogularis*	Breeding	0.54	No	NA	2
		Non-breeding	0.61	No	NA	
Pied currawong	*Strepera graculina*	Breeding	0.70	Yes	No	1
		Non-breeding	0.66	No	NA	
Rainbow bee-eater	*Merops ornatus*	Breeding	0.63	No	NA	2
		Non-breeding	0.71	Yes	No	
Red-backed kingfisher	*Todiramphus pyrrhopygius*	Breeding	0.84	Yes	No	1
		Non-breeding	0.84	Yes	No	
Red-browed pardalote	*Pardalotus rubricatus*	Breeding	0.87	Yes	No	2
		Non-breeding	0.81	Yes	No	
Red-capped robin	*Petroica goodenovii*	Breeding	0.79	Yes	Yes	2
		Non-breeding	0.79	Yes	Yes	
Red-rumped parrot	*Psephotus haematonotus*	Breeding	0.71	Yes	Yes	1
		Non-breeding	0.70	No	NA	

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Regent parrot	*Polytelis anthopeplus monarchoides*	Breeding	0.78	Yes	Yes	4#
		Non-breeding	0.76	Yes	Yes	
Restless flycatcher	*Myiagra inquieta*	Breeding	0.71	Yes	Yes	3
		Non-breeding	0.72	Yes	Yes	
Rufous songlark	*Cincloramphus mathewsi*	Breeding	0.73	Yes	Yes	2
		Non-breeding	0.79	Yes	Yes	
Rufous whistler	*Pachycephala rufiventris*	Breeding	0.63	No	NA	3
		Non-breeding	0.62	No	NA	
Sacred kingfisher	*Todiramphus sanctus*	Breeding	0.65	No	NA	1
		Non-breeding	0.70	Yes	Yes	
Scarlet robin	*Petroica multicolor*	Breeding	0.79	Yes	No	3
		Non-breeding	0.77	Yes	No	
Southern boobook	*Ninox boobook*	Breeding	0.69	No	NA	2
		Non-breeding	0.67	No	NA	
Southern whiteface	*Aphelocephala leucopsis*	Breeding	0.76	Yes	Yes	3
		Non-breeding	0.75	Yes	Yes	
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*	Breeding	0.79	Yes	Yes	3
		Non-breeding	0.78	Yes	Yes	
Striated pardalote	*Pardalotus striatus*	Breeding	0.61	No	NA	3
		Non-breeding	0.61	No	NA	
Sulphur-crested cockatoo	*Cacatua galerita*	Breeding	0.66	No	NA	3
		Non-breeding	0.67	No	NA	
Superb fairy-wren	*Malurus cyaneus*	Breeding	0.63	No	NA	2
		Non-breeding	0.61	No	NA	
Superb parrot	*Polytelis swainsonii*	Breeding	0.74	Yes	No	4#
		Non-breeding	0.78	Yes	Yes	
Tawny frogmouth	*Podargus strigoides*	Breeding	0.63	No	NA	2
		Non-breeding	0.64	No	NA	
Tree martin	*Petrochelidon nigricans*	Breeding	0.57	No	NA	1
		Non-breeding	0.63	No	NA	
Varied sittella	*Daphoenositta chrysoptera*	Breeding	0.68	No	NA	3
		Non-breeding	0.69	No	NA	
Variegated fairy-wren	*Malurus lamberti*	Breeding	0.66	No	NA	2
		Non-breeding	0.67	No	NA	
Wedge-tailed eagle	*Aquila audax*	Breeding	0.61	No	NA	1
		Non-breeding	0.62	No	NA	
Weebill	*Smicrornis brevirostris*	Breeding	0.73	Yes	Yes	3
		Non-breeding	0.72	Yes	Yes	

Common name	Scientific name	Season	Mean test AUC	AUC > 0.7	Floodplain-dependent	Zonation weight
Whistling kite	*Haliastur sphenurus*	Breeding	0.77	Yes	Yes	3
		Non-breeding	0.75	Yes	Yes	
White-breasted woodswallow	*Artamus leucorynchus*	Breeding	0.77	Yes	Yes	2
		Non-breeding	0.78	Yes	Yes	
White-browed babbler	*Pomatostomus superciliosus*	Breeding	0.75	Yes	No	3
		Non-breeding	0.75	Yes	No	
White-browed woodswallow	*Artamus superciliosus*	Breeding	0.80	Yes	Yes	2
		Non-breeding	0.77	Yes	Yes	
White-plumed honeyeater	*Ptilotula penicillata*	Breeding	0.72	Yes	Yes	2
		Non-breeding	0.71	Yes	Yes	
White-winged chough	*Corcorax melanorhamphos*	Breeding	0.71	Yes	Yes	2
		Non-breeding	0.72	Yes	Yes	
White-winged fairy-wren	*Malurus leucopterus*	Breeding	0.84	Yes	Yes	2
		Non-breeding	0.85	Yes	Yes	
White-winged triller	*Lalage tricolor*	Breeding	0.67	No	NA	3
		Non-breeding	0.78	Yes	No	
Willie wagtail	*Rhipidura leucophrys*	Breeding	0.60	No	NA	1
		Non-breeding	0.60	No	NA	
Yellow rosella	*Platycercus elegans flaveolus*	Breeding	0.77	Yes	Yes	2*
		Non-breeding	0.82	Yes	Yes	
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*	Breeding	0.63	No	NA	3
		Non-breeding	0.67	No	NA	
Yellow thornbill	*Acanthiza nana*	Breeding	0.64	No	NA	3
		Non-breeding	0.66	No	NA	
Yellow-throated miner	*Manorina flavigula*	Breeding	0.75	Yes	No	2
		Non-breeding	0.78	Yes	Yes	
Zebra finch	*Taeniopygia guttata*	Breeding	0.86	Yes	No	2
		Non-breeding	0.85	Yes	No	

*Taxon not assessed by IUCN, so assigned the Zonation weighting of 2 (Least Concern with a stable population);
#Classified as threatened under the EPBC Act, so assigned the Zonation weighting of 4.

Appendix 2. Environmental predictor variables

Environmental predictor variables used in habitat suitability modelling. Each variable was screened for collinearity with other variables ($|r_{Pearson}| > 0.7$). For collinear variable pairs, the variable with the highest a priori importance rank was retained for further analyses. The retained variables are indicated by an asterisk in the first column.

Variable	Description	Temporal variability	Native resolution	Source	Ranked a priori importance	Reference
NDVI mean*	*The mean value within each grid cell of all normalised difference vegetation index (NDVI) values recorded during each breeding and non-breeding season.*	Dynamic	250 m and 0.01°	MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006 (Didan 2015); and the Bureau of Meteorology's monthly Normalized Difference Vegetation Index (NDVI) – AVHRR dataset for data between 1997 and 2000 http://www.auscover.org.au/purl/avhrr-ndvi-bom	1	Selwood et al. (2018) Journal of Applied Ecology, 55: 641-650
Tree cover	*Mean coverage of treed vegetation (%) between the years 2000 and 2015.*	Static	250 m	MOD44B.051 Terra Vegetation Continuous Fields Yearly Global 250m. Downloaded via Google Earth Engine https://developers.google.com/earth-engine/datasets/catalog/MODIS_006_MOD44B	2	Oliver et al. (2003) Emu - Austral Ornithology, 103: 171-176; Kutt and Martin (2010) Biodiversity and Conservation, 19: 2247-2262
Canopy height	*Mean canopy height (i.e. distance between the ground and the tree tops) within each grid cell.*	Static	1 km	Simard et al. (2011) Downloaded from https://csdms.colorado.edu/wiki/Data:Global_Forest_Heights	3	Roll et al. (2015) Global Ecology and Biogeography, 24: 814-825
Two-year lagged cumulative rainfall	*The cumulative total rainfall that fell in the two years leading up to each breeding and non-breeding season.*	Dynamic	0.05°	Derived from the Australian Gridded Climate Data dataset (Jones et al. 2009). http://opendap.bom.gov.au:8080/thredds/catalog.html	4	Stevens & Watson (2013) Emu - Austral Ornithology, 113: 112-121
Distance to large patch of treed vegetation*	*Distance to the nearest patch of treed vegetation with an area >40 ha.*	Static	NA	Derived from the Australian Federal Government's National Vegetation Information System Major Vegetation Groups (version 5.1) dataset. Downloaded from https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products#detailed51	5	Radford et al. (2005) Biological Conservation, 124: 317-337

Variable	Description	Temporal variability	Native resolution	Source	Ranked a priori importance	Reference
Diversity of vegetation types 3 km*	*The number of unique vegetation classes within a radius of 3 km from each grid cell.*	Static	NA	Derived from the Australian Federal Government's National Vegetation Information System Major Vegetation Groups (version 5.1) dataset. Downloaded from https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products#detailed51	6	Manning et al. (2006) Landscape Ecology, 21: 1119-1133
Cumulative rainfall	*The cumulative total rainfall for each breeding and non-breeding season.*	Dynamic	0.05°	Derived from the Australian Gridded Climate Data dataset (Jones et al. 2009). http://opendap.bom.gov.au:8080/thredds/catalog.html	7	Stevens & Watson (2013) Emu - Austral Ornithology, 113: 112-121
Diversity of vegetation types 20 km	*The number of unique vegetation classes within a radius of 20 km from each grid cell.*	Static	NA	Derived from the Australian Federal Government's National Vegetation Information System Major Vegetation Groups (version 5.1) dataset. Downloaded from https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products#detailed51	8	Watson et al. (2014) Landscape Ecology, 29: 1249-1259
Mean annual precipitation	*The long-term mean of the annual cumulative rainfall.*	Static	30 arc second	Fick and Hijmans (2017) Downloaded from: http://worldclim.org/version2	9	Kent et al. (2014) Ecology and Evolution, 4: 1963-1971
Precipitation seasonality*	*Coefficient of variation of the monthly mean precipitation values derived from a long-term dataset.*	Static	30 arc second	Fick and Hijmans (2017) Downloaded from: http://worldclim.org/version2	10	Andrew and Fox (2020) Journal of Biogeography, doi:10.1111/jbi.13832; Kent et al. (2014) Ecology and Evolution, 4: 1963-1971
Mean annual temperature	*The long-term mean annual temperature.*	Static	30 arc second	Fick and Hijmans (2017) Downloaded from: http://worldclim.org/version2	11	Kent et al. (2014) Ecology and Evolution, 4: 1963-1971

Variable	Description	Temporal variability	Native resolution	Source	Ranked a priori importance	Reference
TPI*	*The topographic position index (TPI) of each grid cell. TPI values indicate the position of a grid cell in the landscape, with values ranging from -1 (hollows and valleys), through 0 (flat) to 1 (ridges and summits).*	Static	270 m	Global ALOS mTPI (Multi-Scale Topographic Position Index) which is the mean grid cell value for individual TPI values calculated with moving window radii of 115.8, 89.9, 35.5, 13.1, 5.6, 2.8, and 1.2 km. https://developers.google.com/earth-engine/datasets/catalog/CSP_ERGo_1_0_Global_ALOS_mTPI	12	Mac Nally et al. (2000) Biological Conservation, 93: 293-302.
Temperature seasonality	*Standard deviation of the monthly mean temperature values derived from a long-term dataset multiplied by a factor of 100.*	Static	30 arc second	Fick and Hijmans (2017) Downloaded from: http://worldclim.org/version2	13	Kent et al. (2014) Ecology and Evolution 4: 1963-1971
Hot dry days run*	*The longest consecutive run of days that qualified as both hot days and dry days (see above) at that grid cell. A value was calculated for each breeding and non-breeding season.*	Dynamic	0.05°	Derived from the Australian Gridded Climate Data dataset (Jones et al. 2009). http://opendap.bom.gov.au:8080/thredds/catalog.html	14	Briscoe et al. (2016) Global Change Biology, 22: 2425-2439
Dry days run*	*The longest consecutive run of days in which rainfall was <1 mm at that grid cell. A value was calculated for each breeding and non-breeding season.*	Dynamic	0.05°	Derived from the Australian Gridded Climate Data dataset (Jones et al. 2009). http://opendap.bom.gov.au:8080/thredds/catalog.html	15	Briscoe et al. (2016) Global Change Biology, 22: 2425-2439

Variable	Description	Temporal variability	Native resolution	Source	Ranked a priori importance	Reference
Hot days run	*The longest consecutive run of days in which the temperature was above the 90th percentile temperature (across the 21-year study span) at that grid cell. A value was calculated for each breeding and non-breeding season.*	Dynamic	0.05°	Derived from the Australian Gridded Climate Data dataset (Jones et al. 2009). http://opendap.bom.gov.au:8080/thredds/catalog.html	16	Briscoe et al. (2016) Global Change Biology, 22: 2425-2439
Distance to watercourse*	*The distance from the centre of each grid cell to the nearest water course.*	Static	NA	Derived from the 15 arc second HydroSHEDS dataset. Downloaded from http://www.hydrosheds.org/downloads	17	Woinarski et al. (2000) Journal of Biogeography, 27: 843-868
Elevation*	*Height of the grid cell above sea level.*	Static	3 arc second	Geoscience Australia's SRTM DEM (Version 1.0). Downloaded from https://data.gov.au/data/dataset/12e0731d-96dd-49cc-aa21-ebfd65a3f67a	18	McCain (2009) Global Ecology and Biogeography, 18: 346-360
Density of roads*	*The length of road per unit of land area.*	Static	5 arc minute	Meijer et al. (2018) Downloaded from: http://geoservice.pbl.nl/download/opendata/GRIP4/GRIP4_density_total.zip	19	Hall et al. (2016) PLoS ONE, 11: e0155219; Hall et al. (2018) Biodiversity and Conservation, 27: 2605-2623
Depth of water table*	*Depth from ground surface to water table.*	Static	30 arc second	Fan et al. (2013) Downloaded from: http://thredds-gfnl.usc.es/thredds/catalog/GLOBALWTDFTP/annualmeans/catalog.html	20	Zolfaghar et al. (2014) Australian Journal of Botany, 62: 428-437
Biome	*Categorical classification based on a region's distinct biogeographic assemblages of species and ecological habitats.*	Static	NA	Derived from Ecoregions2017 (Dinerstein et al. 2017). Downloaded from https://ecoregions2017.appspot.com/	21	Friggens and Finch (2015) PLoS ONE, 10: e0144089

Appendix 3. Detailed methods for a) habitat suitability modelling and b) Zonation specifications

A. Habitat suitability modelling

Boosted regression tree (BRT) models were produced to map predicted habitat suitability for the breeding season and non-breeding season of 108 floodplain-associated terrestrial bird species (216 resultant models). These were based on the relationship between species occurrence and a set of environmental predictor variables (21 considered in this study; see Appendix 2).

Environmental variables were mapped to a 983 × 1110 m spatial grid and the values of these variables at the location of presence and background points were extracted. For temporally dynamic variables (e.g., normalised difference vegetation index (NDVI), and cumulative rainfall), environment data were extracted to presence and background points according to the time period (year × season [breeding or non-breeding]) that each presence or background datum point was collected. Pseudo-absence (background) points were obtained for each of these two temporal windows using target group sampling (Phillips et al. 2009). This approach uses the presence points of species with similar ecology to the species being modelled to characterise the range of habitat conditions that are potentially available. We used the presence records of the 107 other floodplain-associated bird species as target group background points. For each model (i.e., species × season combination), we sampled the total available pool of target group background points to produce a subset with a 1:1 ratio in the number of presence points to target group background points (Barbet-Massin et al. 2012).

Presence and background points for each species × season combination were divided into five spatially-explicit partitions to be used for five-fold cross-validation following Valavi et al. (2018). Cross-validation involves one of the data folds being left out of model training so it can be used to test the predictive performance of a model trained using the remaining data folds. Iterative repetition of this process occurs so that each data fold is used for model testing once. A final model was produced by training a model on the full dataset, with the assumption that estimates of predictive error from individual model folds are conservative compared to the actual predictive performance of the model built on the entire dataset (Roberts et al. 2017). All modelling was carried out using the 'gbm.step' function of the R package *dismo* (Hijmans et al. 2016). Optimum values to use for the learning rate, tree complexity, and bag fraction parameters were identified by exploring predictive deviance for a set of plausible combinations of these parameters for the breeding and non-breeding seasons for each species (Elith et al. 2008). The combination of parameter values that minimised predictive deviance and resulted in a model comprised of >1000 trees was used in the final model for each species (Elith et al. 2008).

Habitat suitability models for 39% of the species-by-season combinations had an AUC value ≤ 0.7 and were not included in any spatial prioritisation runs. These species were typically abundant, widespread species (e.g., Australian magpie and striated pardalote). Model performance for species with widespread occurrence is often poor, reflecting their weak habitat affinities (Elith et al. 2006, Andrew and Fox 2020). Furthermore, our use of target group background sampling is likely to have reduced the AUC value relative to if we had used random background selection even though target group background-derived models are likely to give a more accurate representation of true habitat suitability (Phillips et al. 2009). Although excluding these species from the spatial prioritisation analyses diminishes the generality of our findings, any increase in extent or quality of MDB floodplain habitats irrespective of where it occurs could benefit these floodplain-associated species owing to their generalist habitat requirements.

B. Zonation settings

The settings used during each Zonation analysis are shown in Figure A3.1. The spatial prioritisation process for each scenario consisted of two stages. The first stage identified priority areas in each breeding and non-breeding season in each year, for the relevant set of species (42 prioritisations). The second stage used these 42 individual time period prioritisation grids to determine spatial priorities for the entire 21-year study period. During both stages, a hierarchical removal mask was used to constrain the prioritisation to grid cells intersecting Murray-Darling Basin Authority-defined floodplains (MDBA 2008). This meant that at each iteration Zonation ranked all grid cells in the MDB and then removed the floodplain grid cell whose removal resulted in the smallest loss of conservation value (cells removed earlier receive a lower priority ranking). By ranking and removing floodplain grid cells first, landscape context information from non-floodplain grid cells was factored into the floodplain prioritisation process.

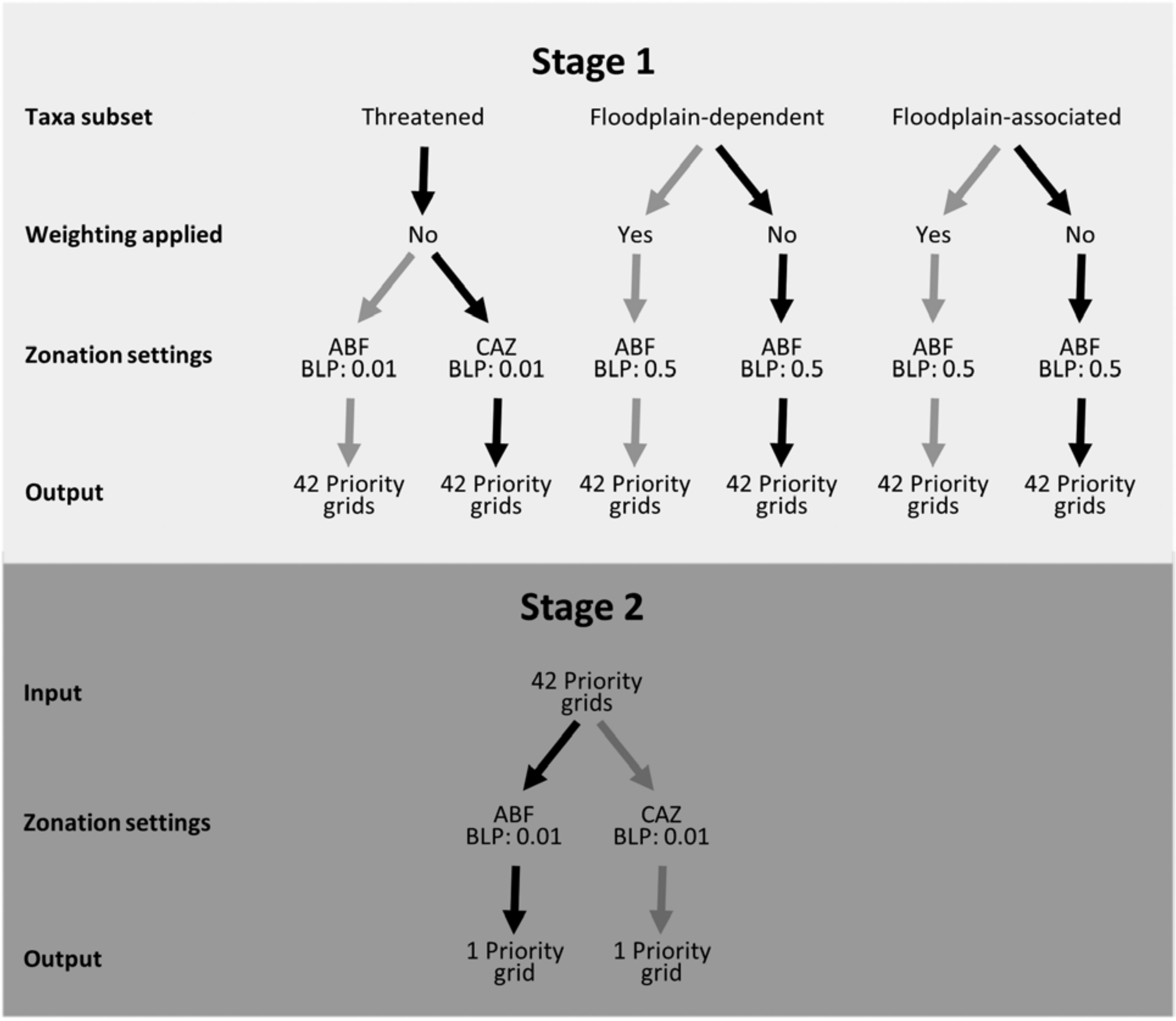


Figure A3.1. Flowchart showing the Zonation run settings and data subsets that were used to identify spatial priorities during this project. The final prioritisation maps presented in this report were produced by following each of the three pathways indicated by black arrows (as opposed to grey arrows). The chart is divided into stage one and stage two sections. The outputs from stage one were parsed separately to stage two resulting in a total of 12 priority grids (i.e., two for each terminus in stage one).

During stage one, we ran a series of Zonation runs to screen for appropriate settings to use in the final spatial prioritisation. For scenario 1, we aggregated conservation values using Zonation's 'additive benefit function' (ABF) and separately using the 'core area Zonation' (CAZ) algorithm. Running the two algorithms was expected to identify where management may benefit multiple threatened species at a given site, as well as giving an understanding on where priorities lie to ensure that core habitat for each threatened species is included in management decision-making (Lehtomäki and Moilanen 2013). For scenarios 2 and 3, we used the ABF as the method for aggregating conservation values, thereby identifying priorities in species rich areas where management is expected to benefit many species (Lehtomäki and Moilanen 2013).

A boundary length penalty (BLP), which penalises solutions with a high edge-to-area ratio, was used to enforce connectivity on each spatial prioritisation (Lehtomäki and Moilanen 2013). We ran Zonation with varying values for the BLP (0.01, 0.1, 0.5, and 1) to determine how the output was influenced by variation in BLP. For stage one of the prioritisation process we set the BLP at 0.01 for scenario 1, and 0.5 for scenarios 2 and 3. A BLP value of 0.5 is large relative to many studies (e.g., Selwood et al. 2019, Sibarani et al. 2019). However, environmental water allocations, the primary management mechanism for floodplain habitats, result in aggregated outcomes by virtue of floodwaters spreading outward from the main channel. Similarly, many other management actions available to floodplain managers, such as feral animal culls and prescribed burning rotations, are typically carried out at the landscape scale (i.e., over an area of >10 km2). Visual screening indicated that the chosen BLP values aggregated high priority areas rather than resulting in high priority areas being spread diffusely across the MDB.

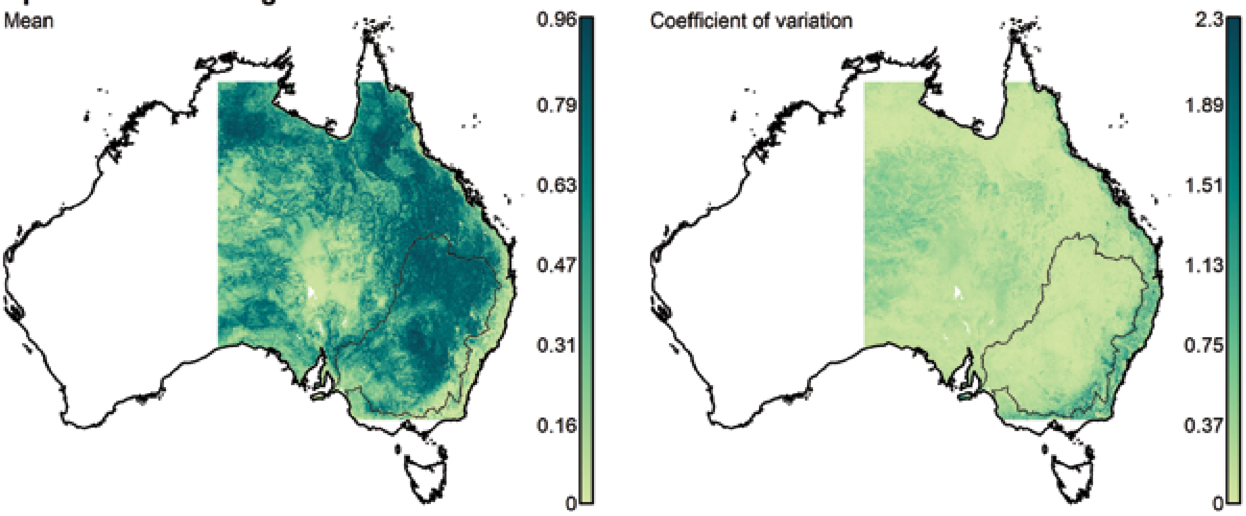
For scenarios 2 and 3, we ran stage one prioritisations with all species influencing the spatial prioritisation equally, and we also ran prioritisations with the contribution of species weighted according to their conservation status (IUCN Red List classification) whereby threatened species influenced priorities more strongly than those classified as Least Concern with an increasing population (Appendix 1). Floodplain priority ranks in each of the 42 pairs of prioritisation grids were significantly correlated (scenario 2: Pearson's $r = 0.43 \pm 0.01$ SE, $p < 0.001$ in all cases; scenario 3: median Pearson's $r = 0.65 \pm 0.01$ SE, $p < 0.001$ in all cases). Due to the similarities in the outputs of these two approaches, we present only the un-weighted prioritisations in this report.

During stage two of the prioritisation process we took the outputs of stage one (i.e., spatial prioritisation grids representing ranked priorities in each of the 21 breeding and 21 non-breeding seasons during the study period) and used them as inputs for further Zonation analyses. During these Zonation runs we ran separate iterations using the ABF and the CAZ algorithms. The former to identify areas that consistently represent high priority areas across breeding and non-breeding seasons, and the latter to retain floodplains that contribute substantially to the spatial priorities in one or only a small number of individual breeding or non-breeding seasons (e.g., ephemeral locations that provide resources when other regions do not). Stage two Zonation runs were carried out with the BLP set to 0.01 because a degree of aggregation had already been enforced during stage one Zonation runs. When CAZ was used instead of ABF during stage two of the spatial prioritisation process the same broad regions were highlighted as high priorities. However, there were some local-scale changes. Owing to the broadly similar patterns of the two approaches, we present only the prioritisation run using the ABF during stage two in this report.

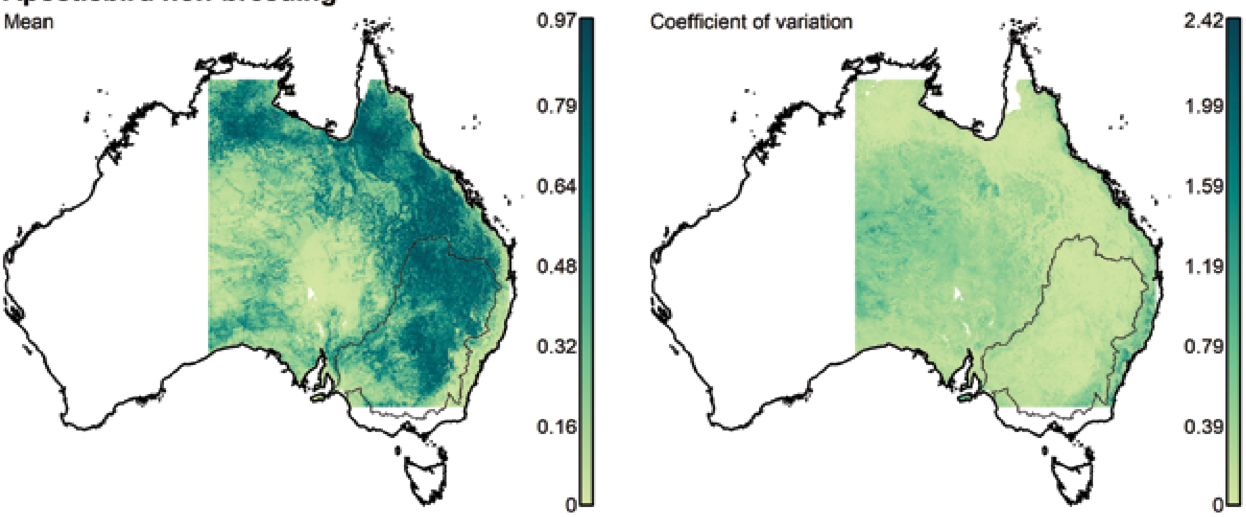
Appendix 4. Habitat suitability maps for each species

The following maps show the mean (left) predicted habitat suitability value across the distribution of each floodplain-associated species during breeding and non-breeding seasons between the years 1998 and 2018. The coefficient of variation (right) is also presented to provide an indication of how variable the predicted habitat suitability score was from year to year at each grid cell.

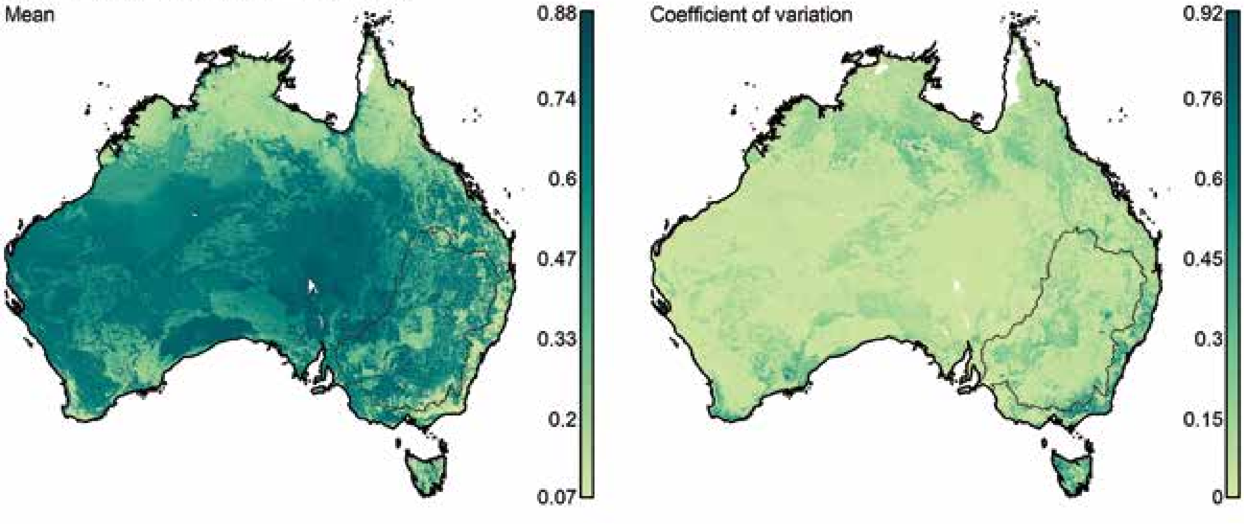
Apostlebird breeding



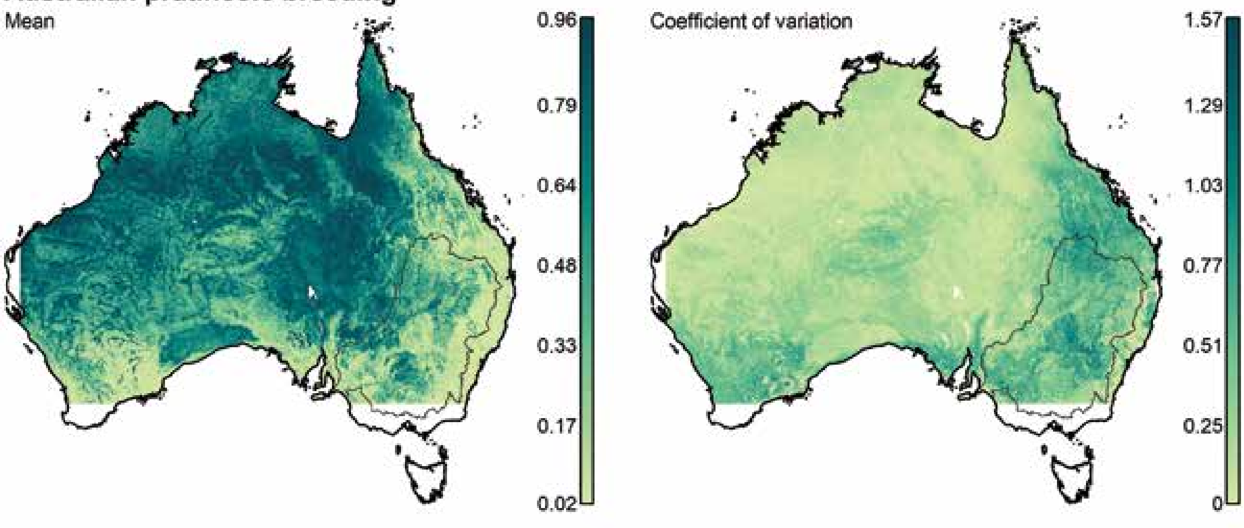
Apostlebird non-breeding



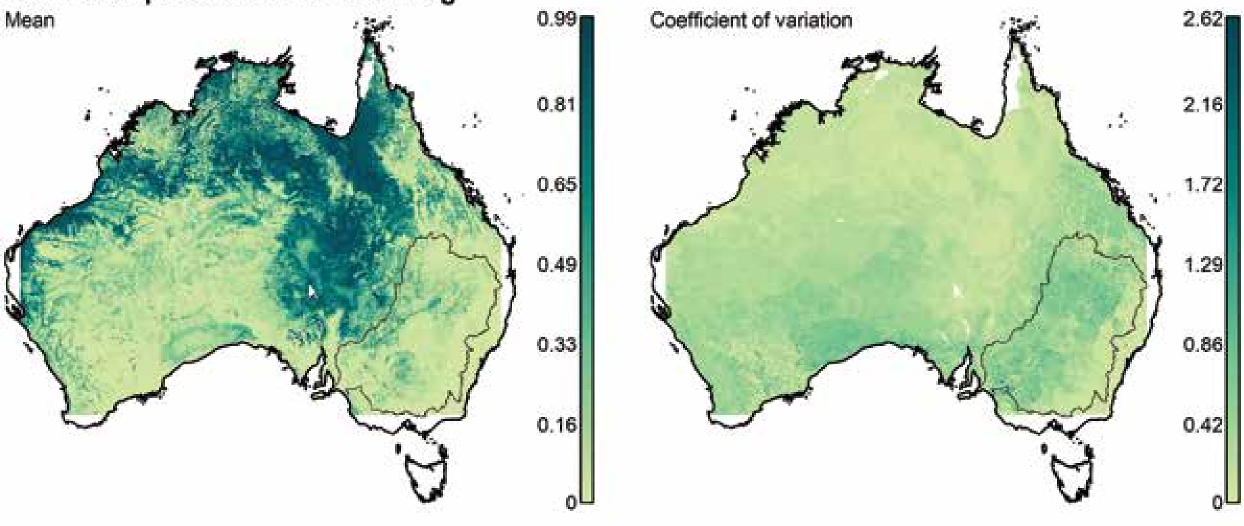
Australasian pipit non-breeding



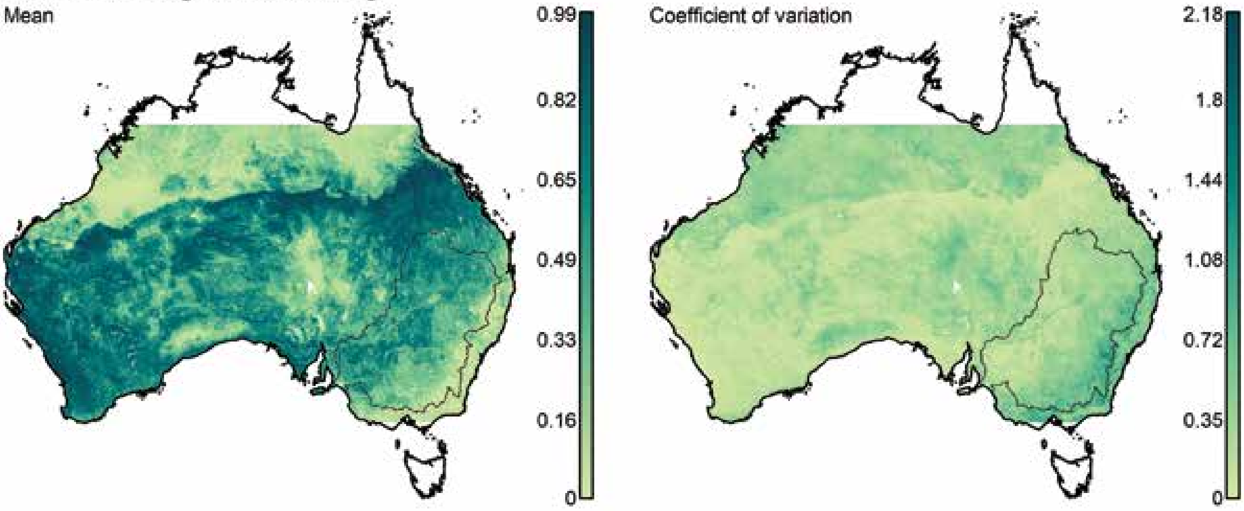
Australian pratincole breeding



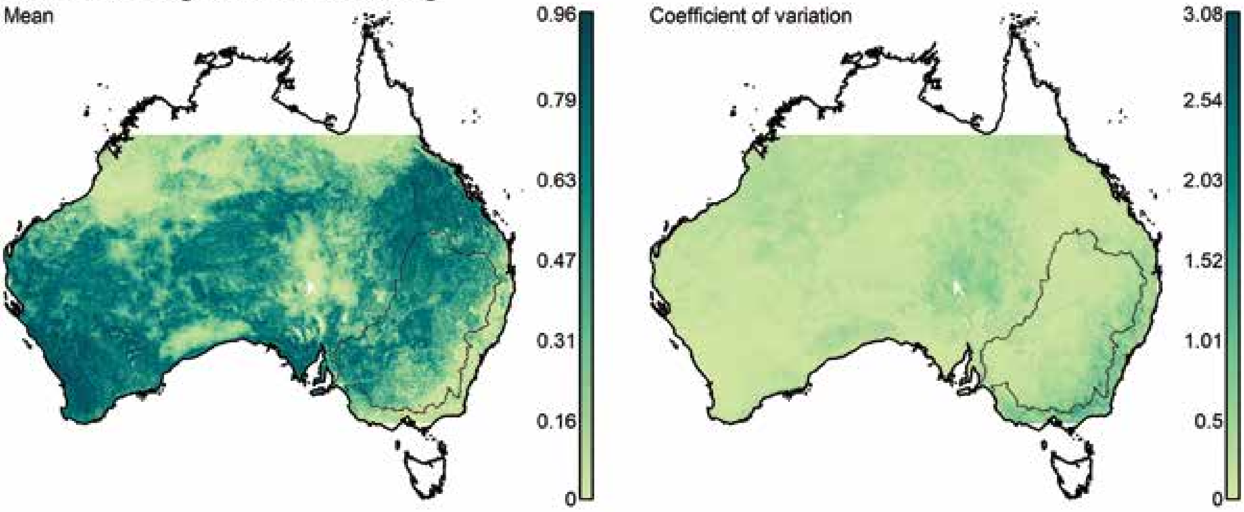
Australian pratincole non-breeding



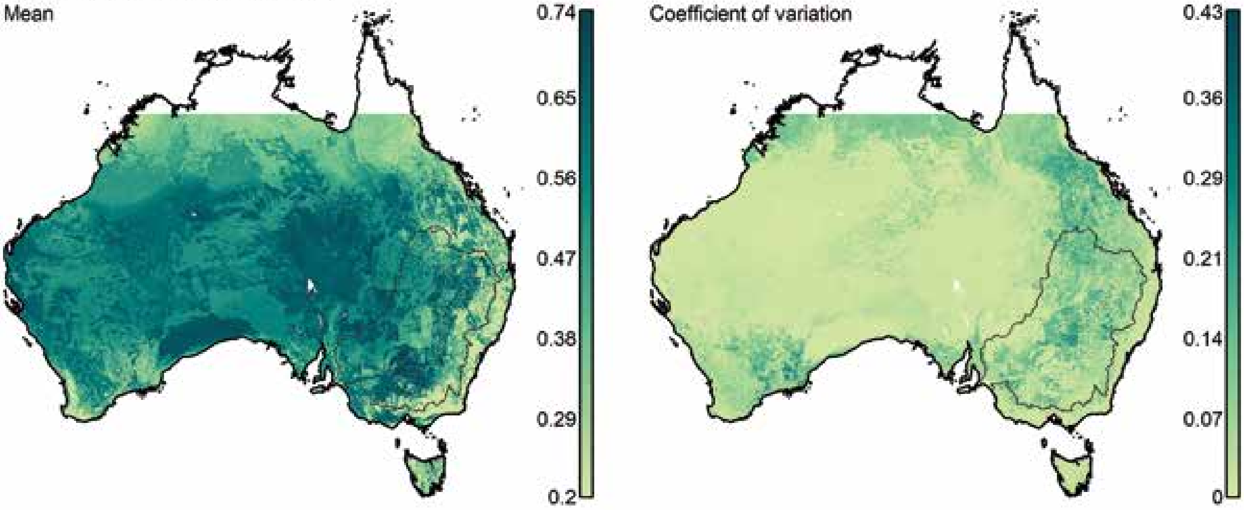
Australian ringneck breeding



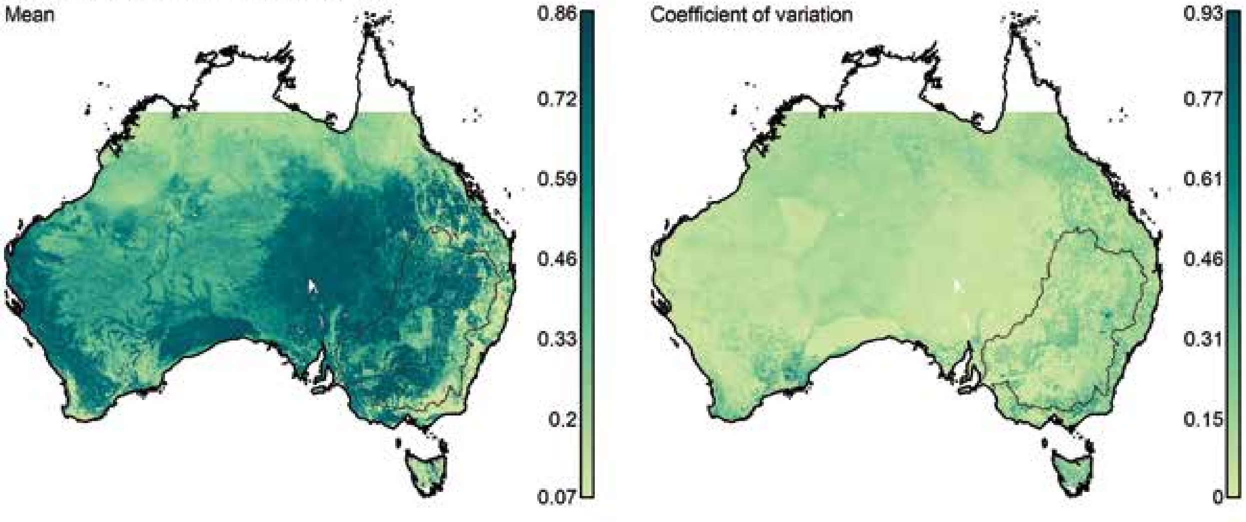
Australian ringneck non-breeding



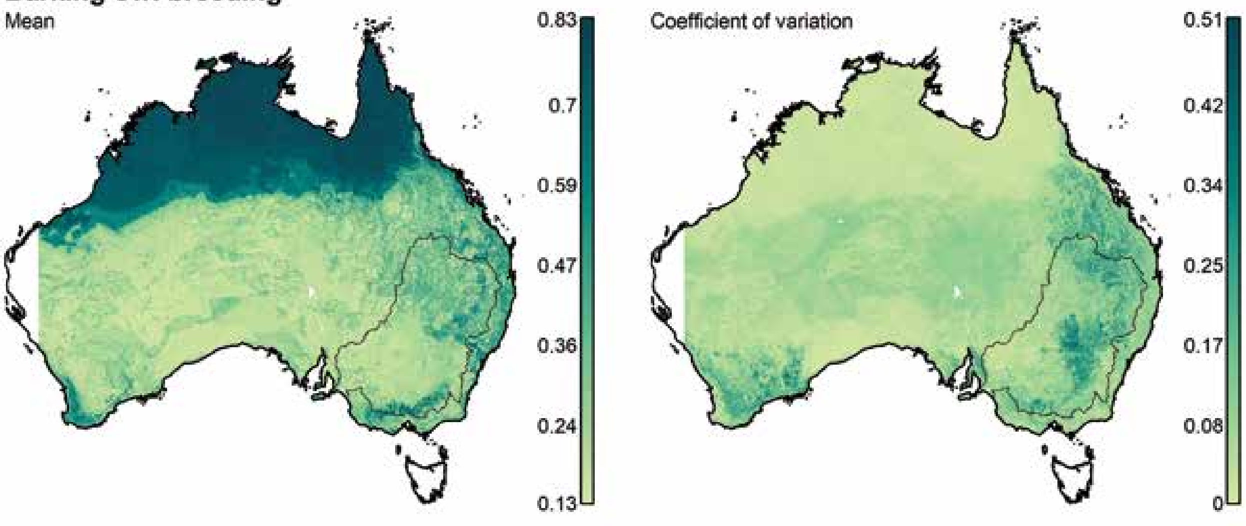
Banded lapwing breeding



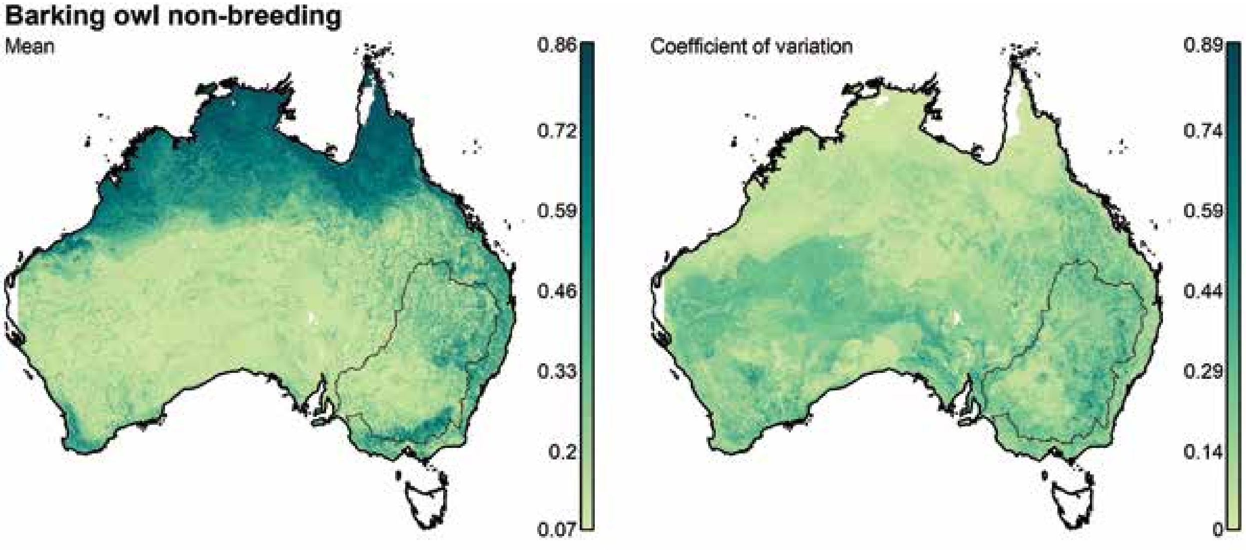
Banded lapwing non-breeding



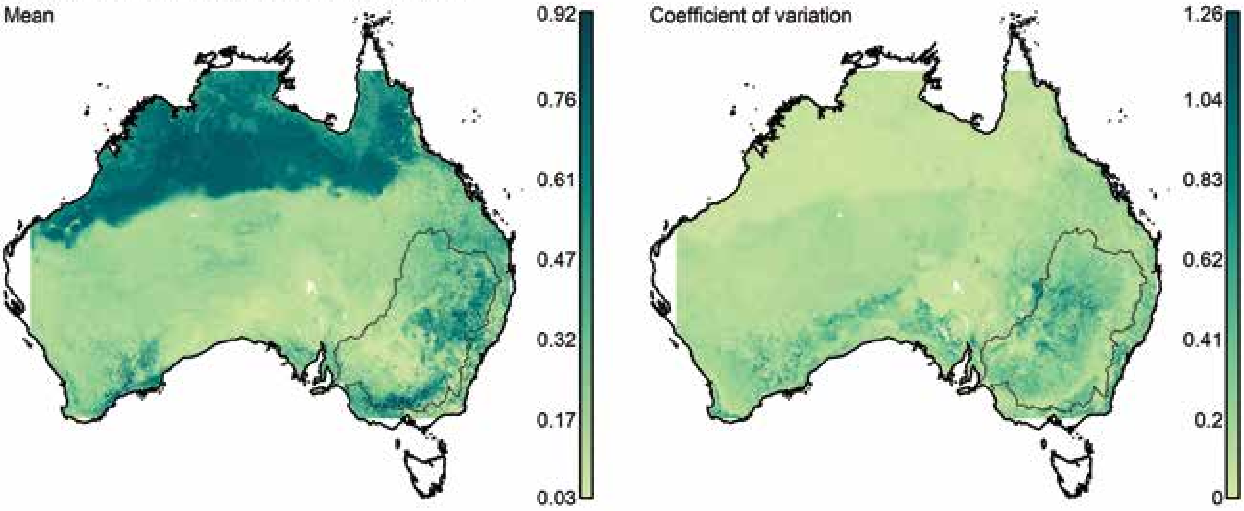
Barking owl breeding



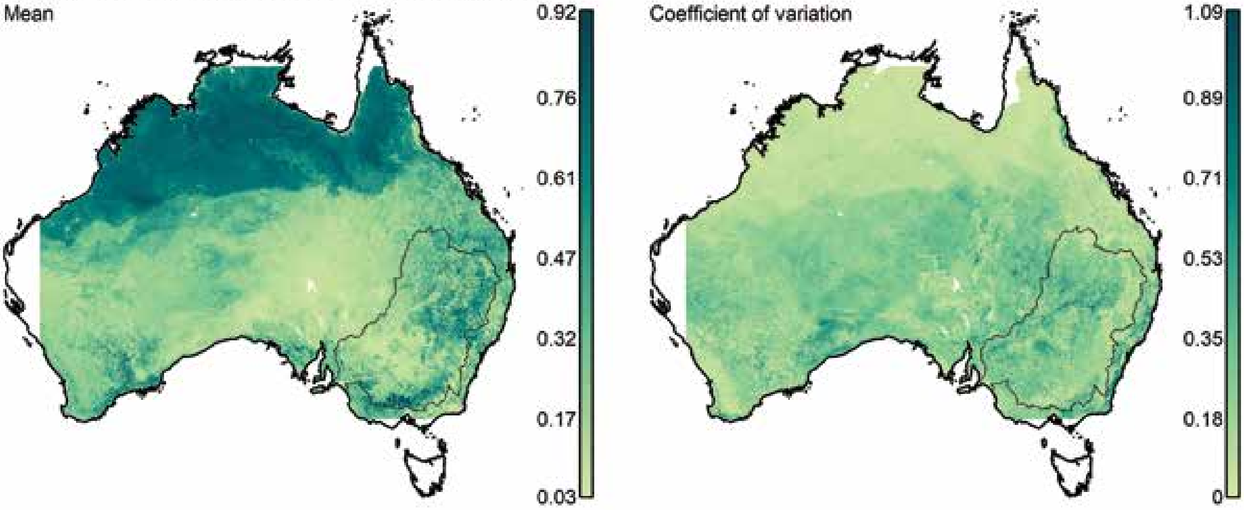
Barking owl non-breeding



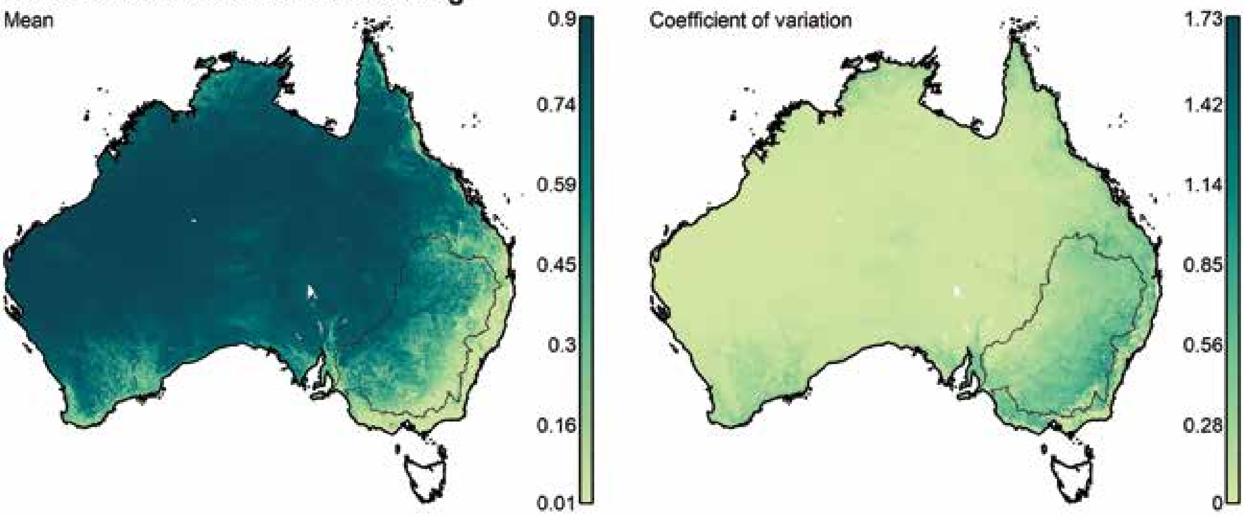
Black-chinned honeyeater breeding



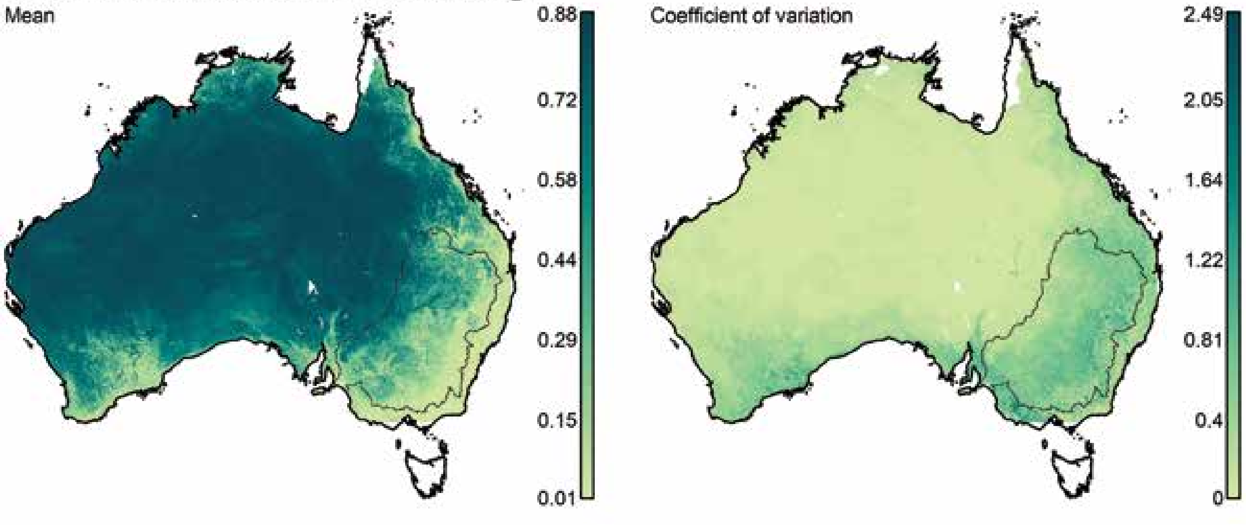
Black-chinned honeyeater non-breeding



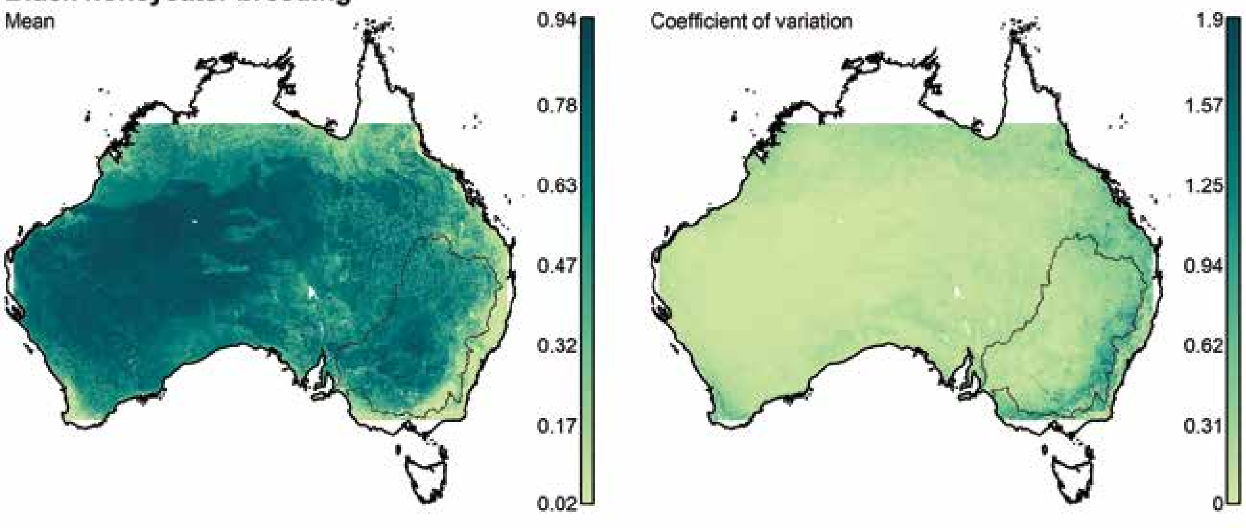
Black-faced woodswallow breeding



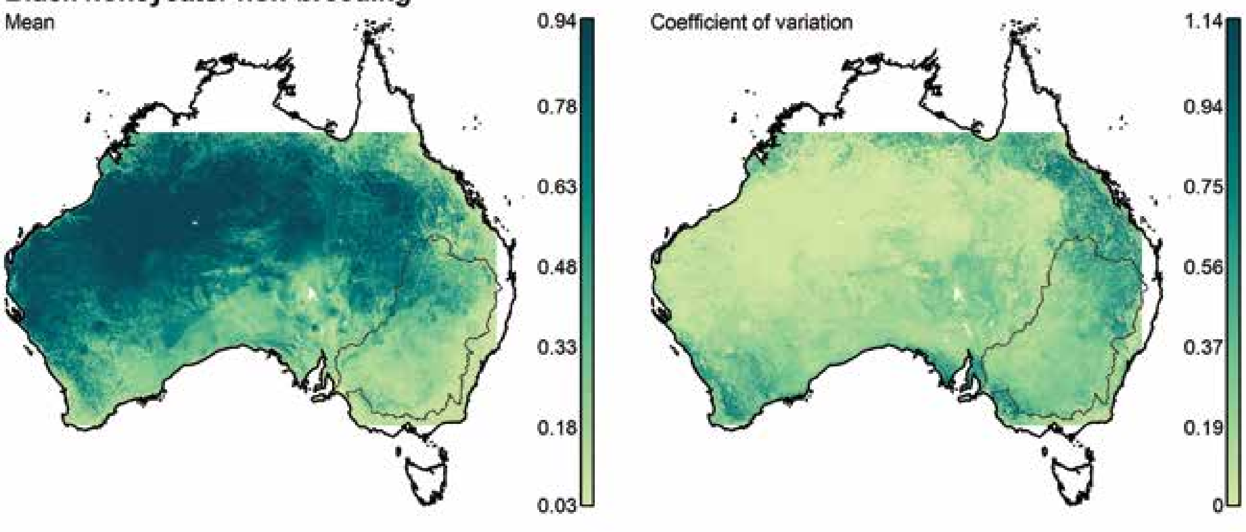
Black-faced woodswallow non-breeding



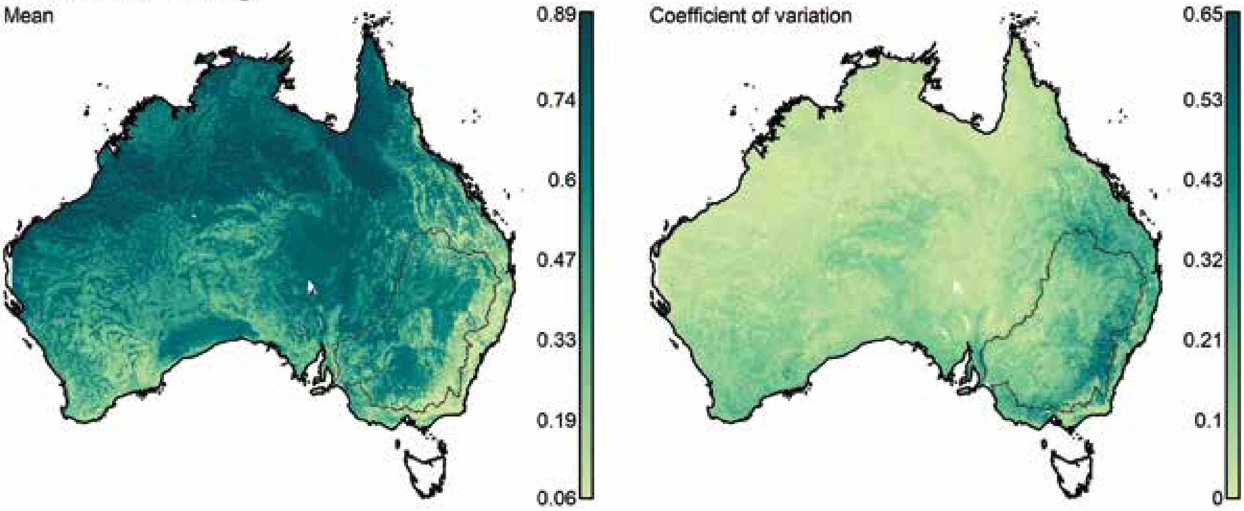
Black honeyeater breeding



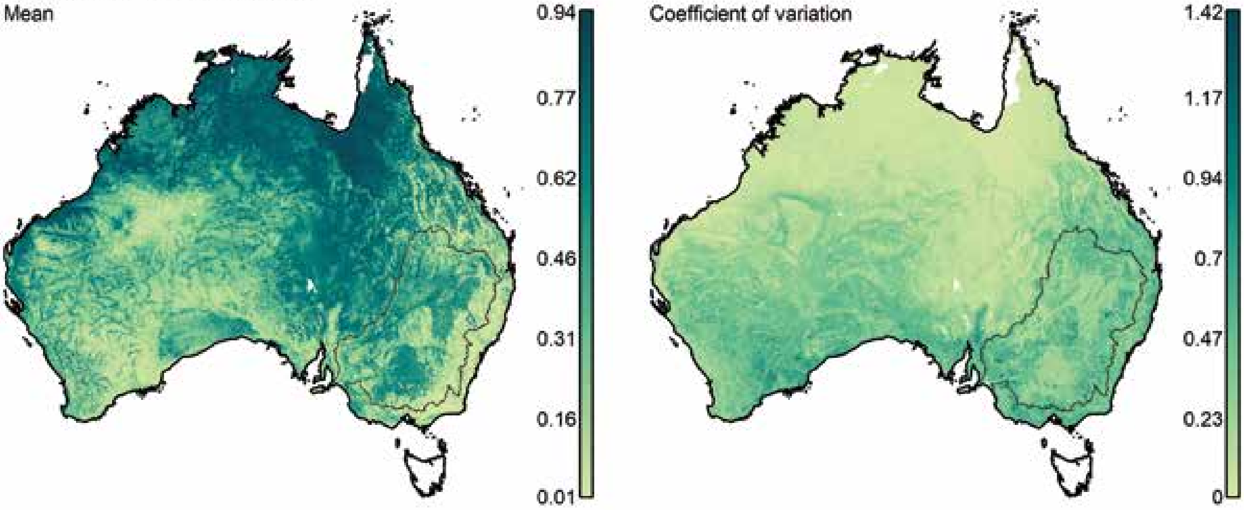
Black honeyeater non-breeding



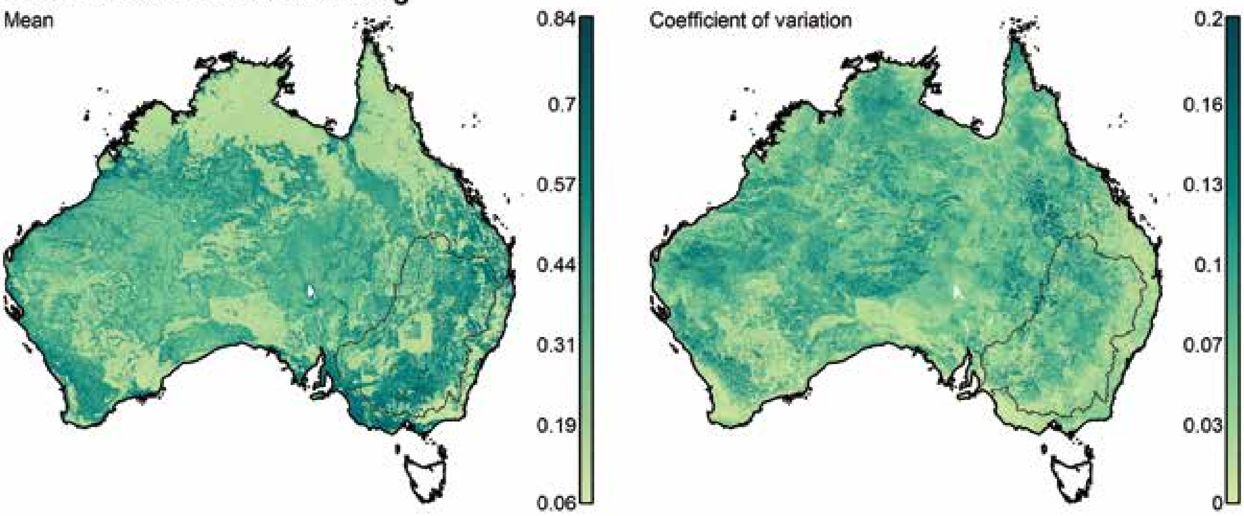
Black kite breeding



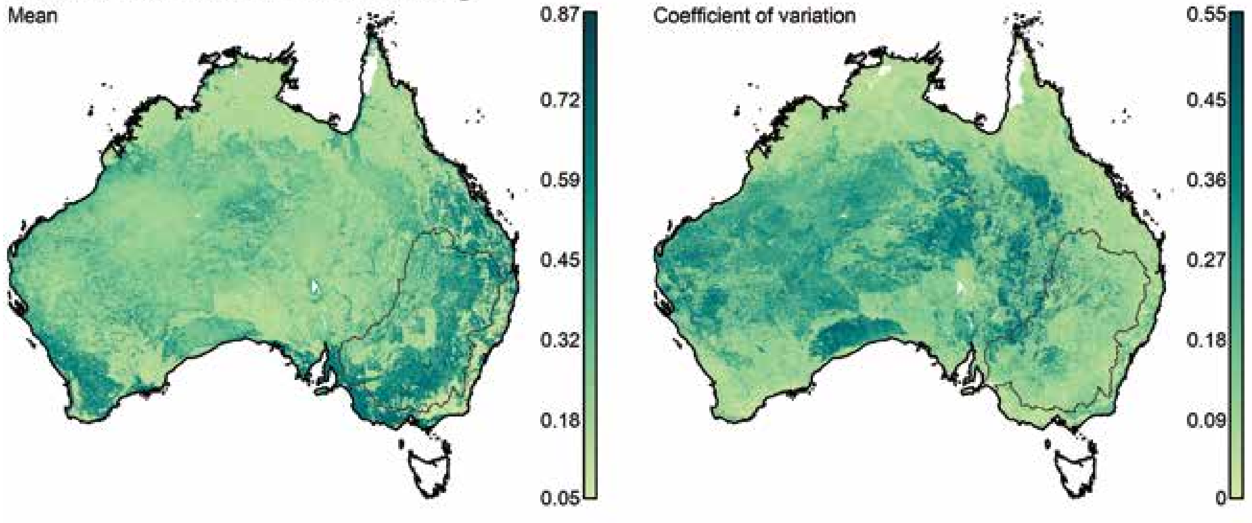
Black kite non-breeding



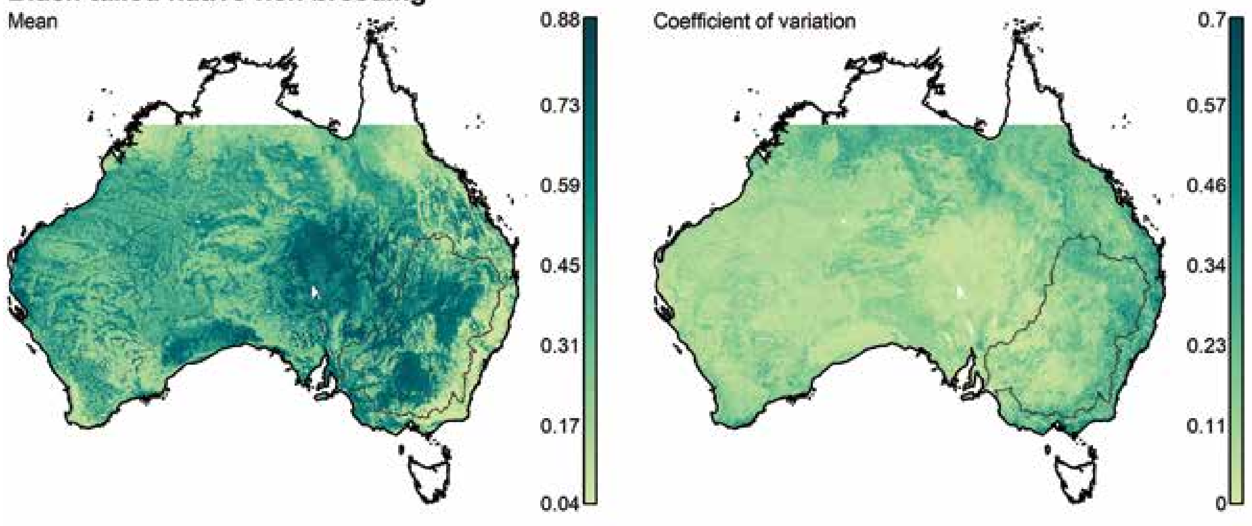
Black-shouldered kite breeding



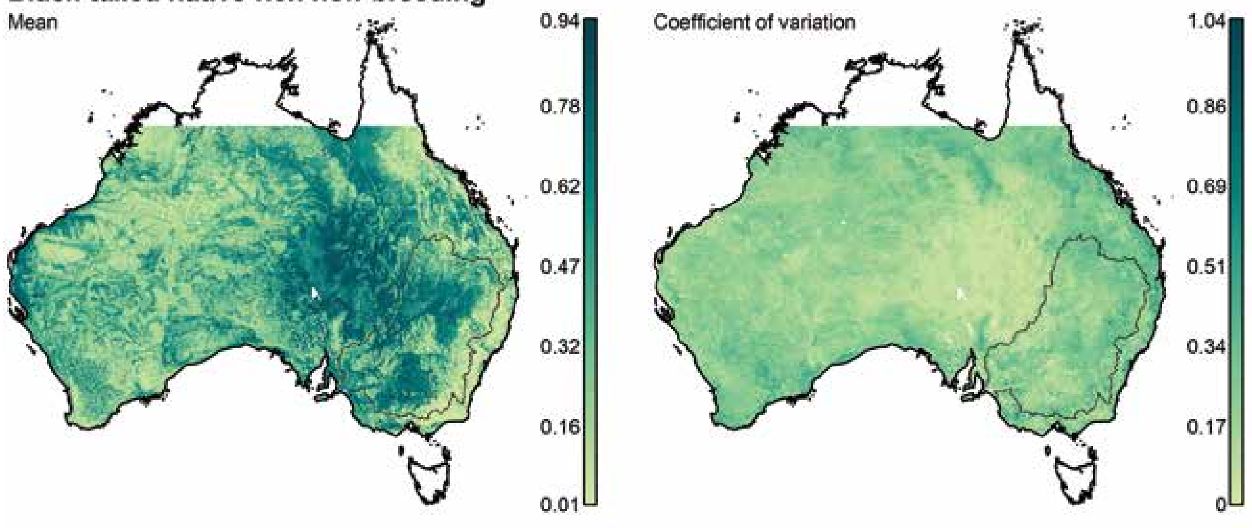
Black-shouldered kite non-breeding



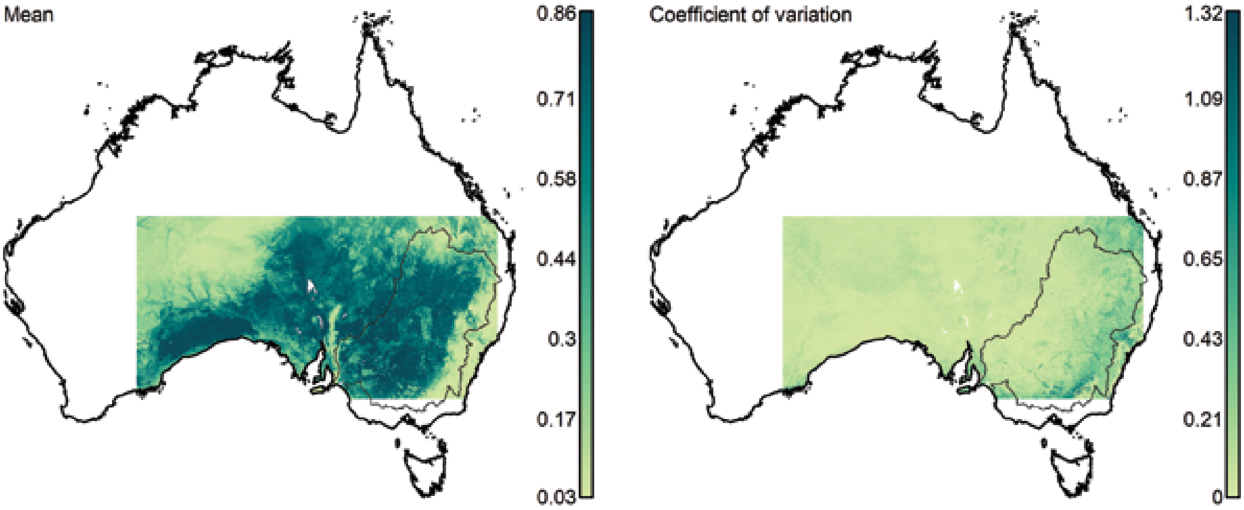
Black-tailed native-hen breeding



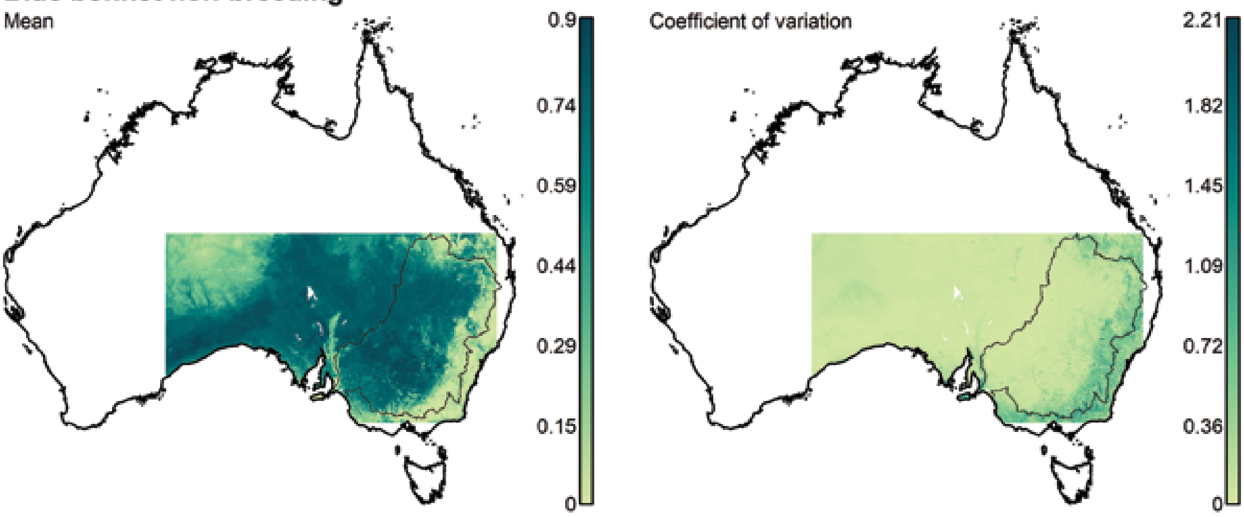
Black-tailed native-hen non-breeding



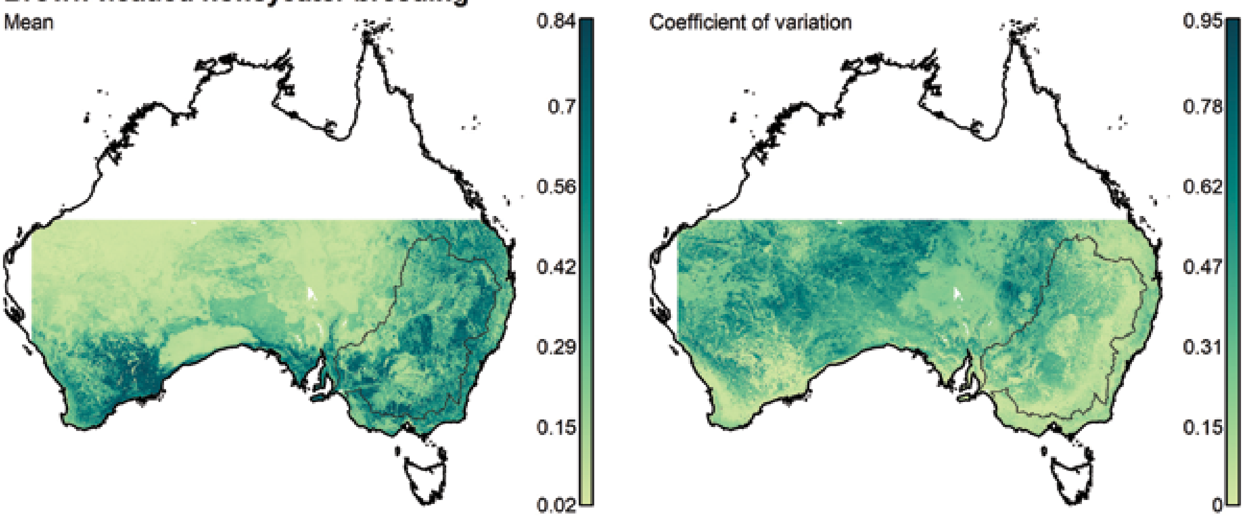
Blue bonnet breeding



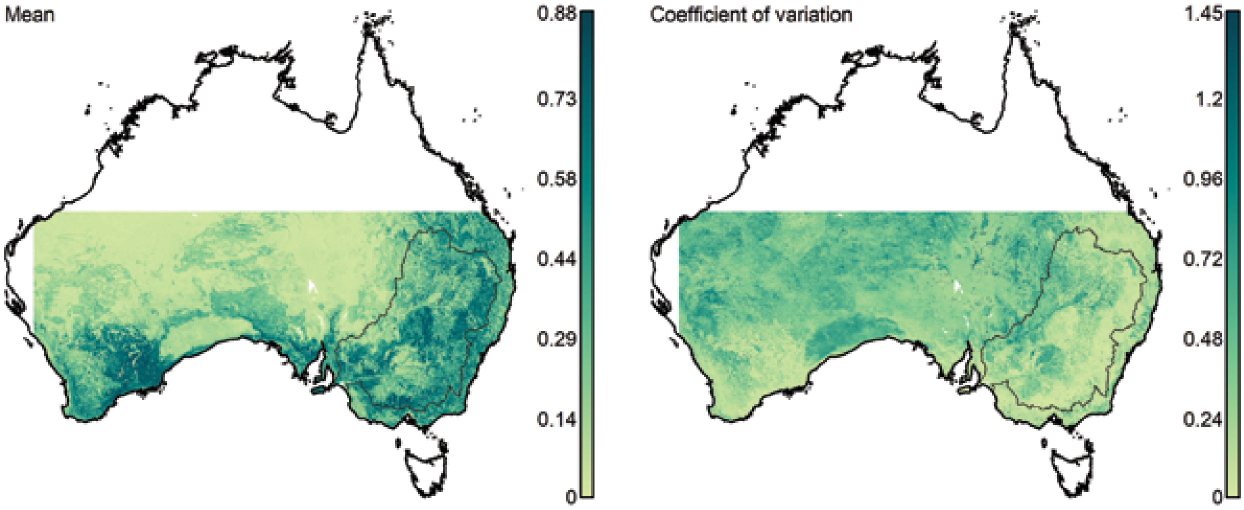
Blue bonnet non-breeding



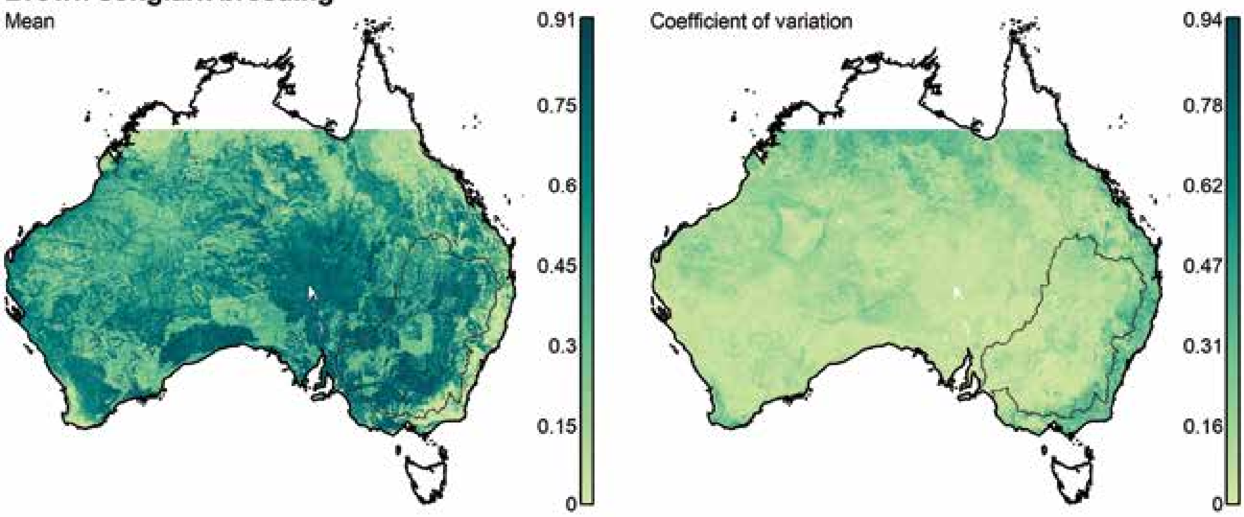
Brown-headed honeyeater breeding



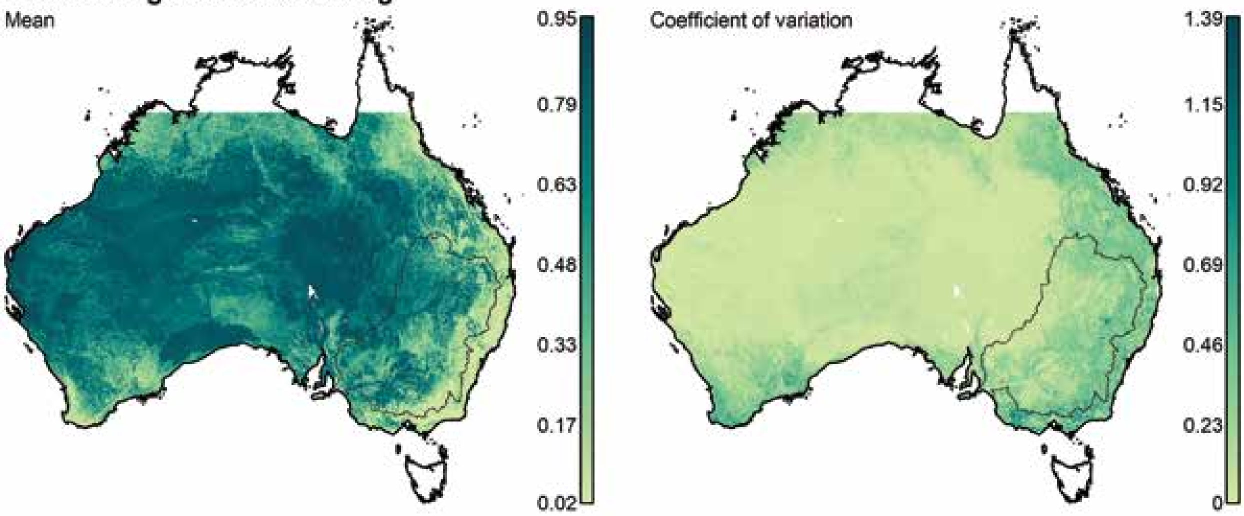
Brown-headed honeyeater non-breeding



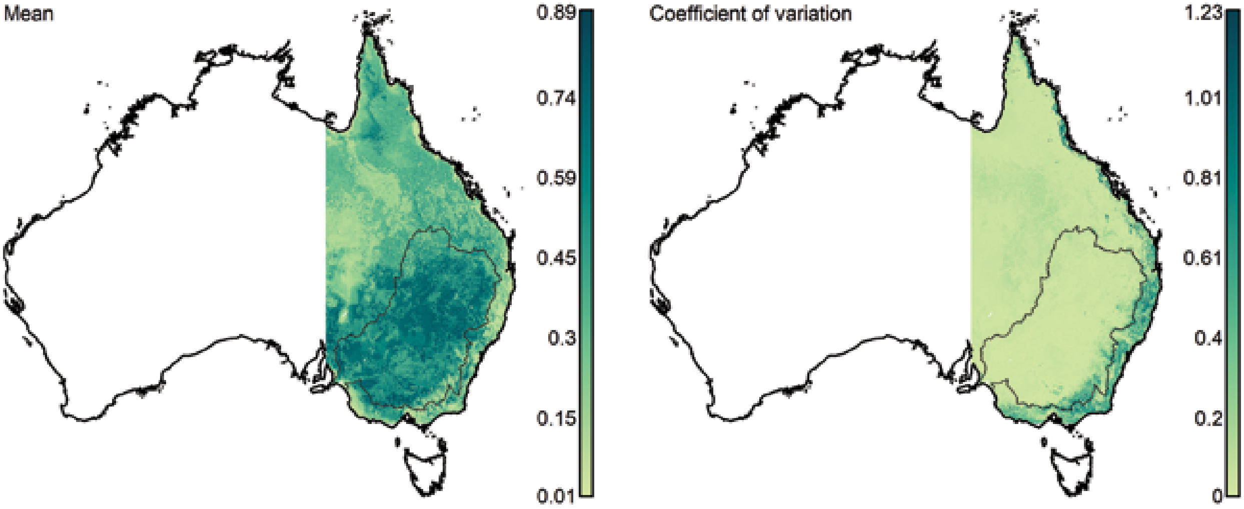
Brown songlark breeding



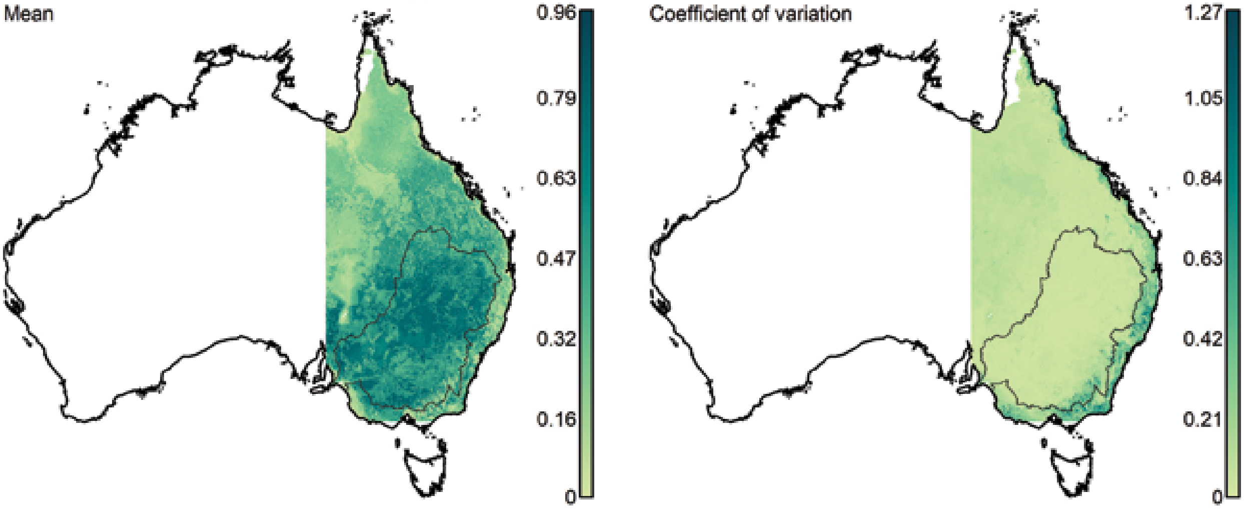
Brown songlark non-breeding



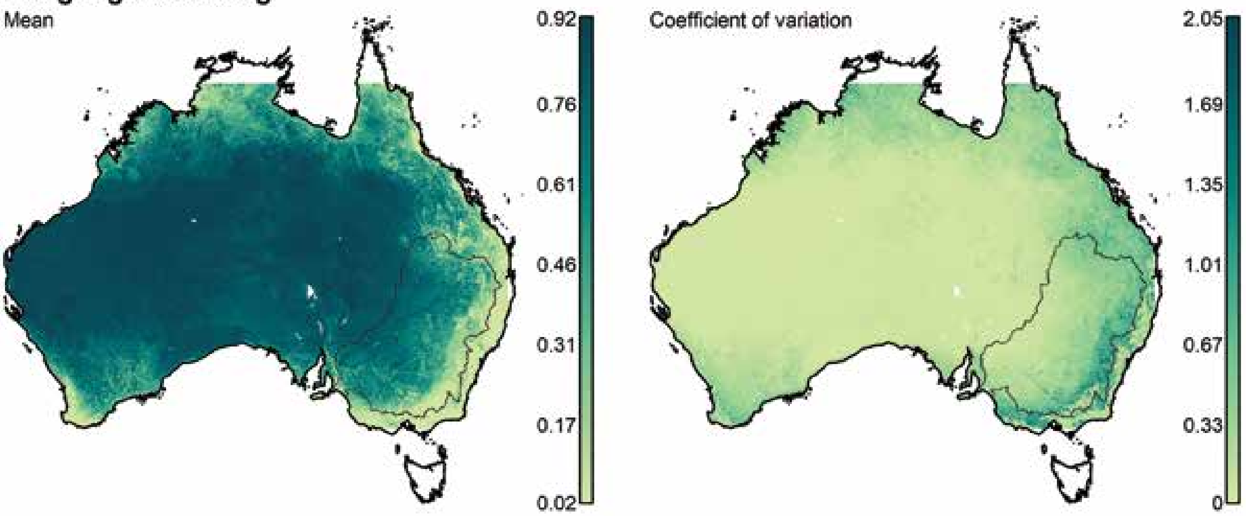
Brown treecreeper breeding

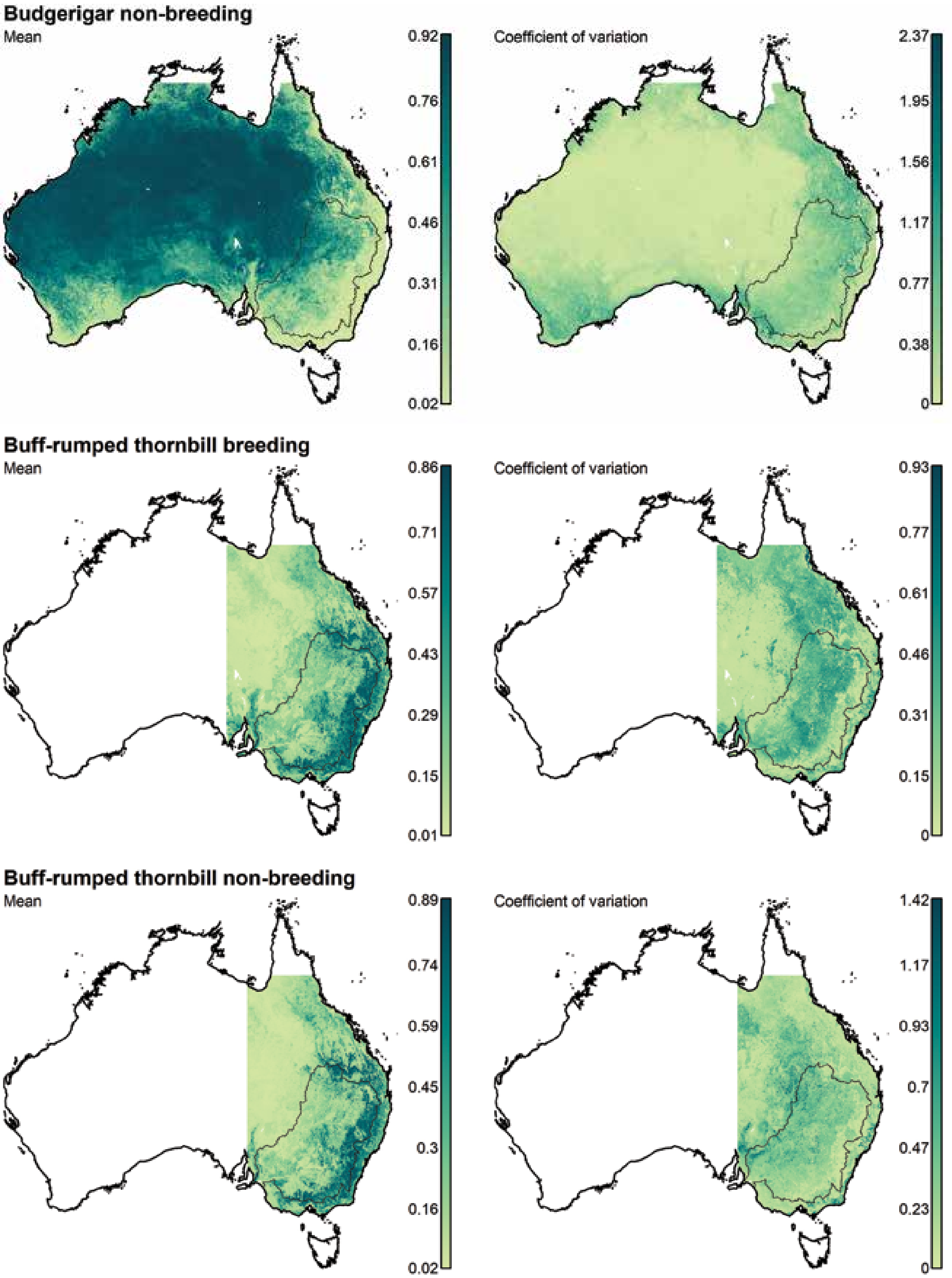


Brown treecreeper non-breeding

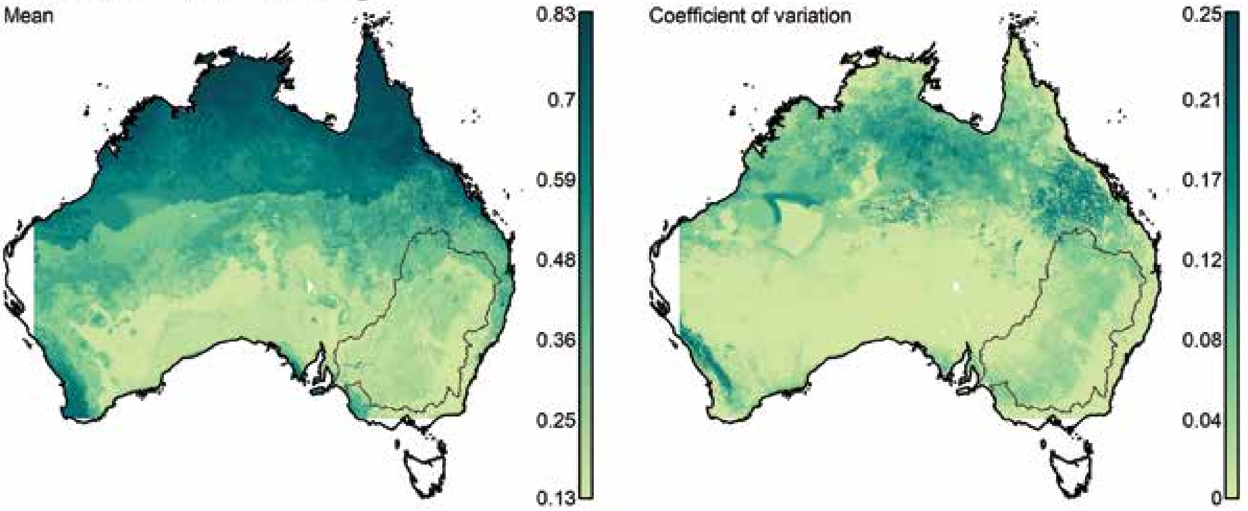


Budgerigar breeding

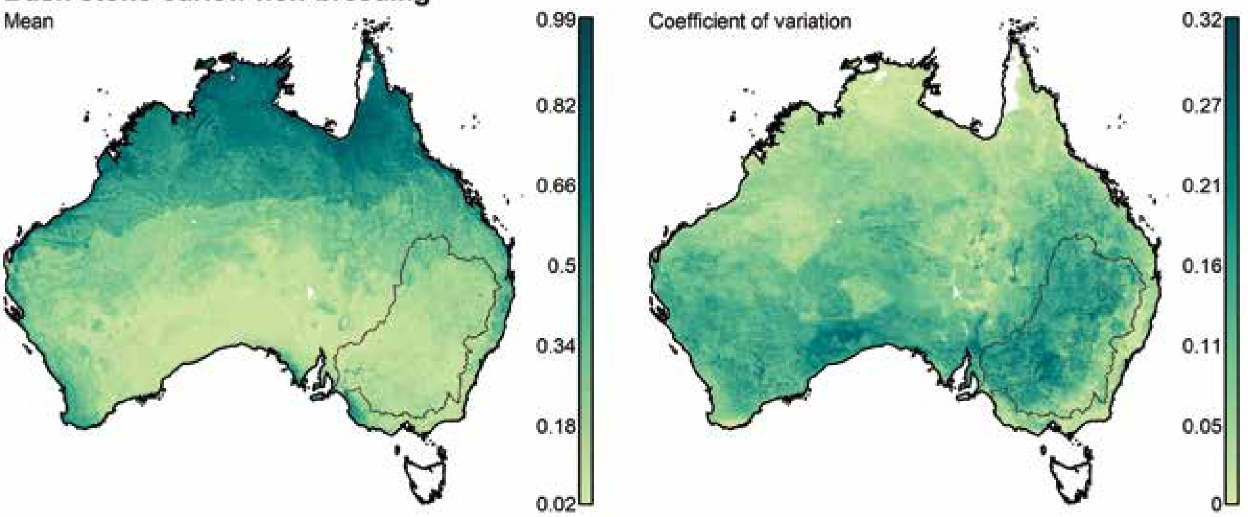



Budgerigar non-breeding
Mean
0.92
0.76
0.61
0.46
0.31
0.16
0.02
Coefficient of variation
2.37
1.95
1.56
1.17
0.77
0.38
0
Buff-rumped thornbill breeding
Mean
0.86
0.71
0.57
0.43
0.29
0.15
0.01
Coefficient of variation
0.93
0.77
0.61
0.46
0.31
0.15
0
Buff-rumped thornbill non-breeding
Mean
0.89
0.74
0.59
0.45
0.3
0.16
0.02
Coefficient of variation
1.42
1.17
0.93
0.7
0.47
0.23
0

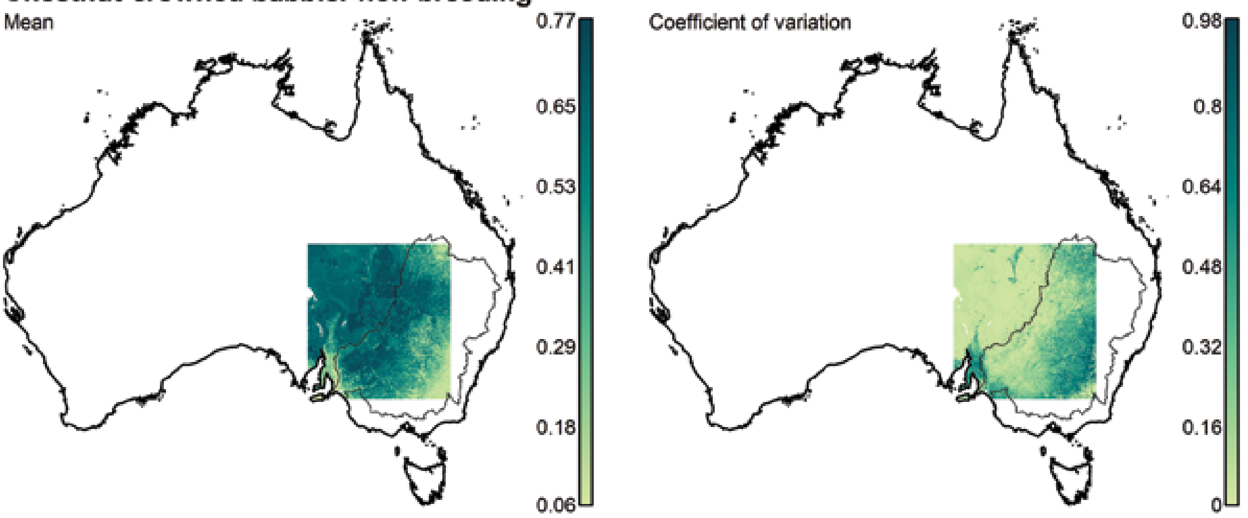
Bush stone-curlew breeding



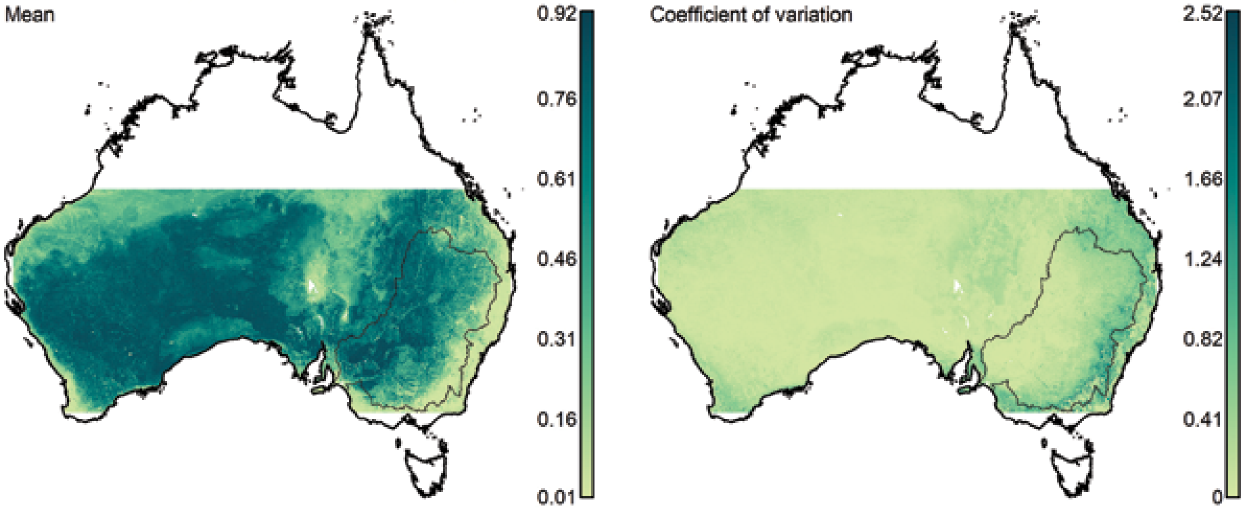
Bush stone-curlew non-breeding



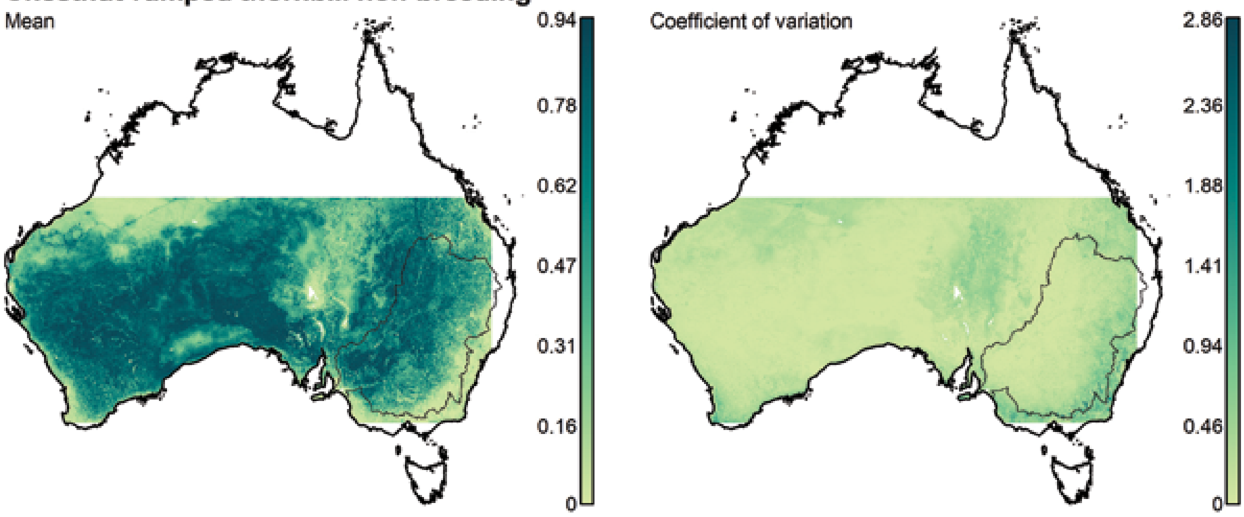
Chestnut-crowned babbler non-breeding



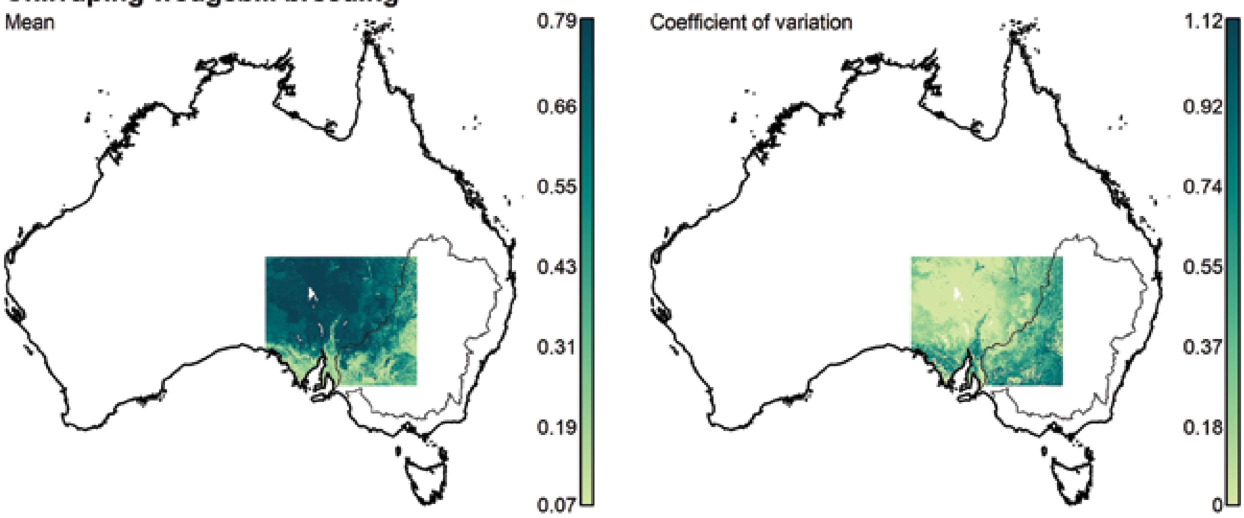
Chestnut-rumped thornbill breeding



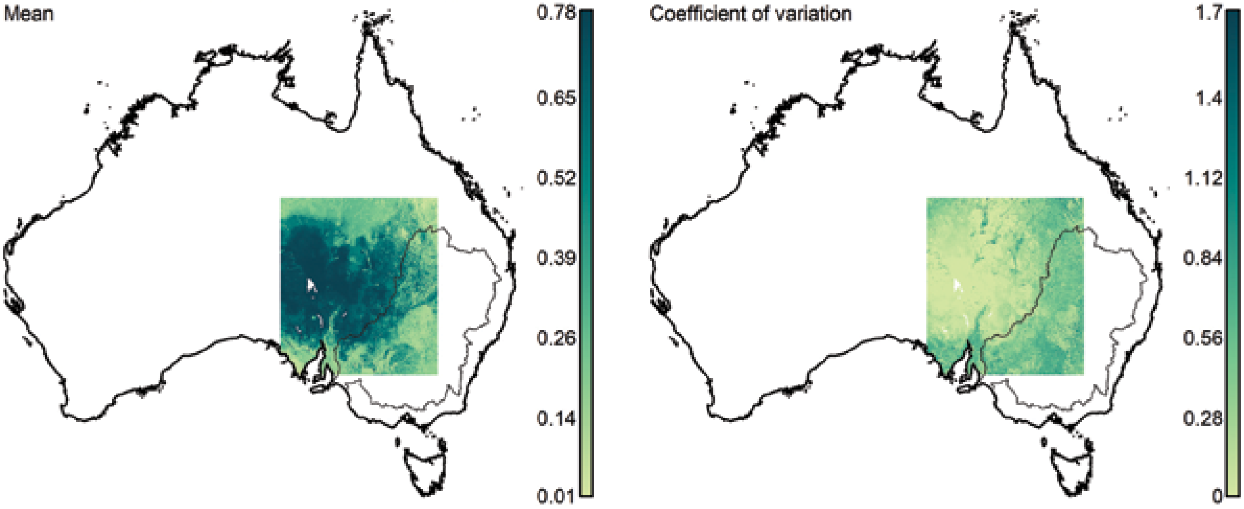
Chestnut-rumped thornbill non-breeding



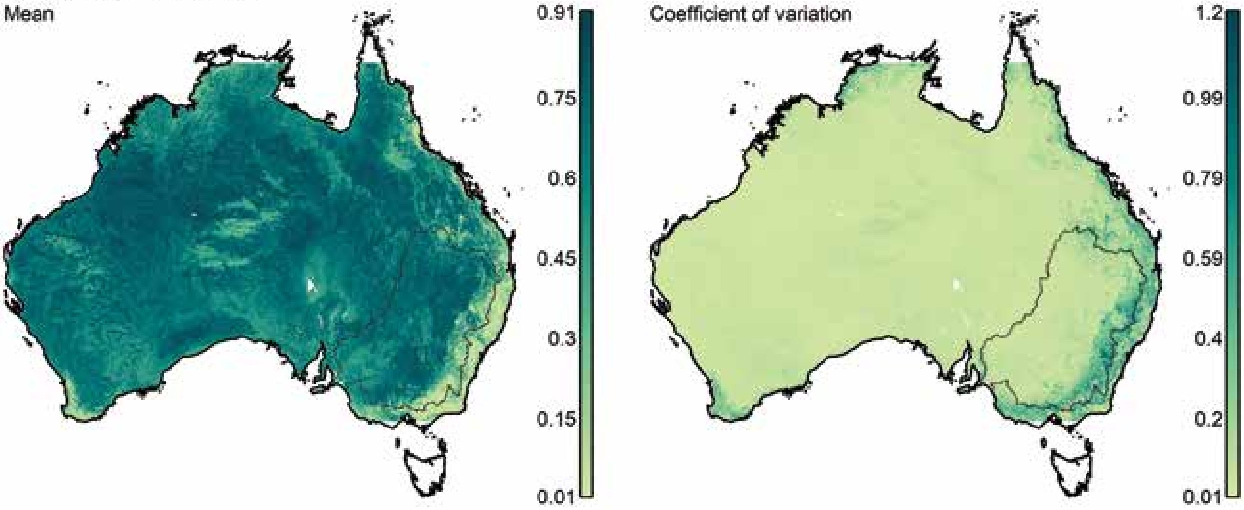
Chirruping wedgebill breeding



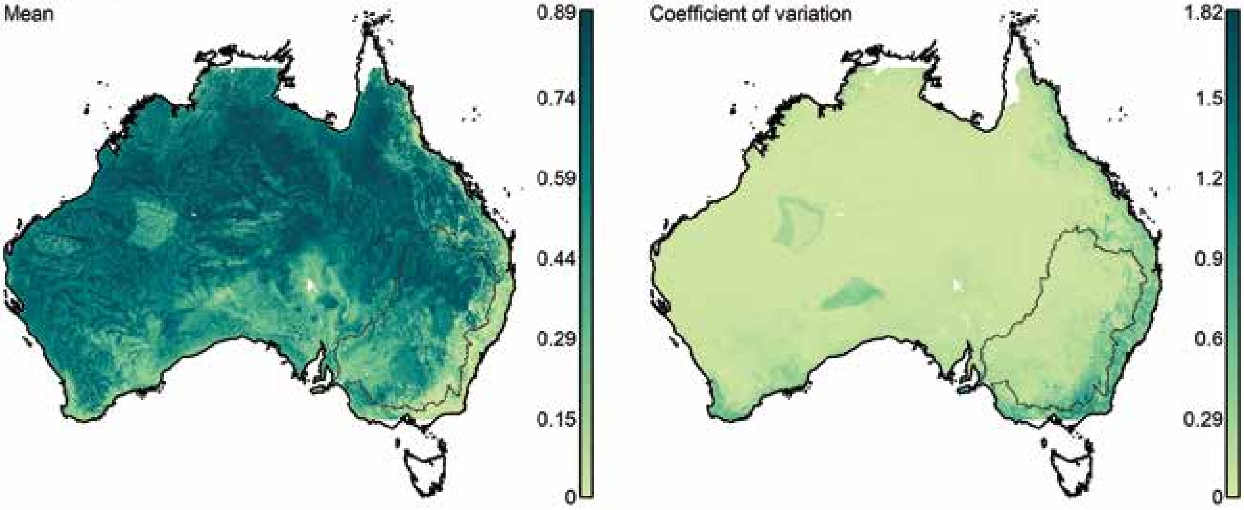
Chirruping wedgebill non-breeding



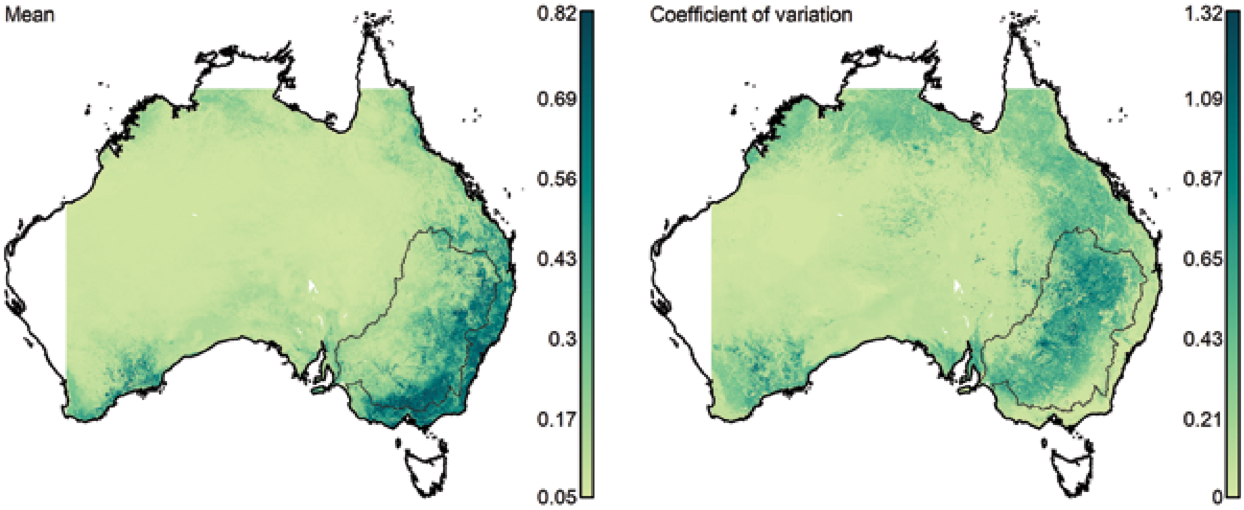
Cockatiel breeding



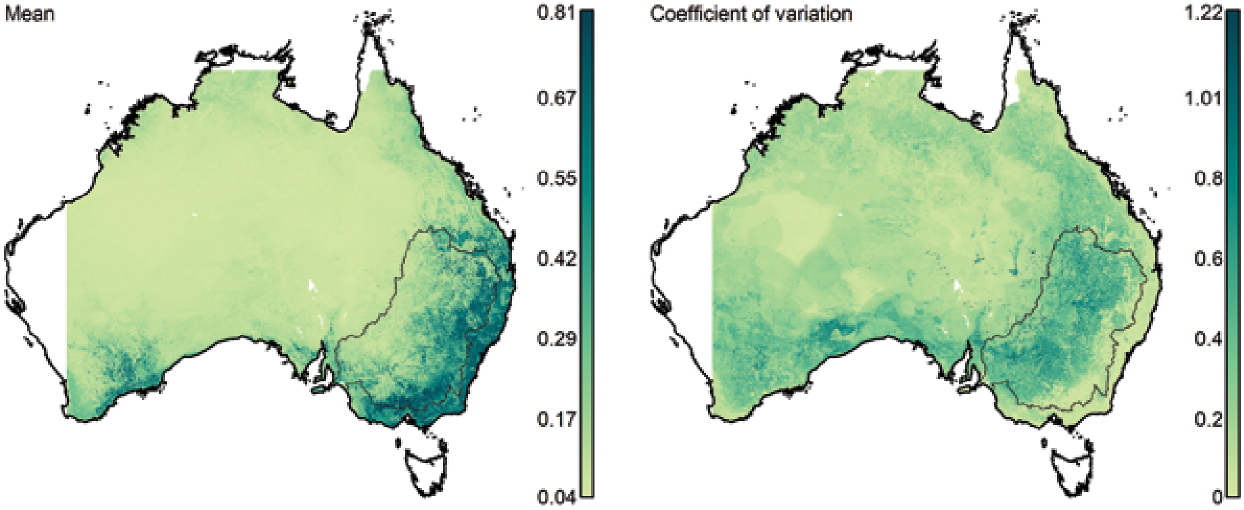
Cockatiel non-breeding



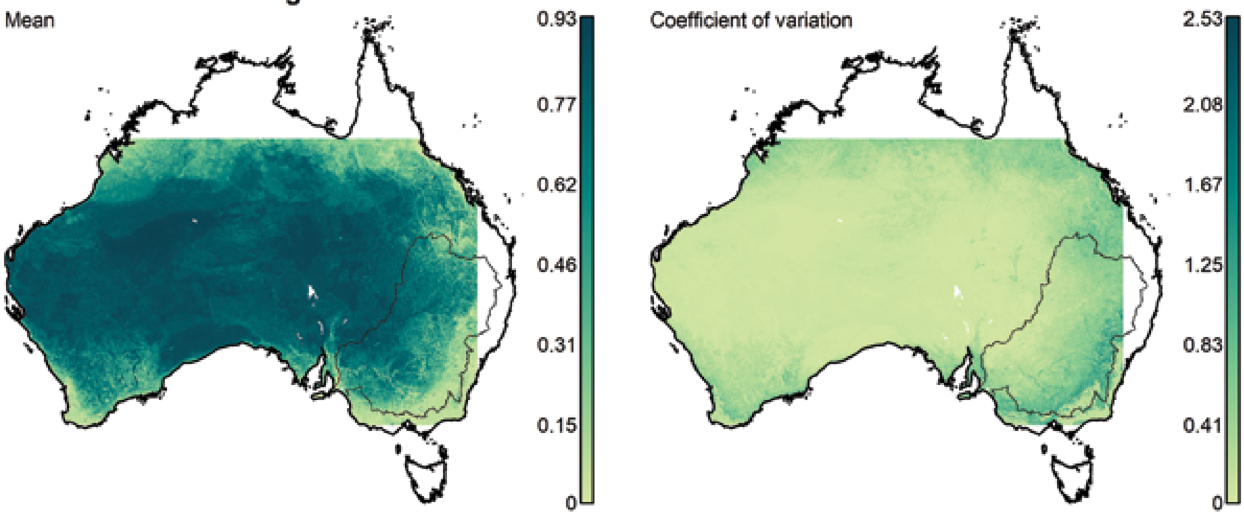
Crested shrike-tit breeding



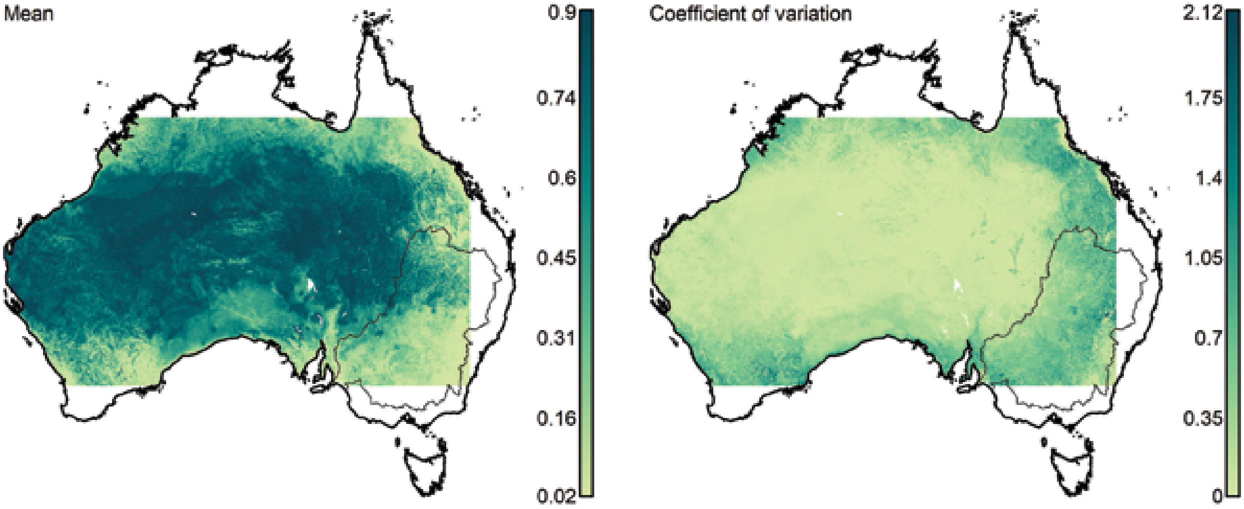
Crested shrike-tit non-breeding



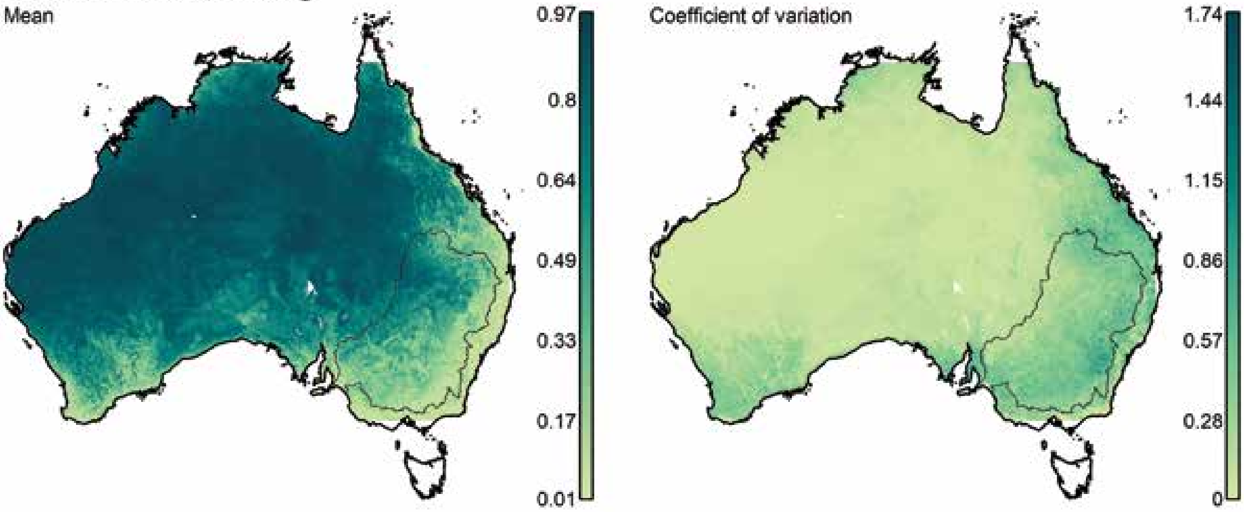
Crimson chat breeding



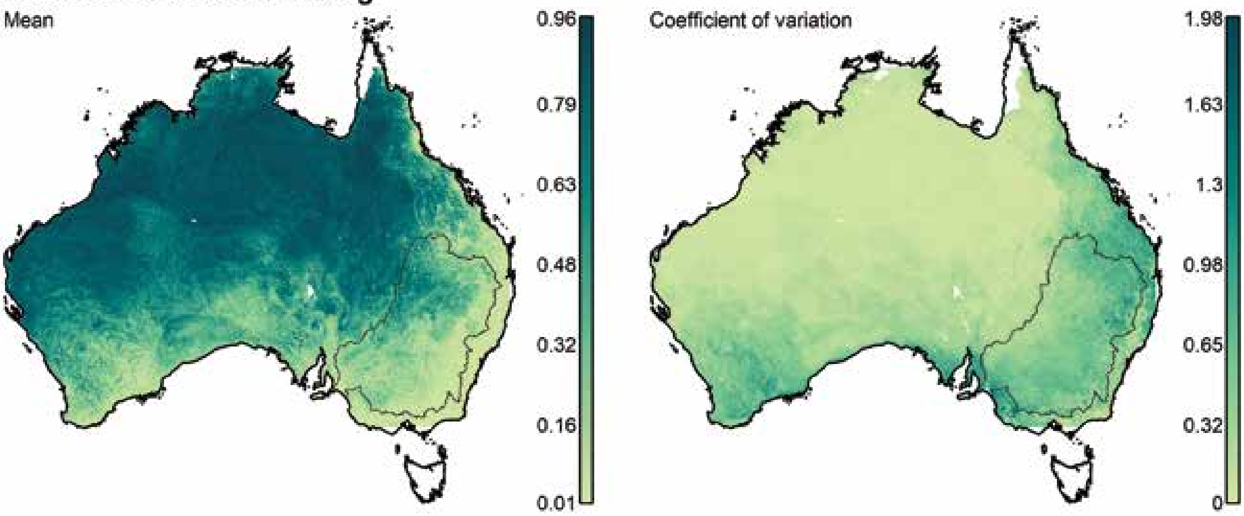
Crimson chat non-breeding



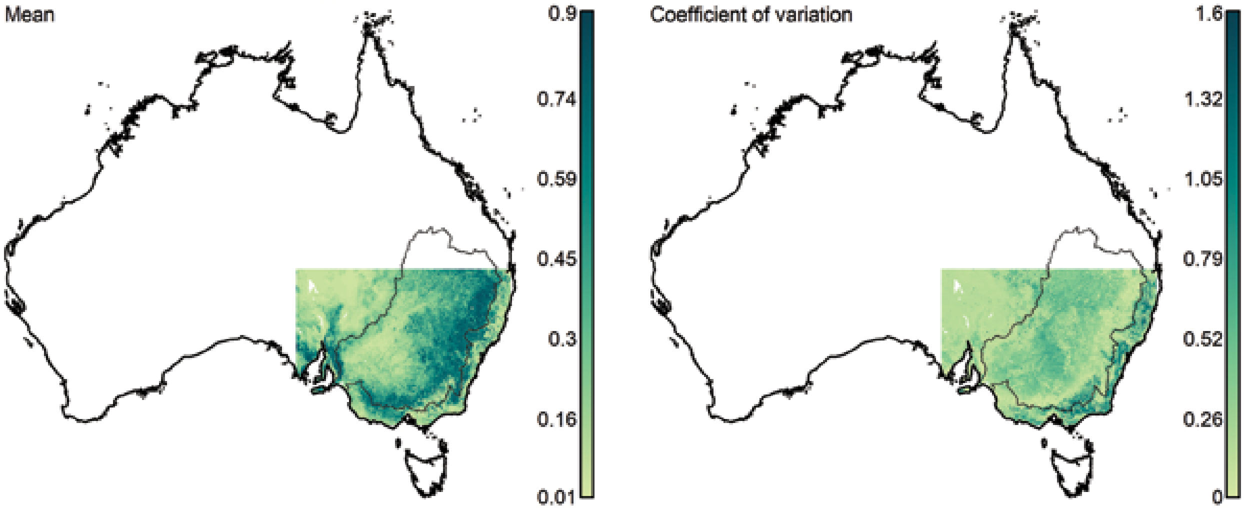
Diamond dove breeding



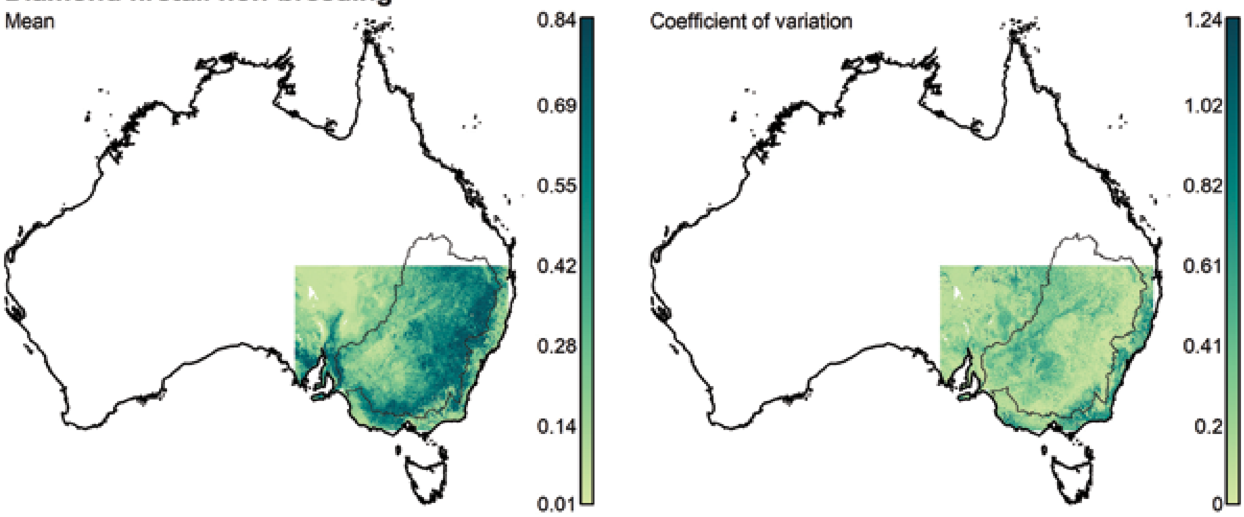
Diamond dove non-breeding



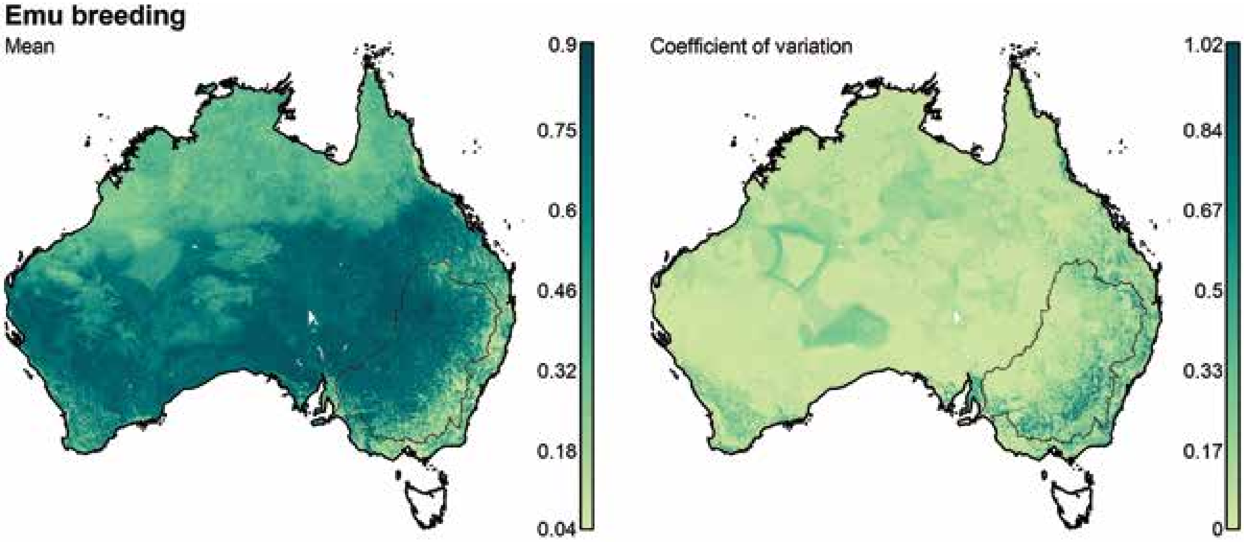
Diamond firetail breeding

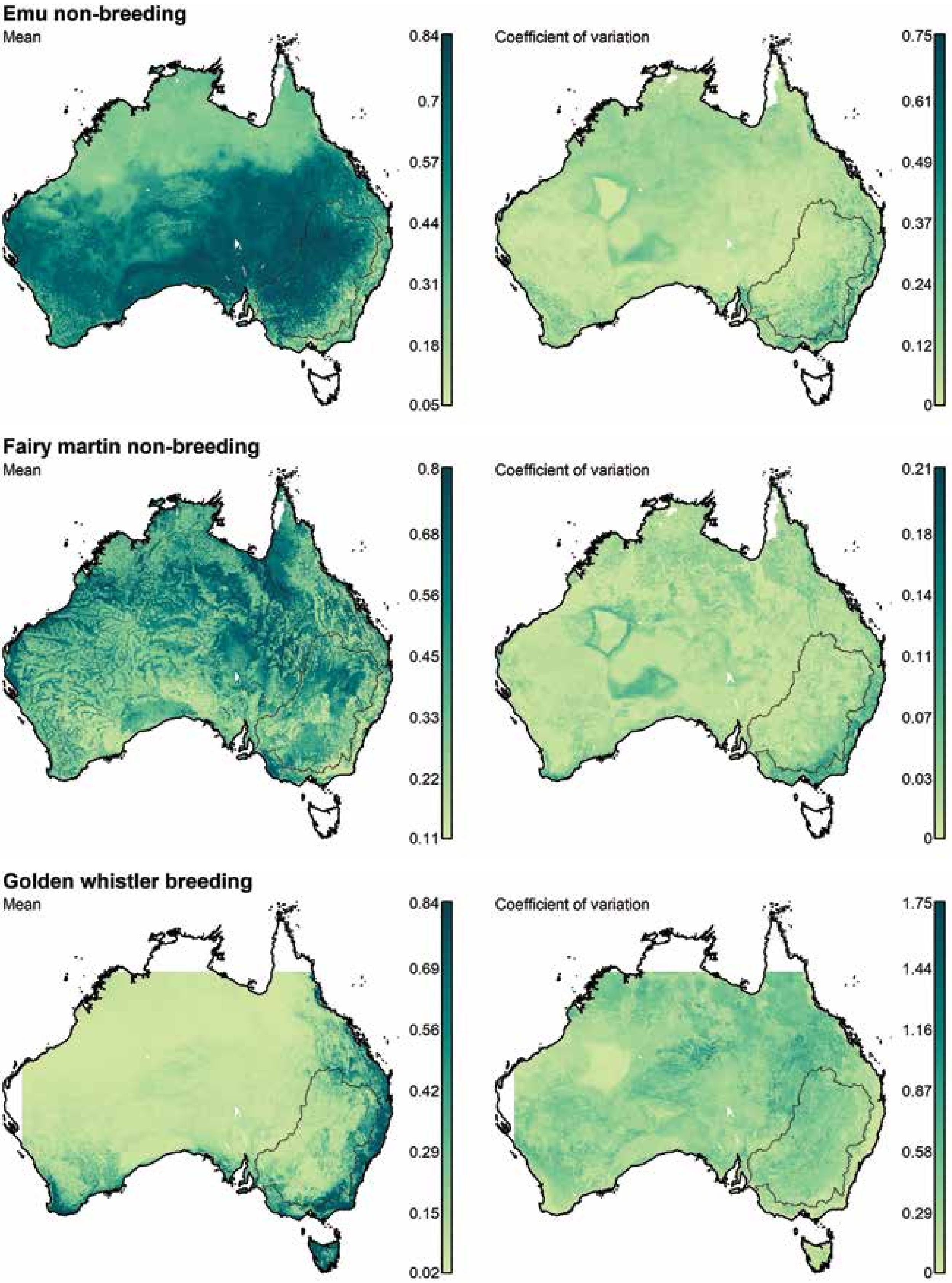


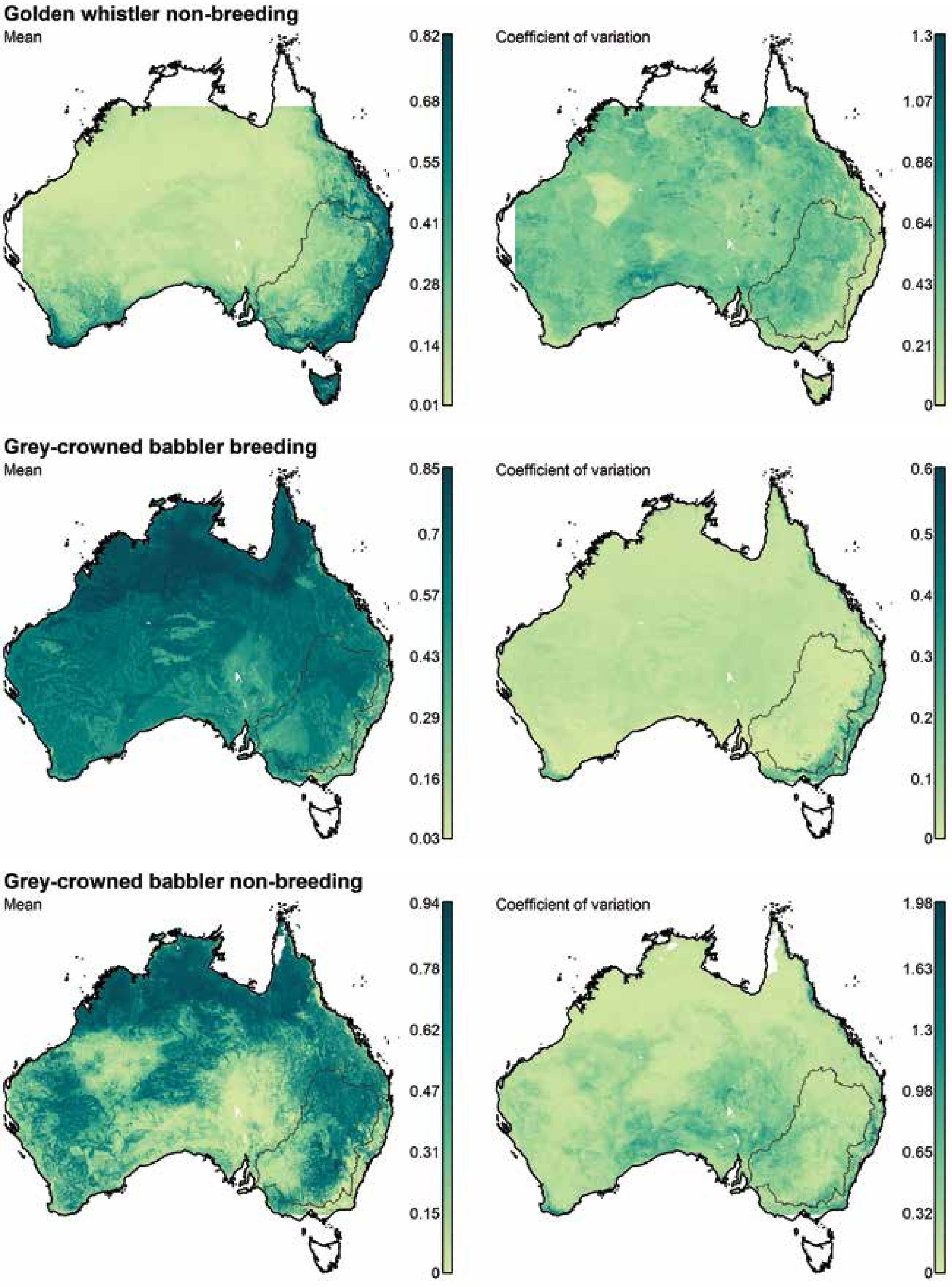
Diamond firetail non-breeding



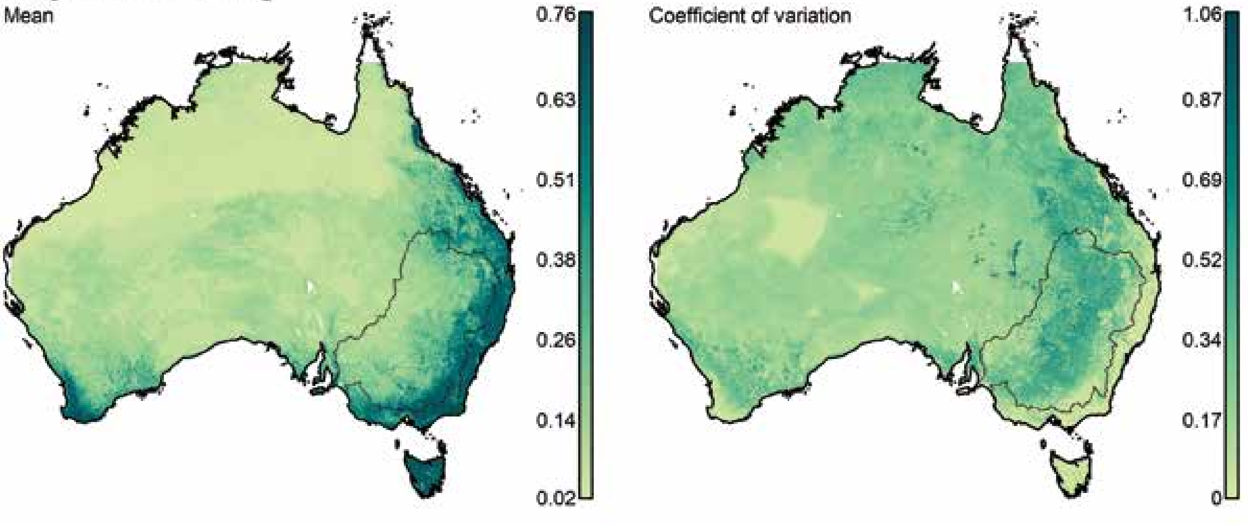
Emu breeding



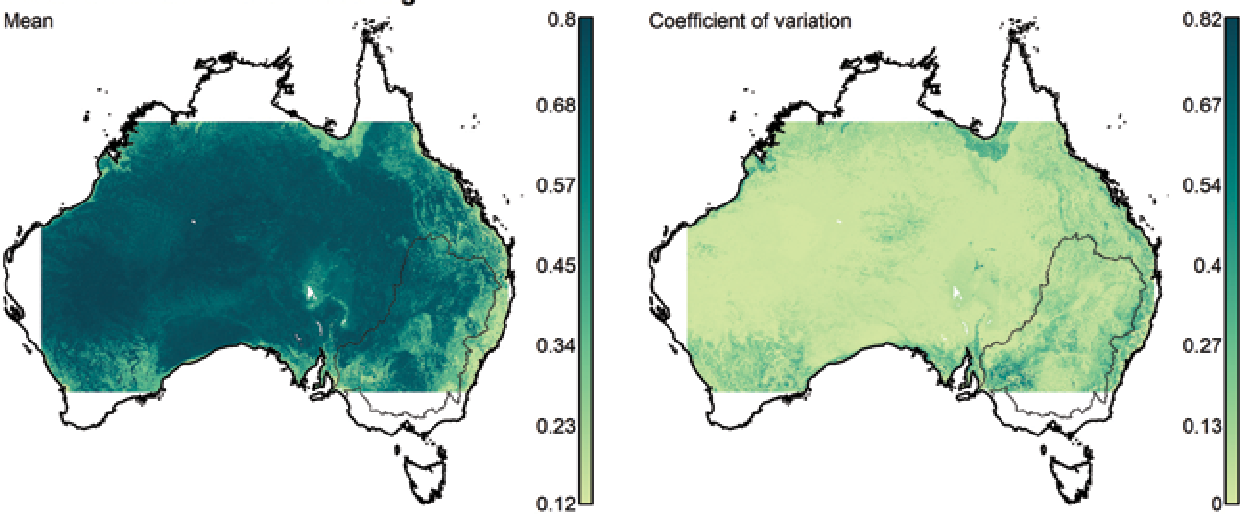

Emu non-breeding
Mean
0.84
0.7
0.57
0.44
0.31
0.18
0.05
Coefficient of variation
0.75
0.61
0.49
0.37
0.24
0.12
0
Fairy martin non-breeding
Mean
0.8
0.68
0.56
0.45
0.33
0.22
0.11
Coefficient of variation
0.21
0.18
0.14
0.11
0.07
0.03
0
Golden whistler breeding
Mean
0.84
0.69
0.56
0.42
0.29
0.15
0.02
Coefficient of variation
1.75
1.44
1.16
0.87
0.58
0.29
0


Golden whistler non-breeding
Mean
0.82
0.68
0.55
0.41
0.28
0.14
0.01
Coefficient of variation
1.3
1.07
0.86
0.64
0.43
0.21
0
Grey-crowned babbler breeding
Mean
0.85
0.7
0.57
0.43
0.29
0.16
0.03
Coefficient of variation
0.6
0.5
0.4
0.3
0.2
0.1
0
Grey-crowned babbler non-breeding
Mean
0.94
0.78
0.62
0.47
0.31
0.15
0
Coefficient of variation
1.98
1.63
1.3
0.98
0.65
0.32
0

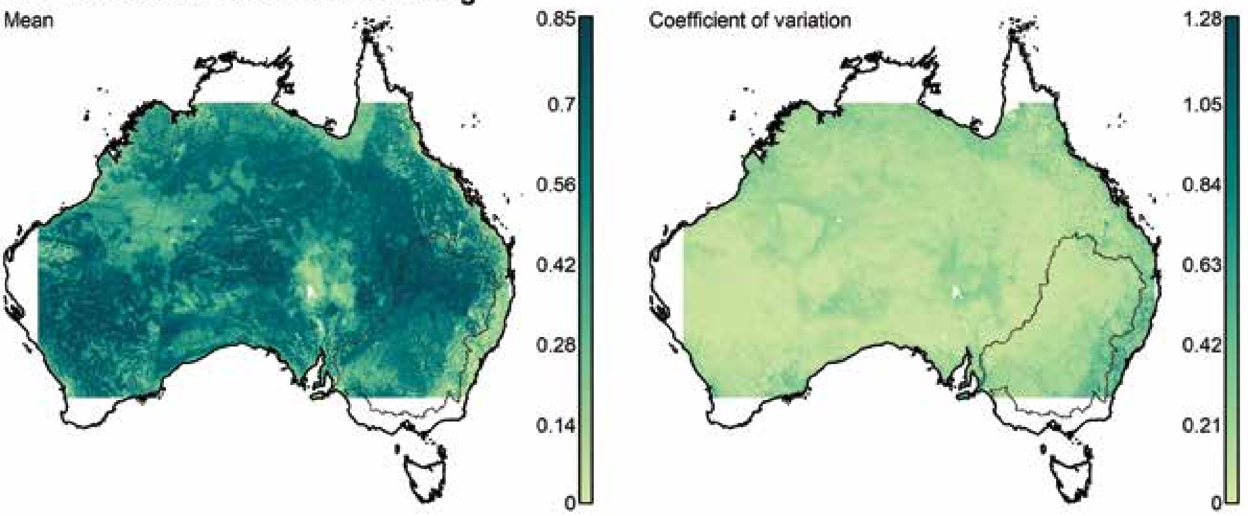
Grey fantail breeding

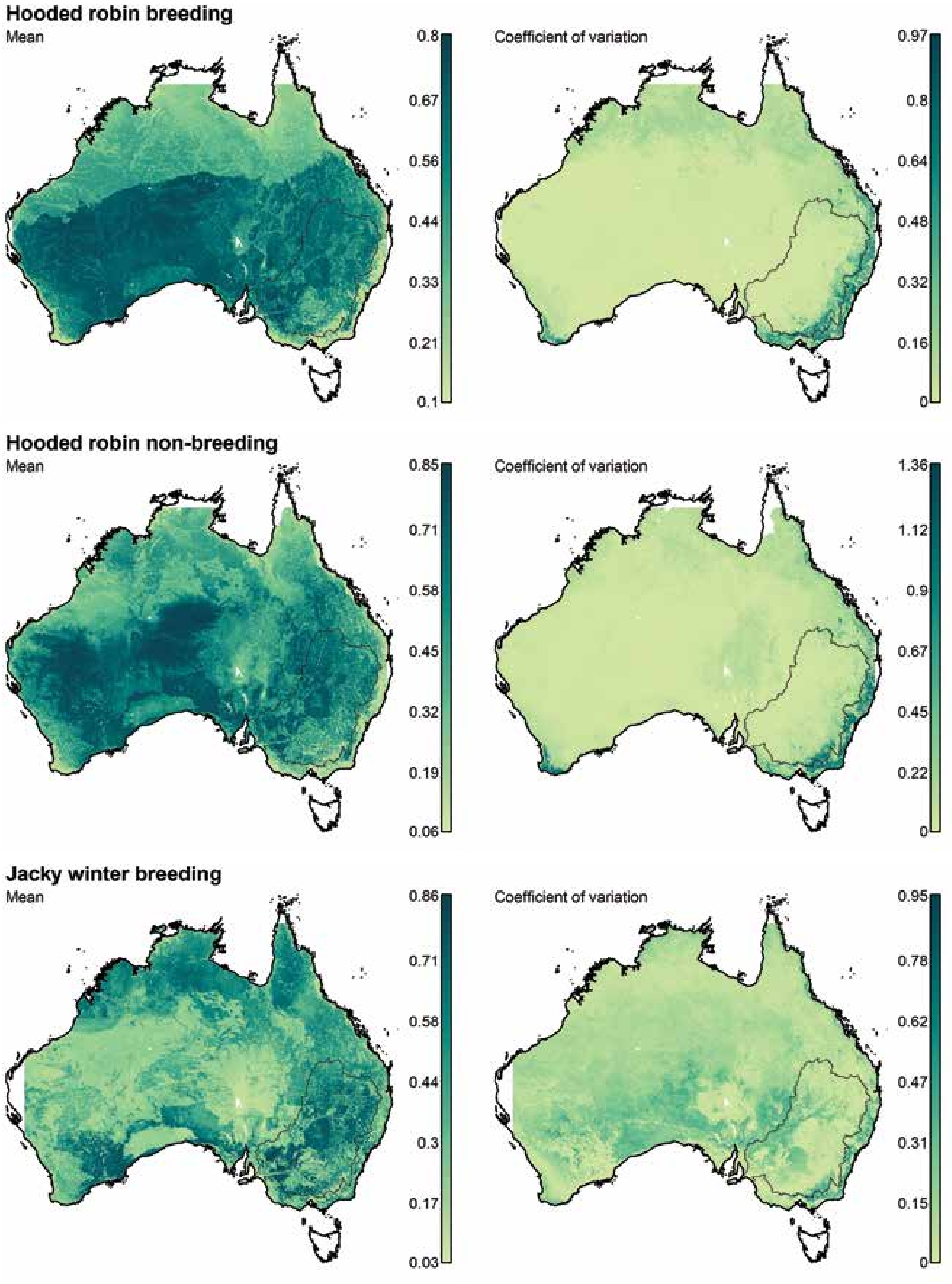


Ground cuckoo-shrike breeding

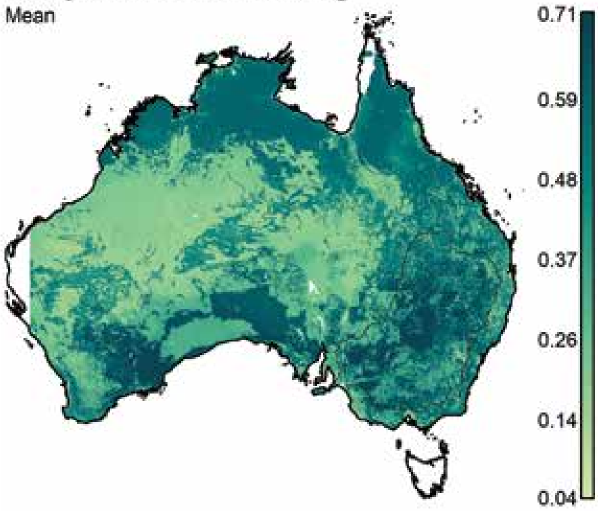


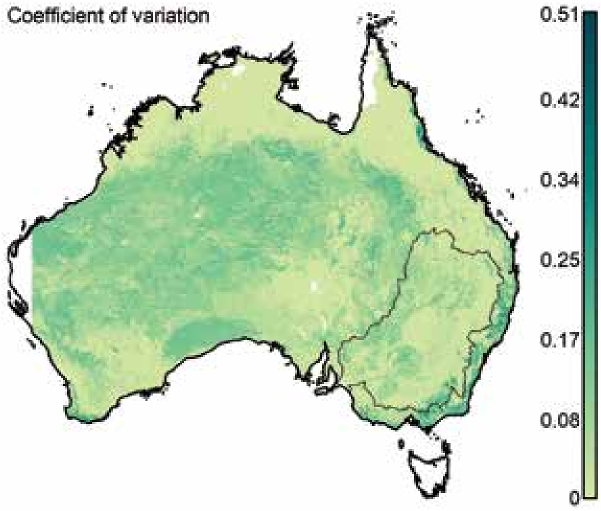
Ground cuckoo-shrike non-breeding



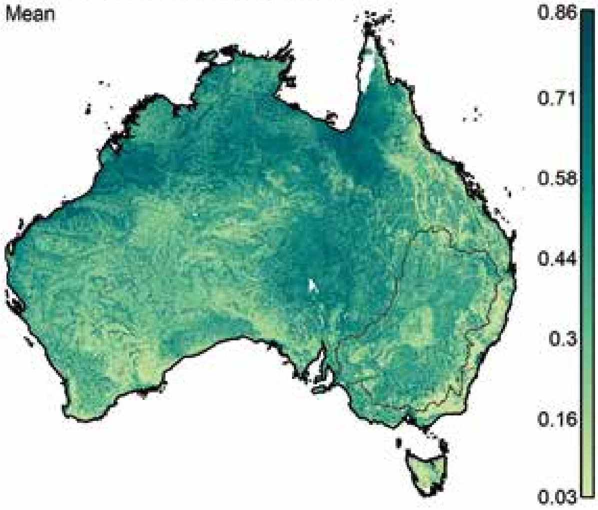

Hooded robin breeding
Mean
0.8
0.67
0.56
0.44
0.33
0.21
0.1
Coefficient of variation
0.97
0.8
0.64
0.48
0.32
0.16
0
Hooded robin non-breeding
Mean
0.85
0.71
0.58
0.45
0.32
0.19
0.06
Coefficient of variation
1.36
1.12
0.9
0.67
0.45
0.22
0
Jacky winter breeding
Mean
0.86
0.71
0.58
0.44
0.3
0.17
0.03
Coefficient of variation
0.95
0.78
0.62
0.47
0.31
0.15
0

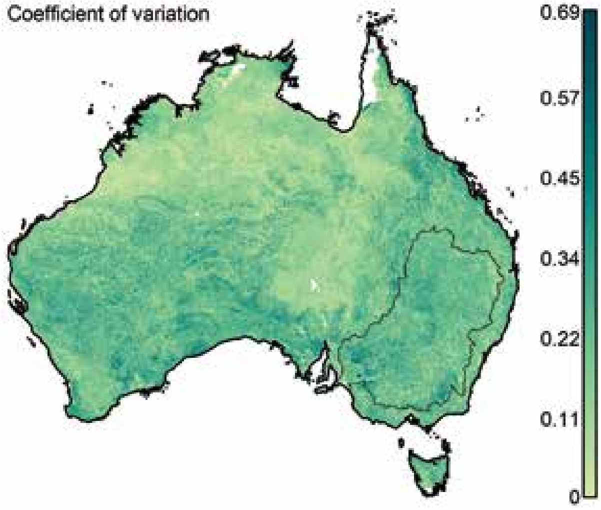
Jacky winter non-breeding



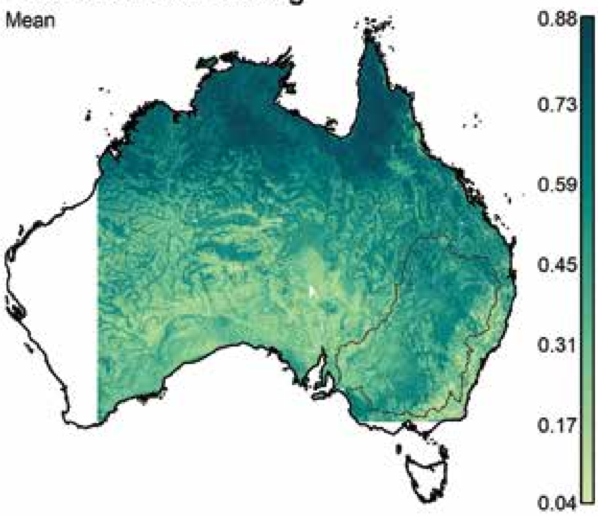


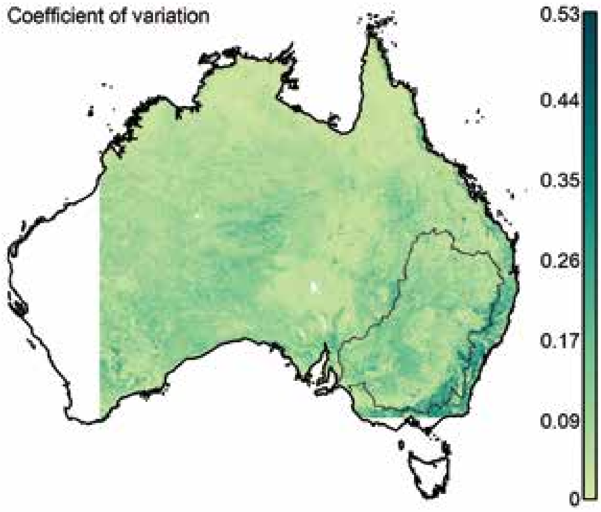
Little corella non-breeding

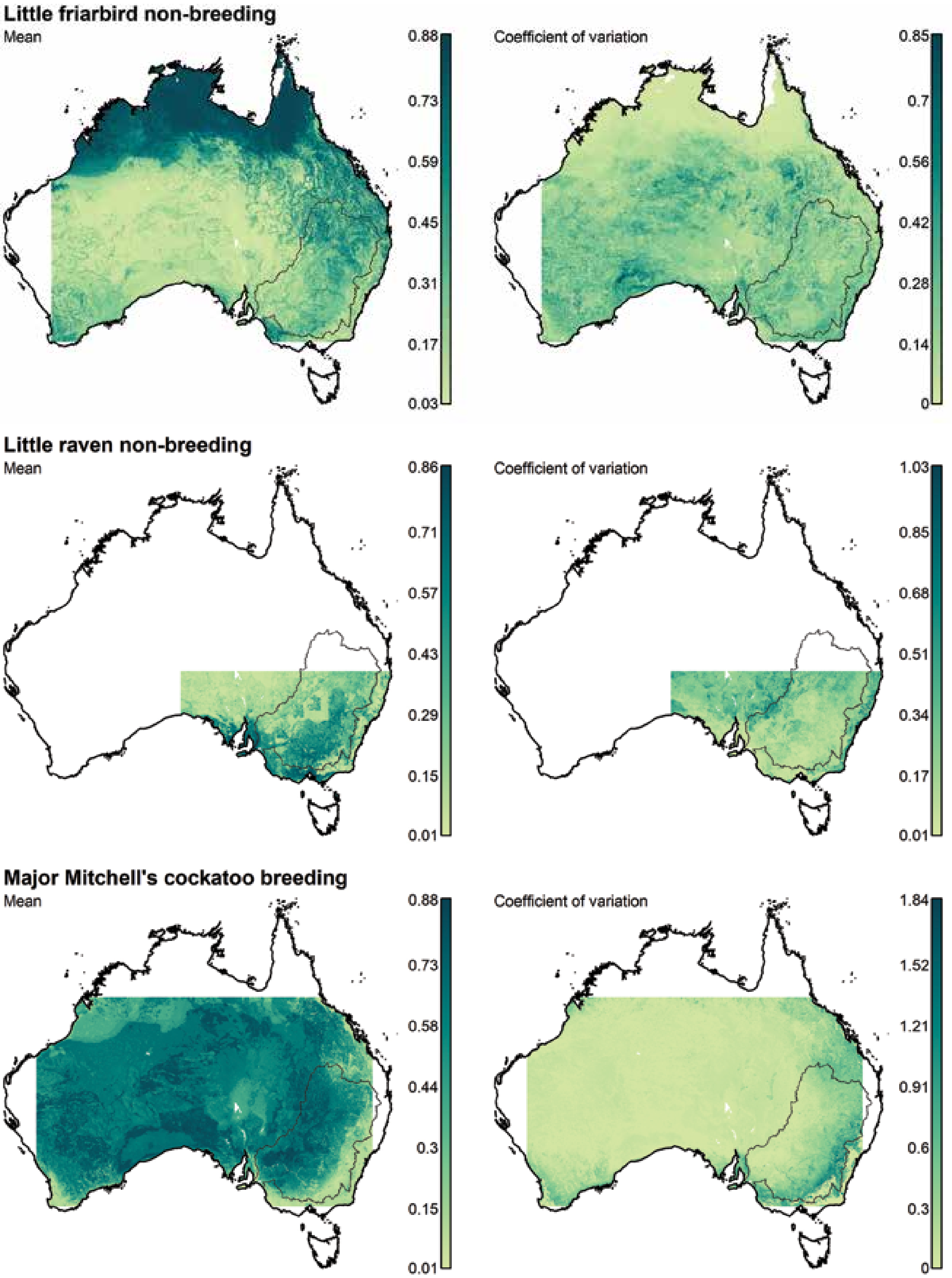




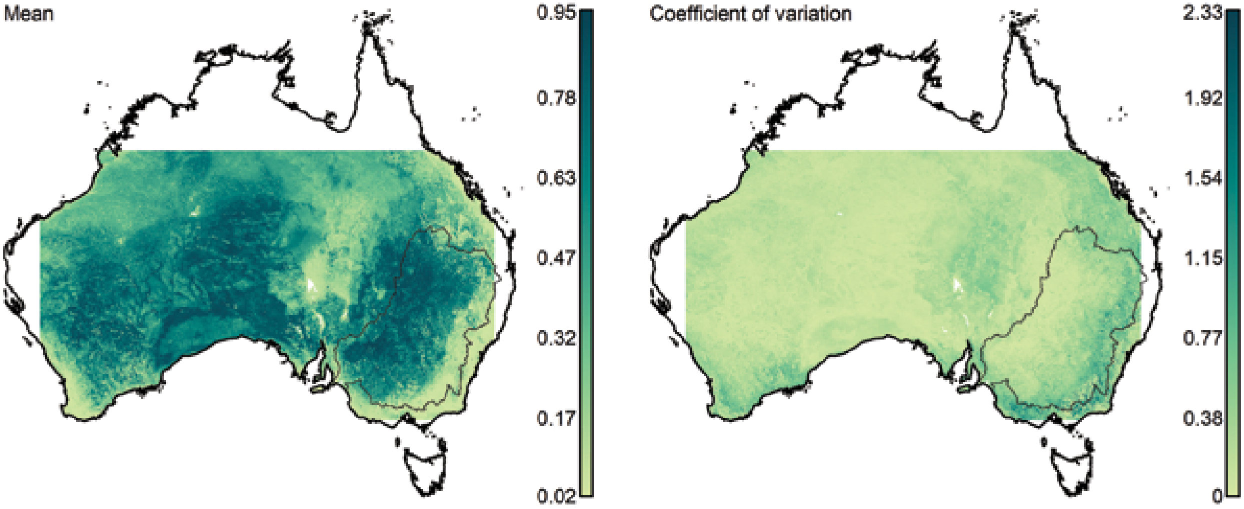
Little friarbird breeding



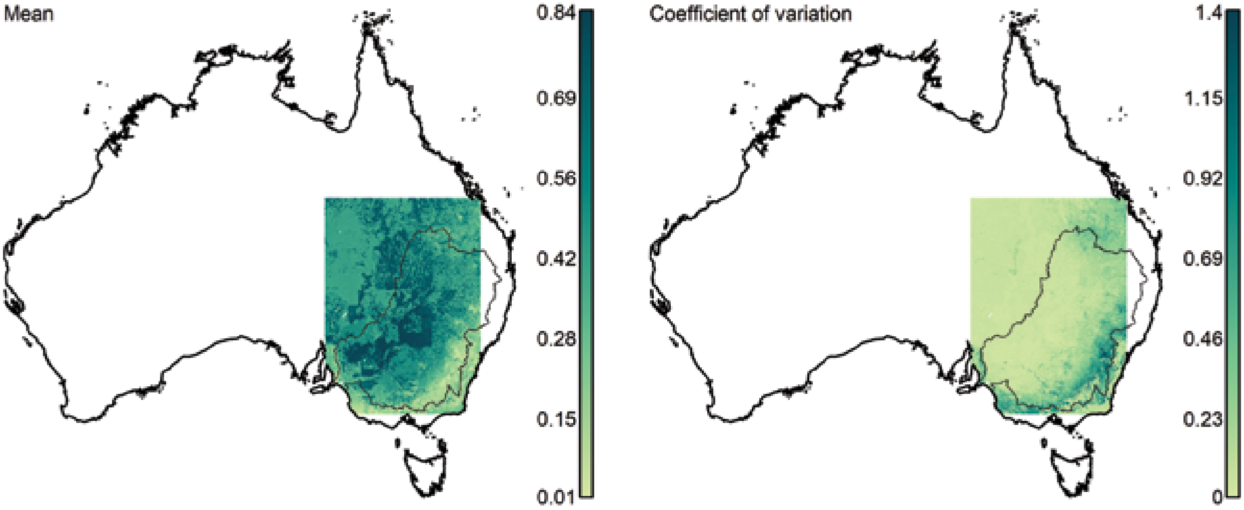



Little friarbird non-breeding
Mean
0.88
0.73
0.59
0.45
0.31
0.17
0.03
Coefficient of variation
0.85
0.7
0.56
0.42
0.28
0.14
0
Little raven non-breeding
Mean
0.86
0.71
0.57
0.43
0.29
0.15
0.01
Coefficient of variation
1.03
0.85
0.68
0.51
0.34
0.17
0.01
Major Mitchell's cockatoo breeding
Mean
0.88
0.73
0.58
0.44
0.3
0.15
0.01
Coefficient of variation
1.84
1.52
1.21
0.91
0.6
0.3
0

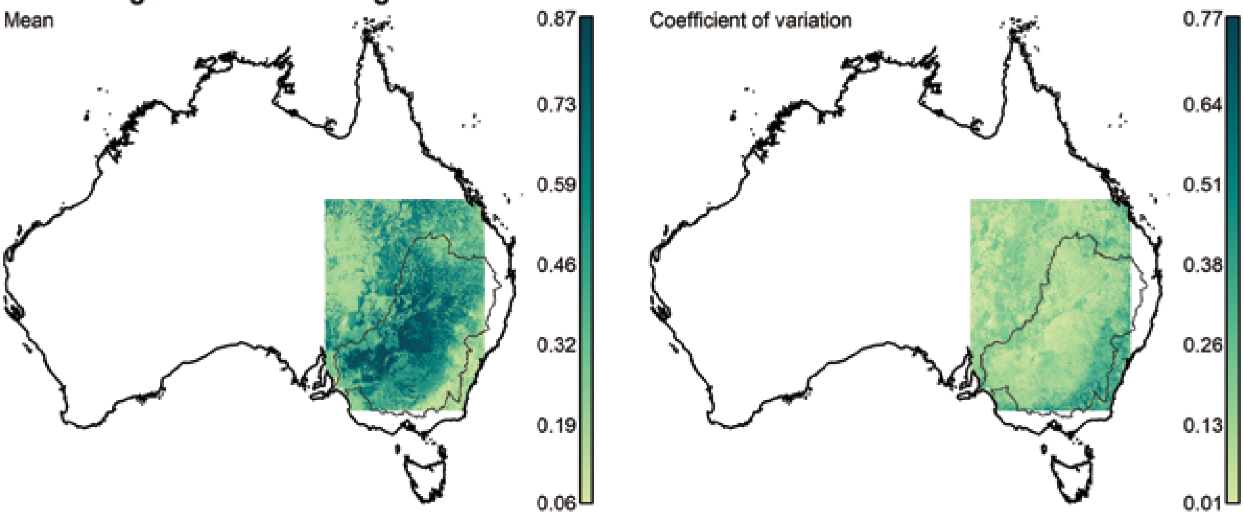
Major Mitchell's cockatoo non-breeding

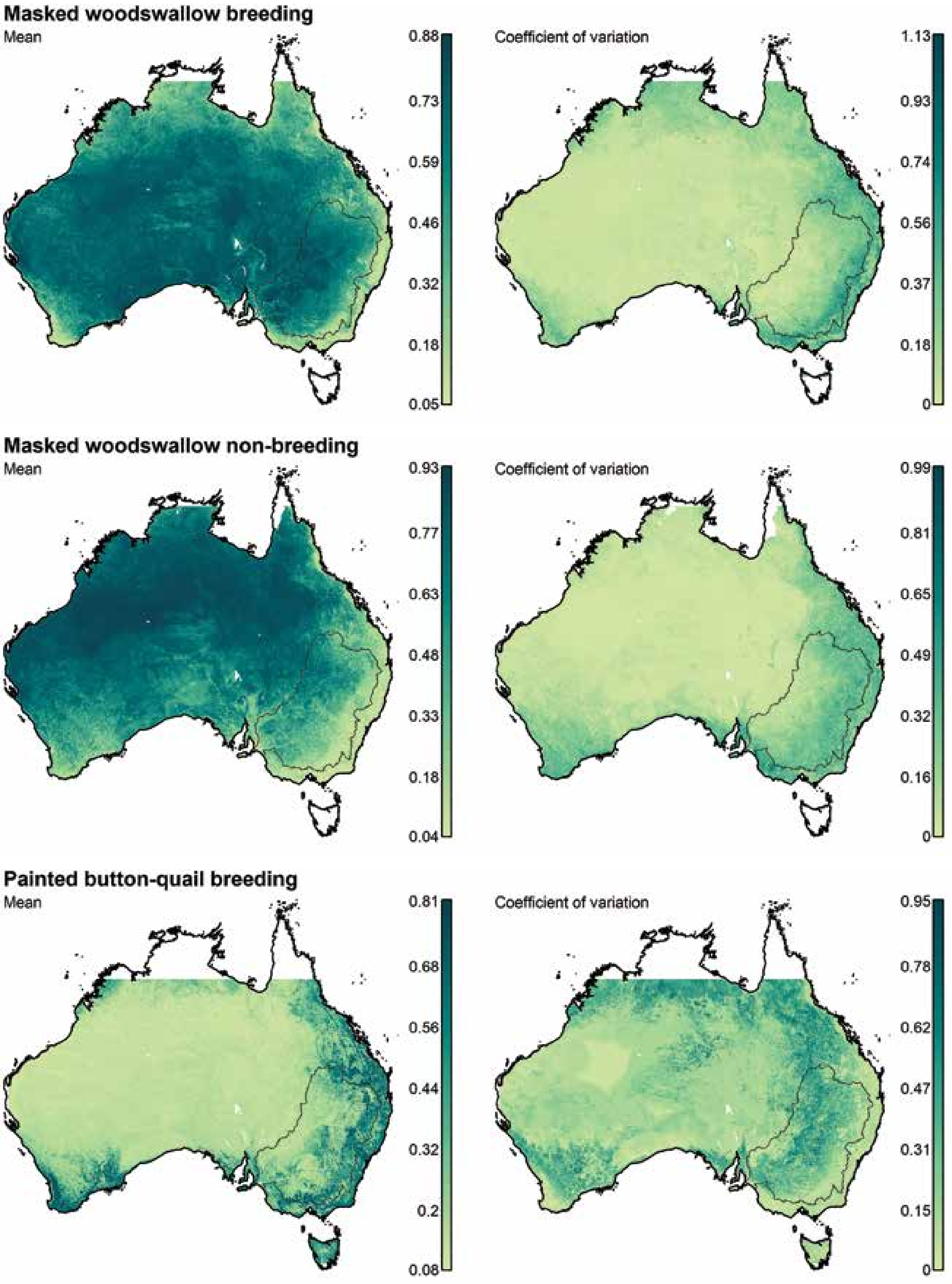


Mallee ringneck breeding

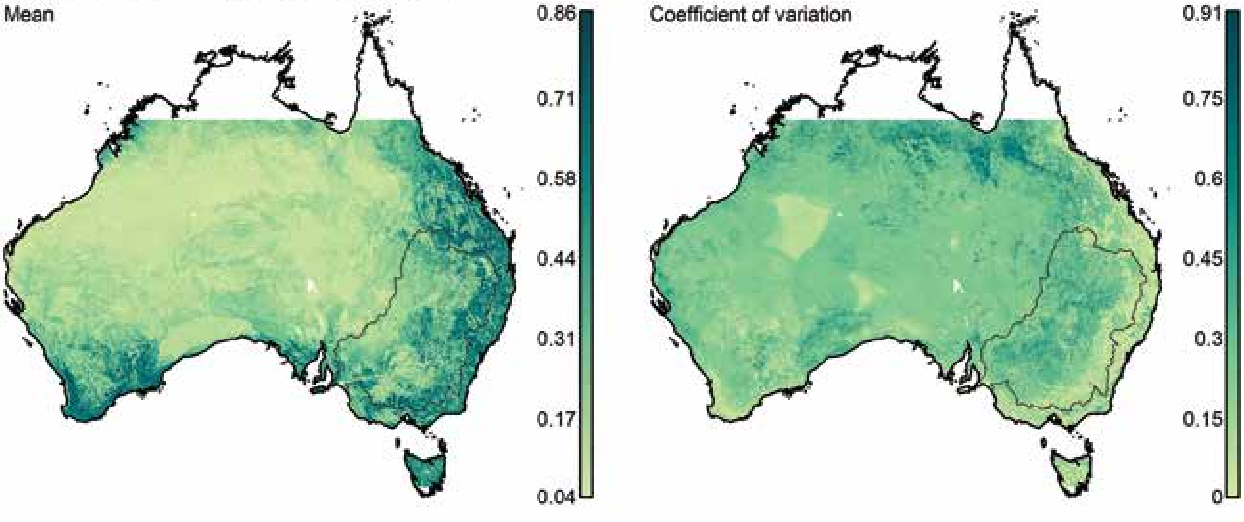


Mallee ringneck non-breeding

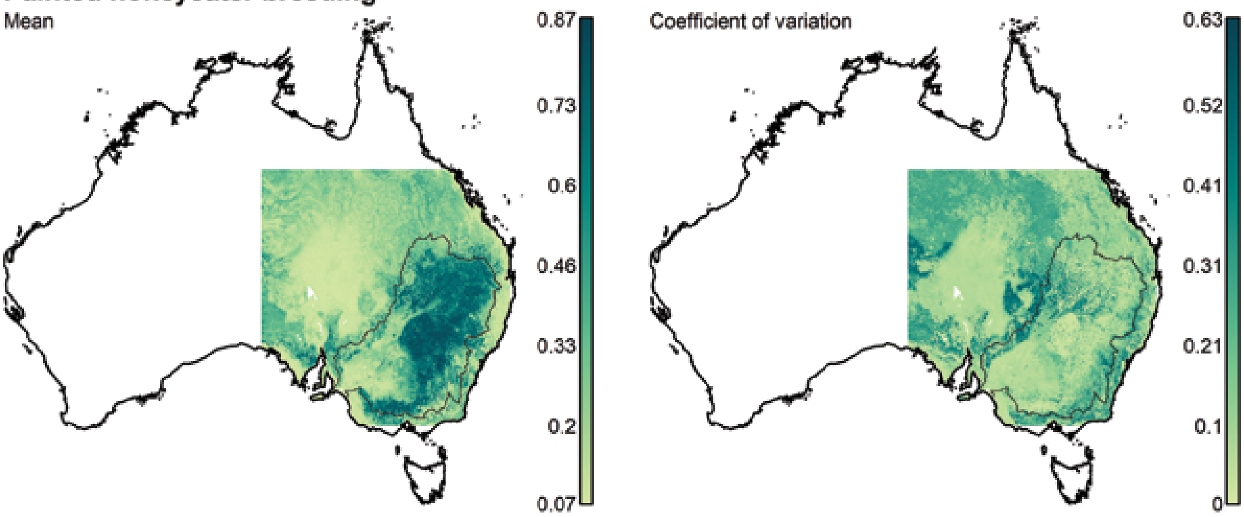



Masked woodswallow breeding
Mean
0.88
0.73
0.59
0.46
0.32
0.18
0.05
Coefficient of variation
1.13
0.93
0.74
0.56
0.37
0.18
0
Masked woodswallow non-breeding
Mean
0.93
0.77
0.63
0.48
0.33
0.18
0.04
Coefficient of variation
0.99
0.81
0.65
0.49
0.32
0.16
0
Painted button-quail breeding
Mean
0.81
0.68
0.56
0.44
0.32
0.2
0.08
Coefficient of variation
0.95
0.78
0.62
0.47
0.31
0.15
0

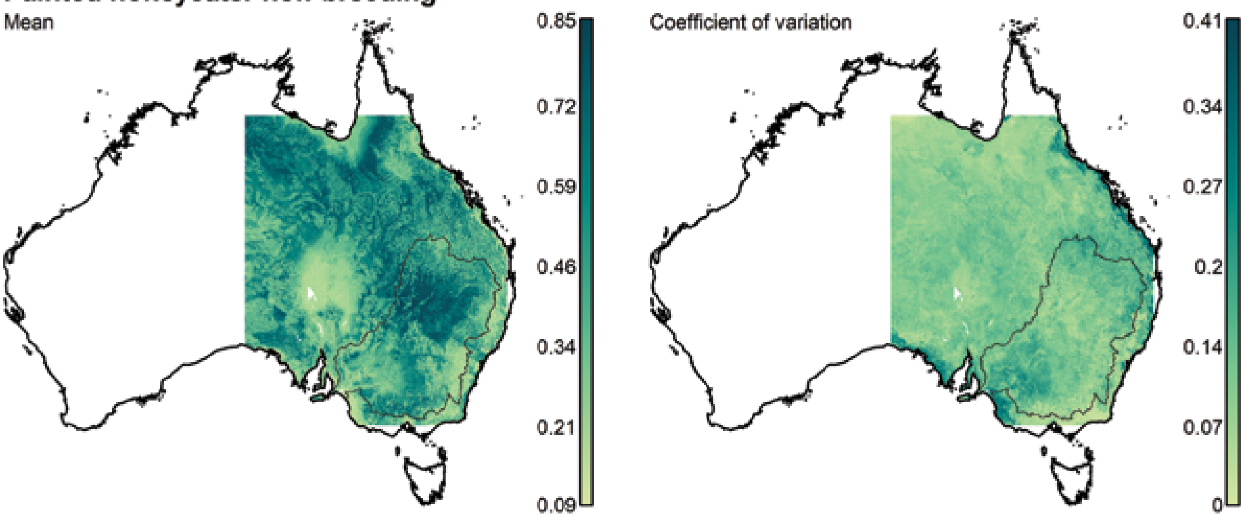
Painted button-quail non-breeding



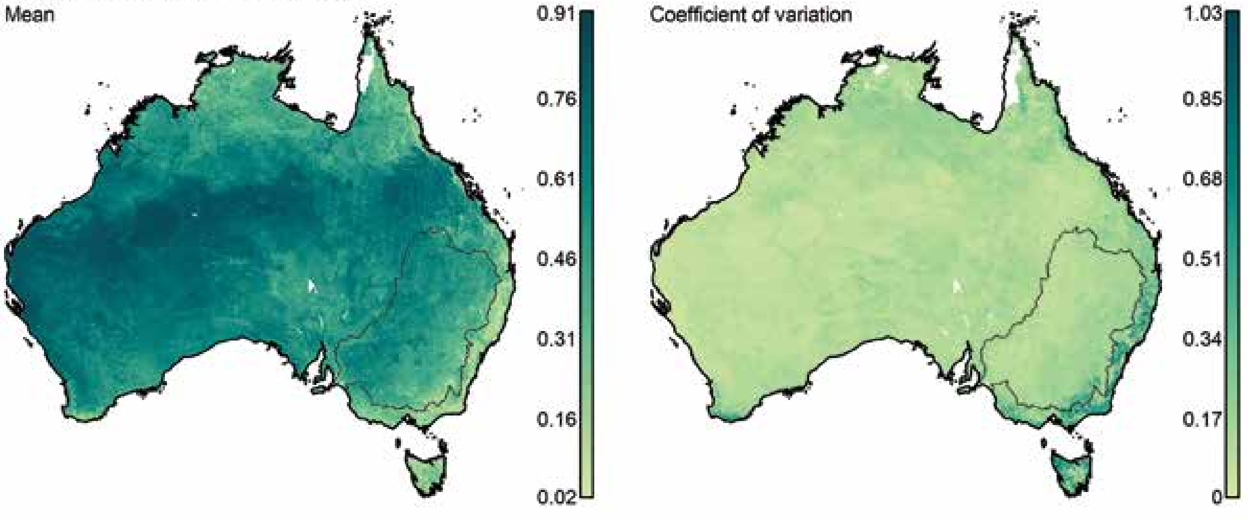
Painted honeyeater breeding



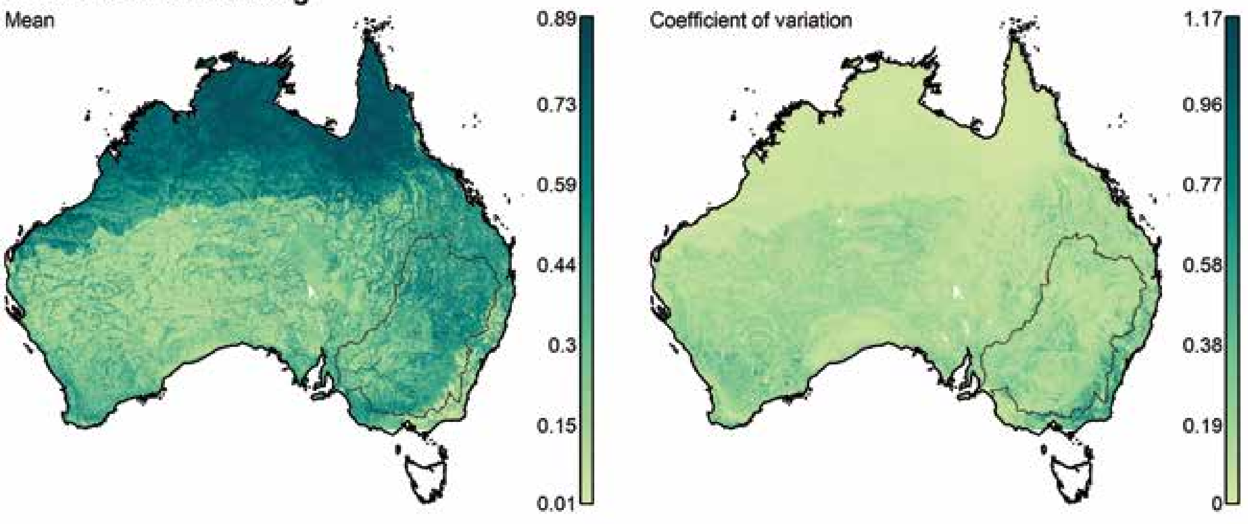
Painted honeyeater non-breeding



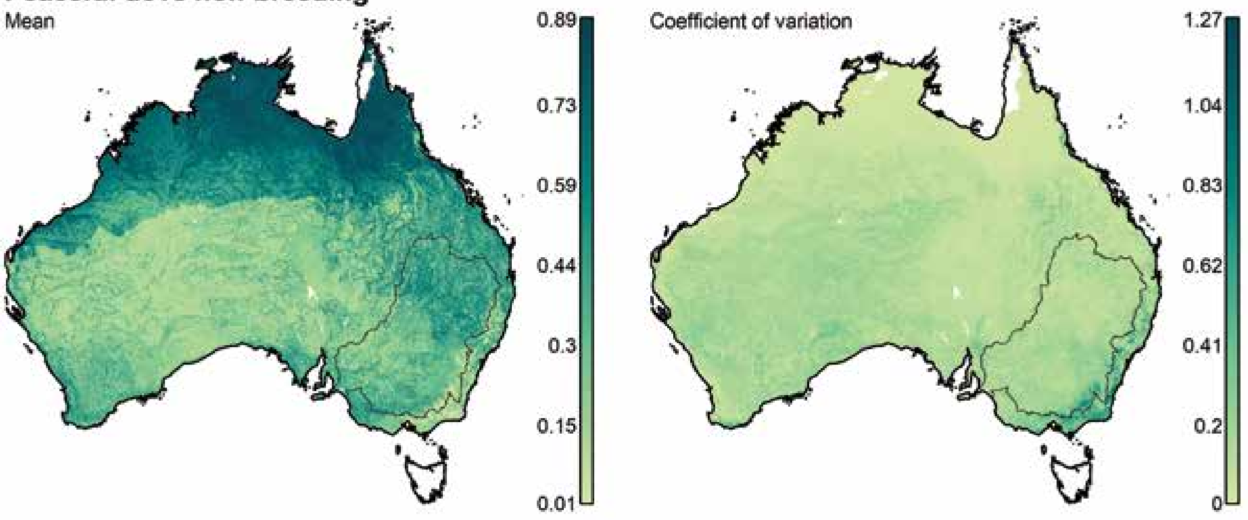
Pallid cuckoo non-breeding



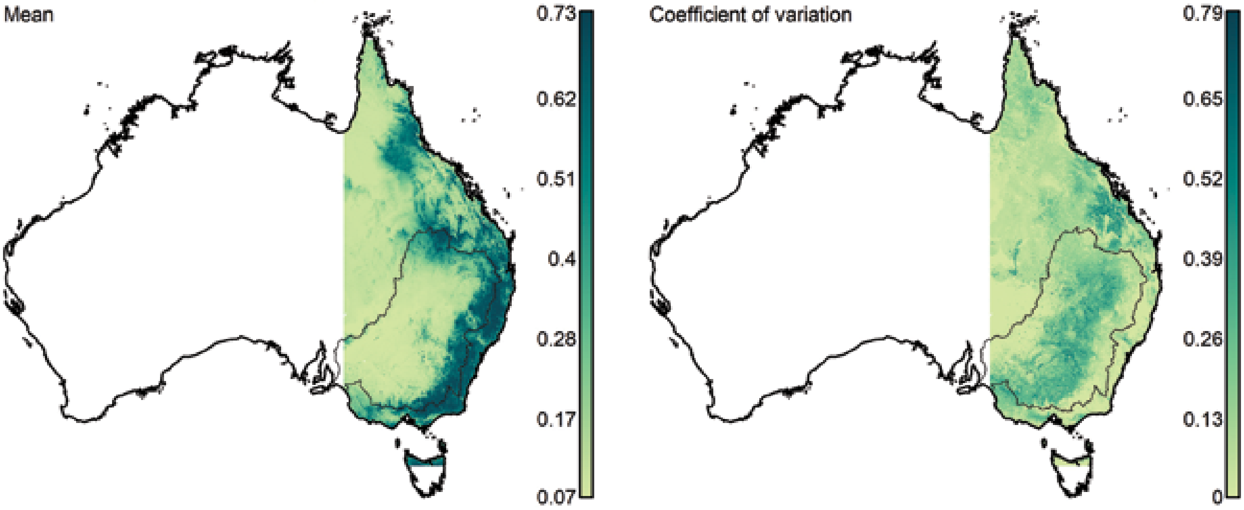
Peaceful dove breeding



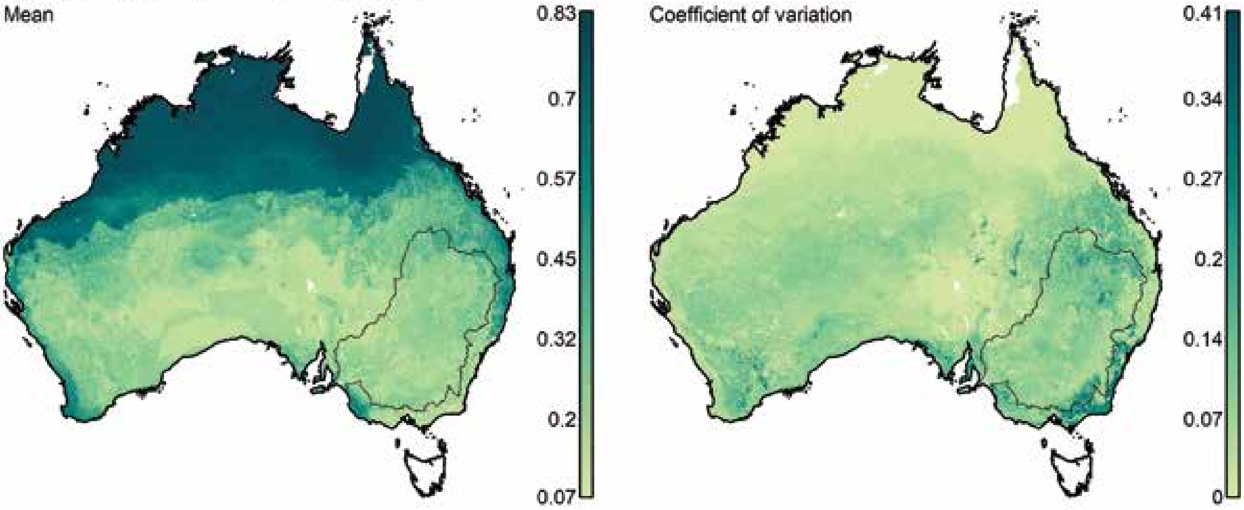
Peaceful dove non-breeding



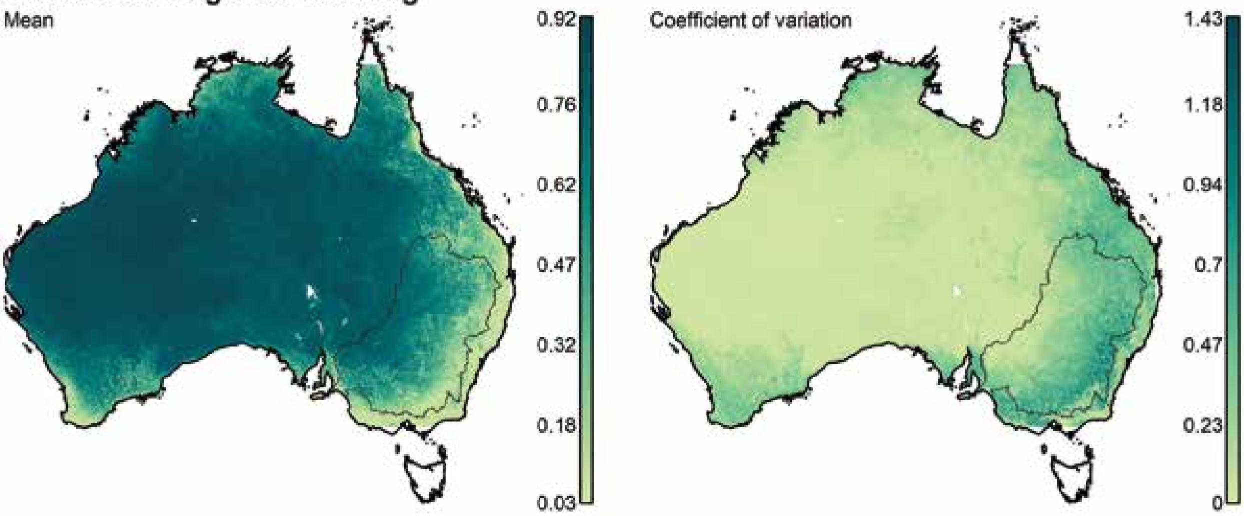
Pied currawong breeding

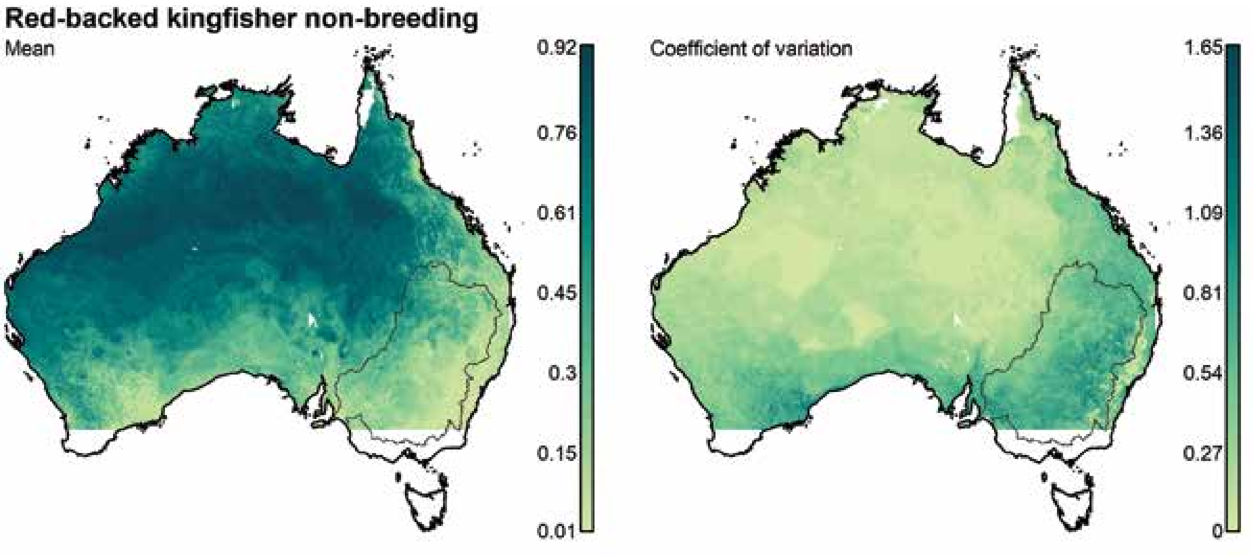


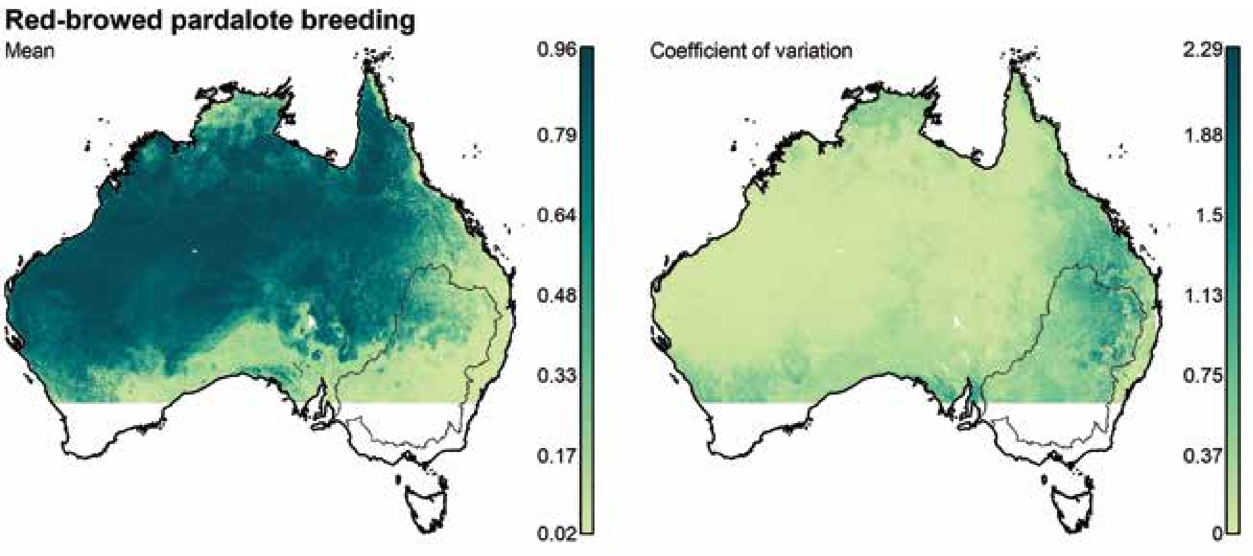
Rainbow bee-eater non-breeding

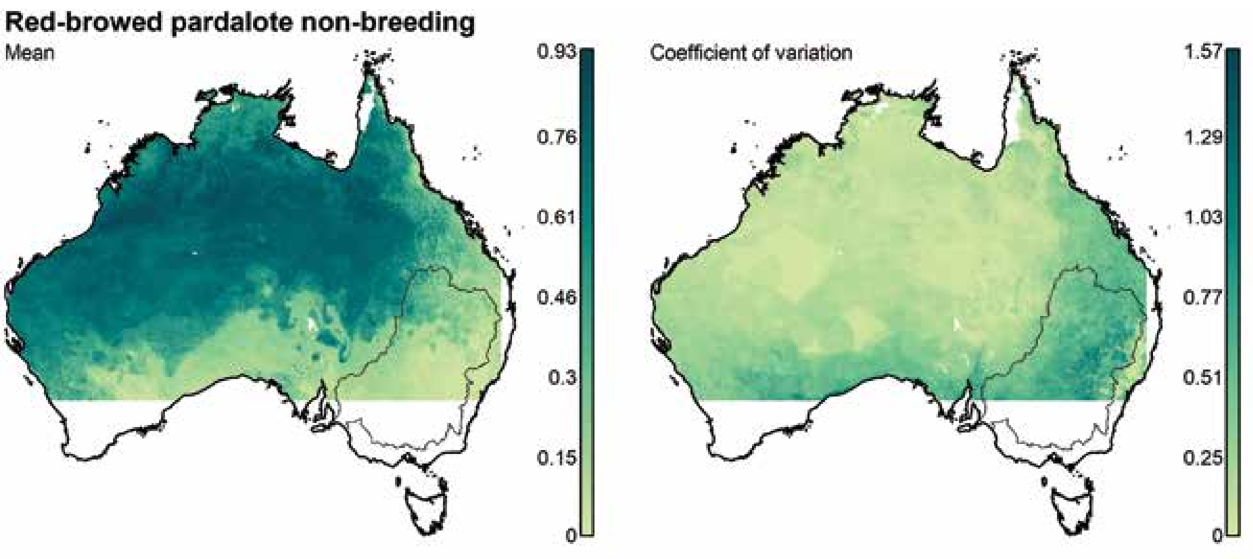


Red-backed kingfisher breeding

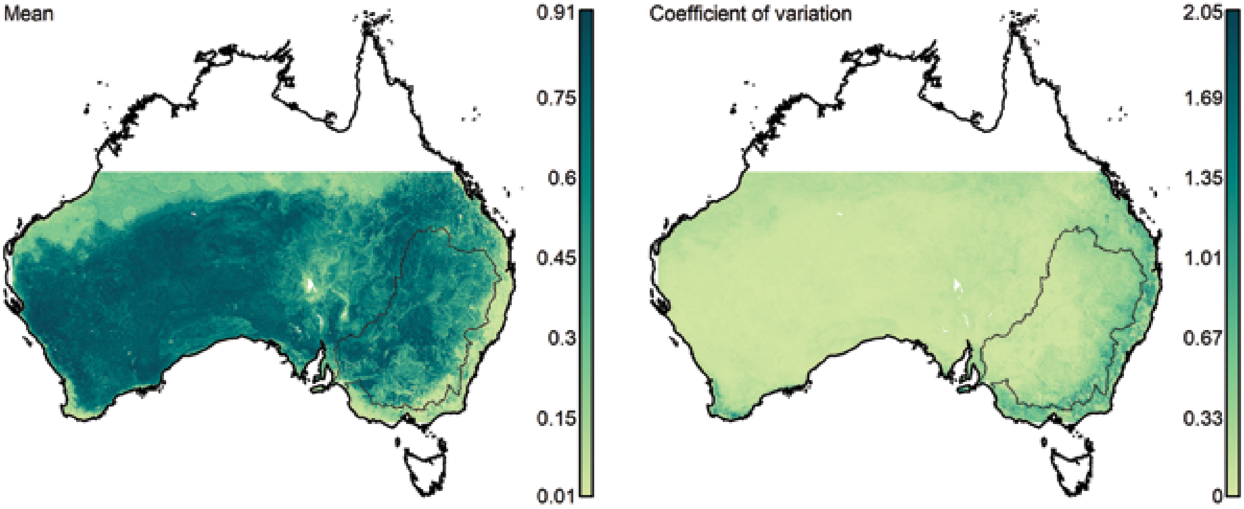



Red-backed kingfisher non-breeding
Mean
0.92
0.76
0.61
0.45
0.3
0.15
0.01
Coefficient of variation
1.65
1.36
1.09
0.81
0.54
0.27
0

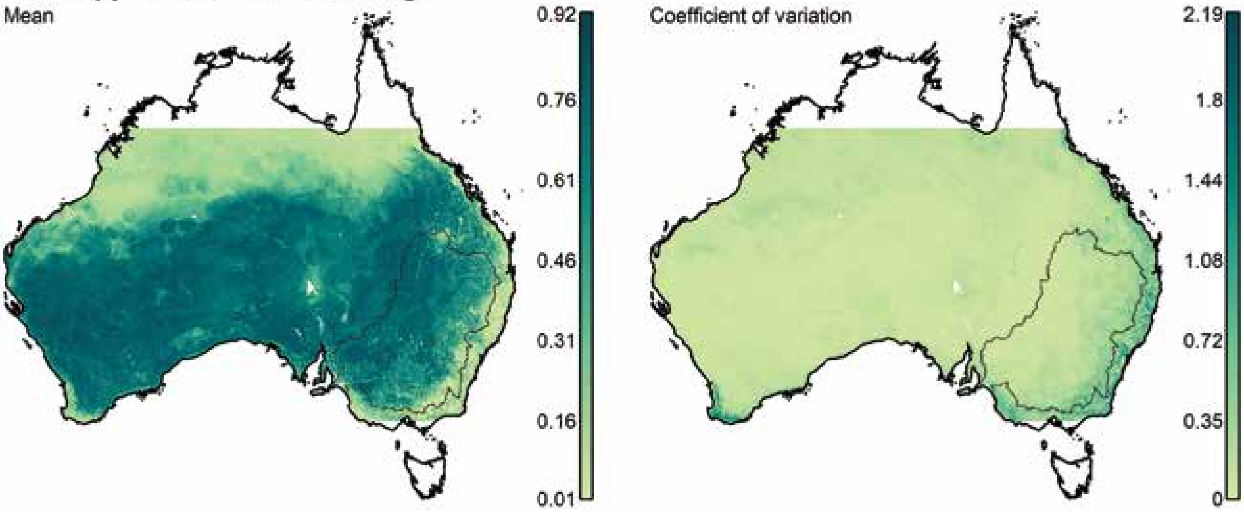

Red-browed pardalote breeding
Mean
0.96
0.79
0.64
0.48
0.33
0.17
0.02
Coefficient of variation
2.29
1.88
1.5
1.13
0.75
0.37
0


Red-browed pardalote non-breeding
Mean
0.93
0.76
0.61
0.46
0.3
0.15
0
Coefficient of variation
1.57
1.29
1.03
0.77
0.51
0.25
0

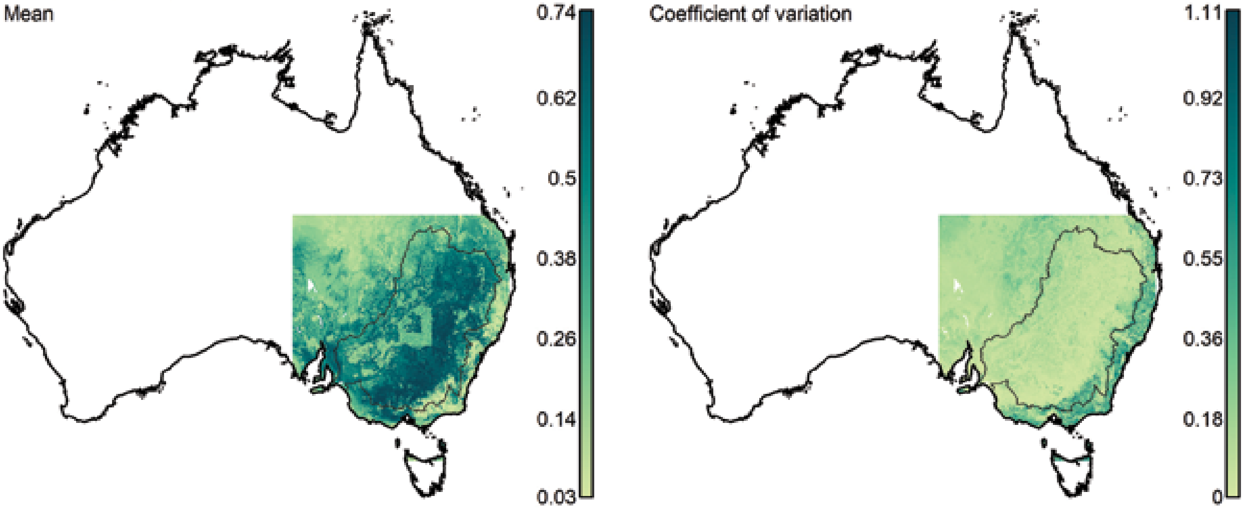
Red-capped robin breeding



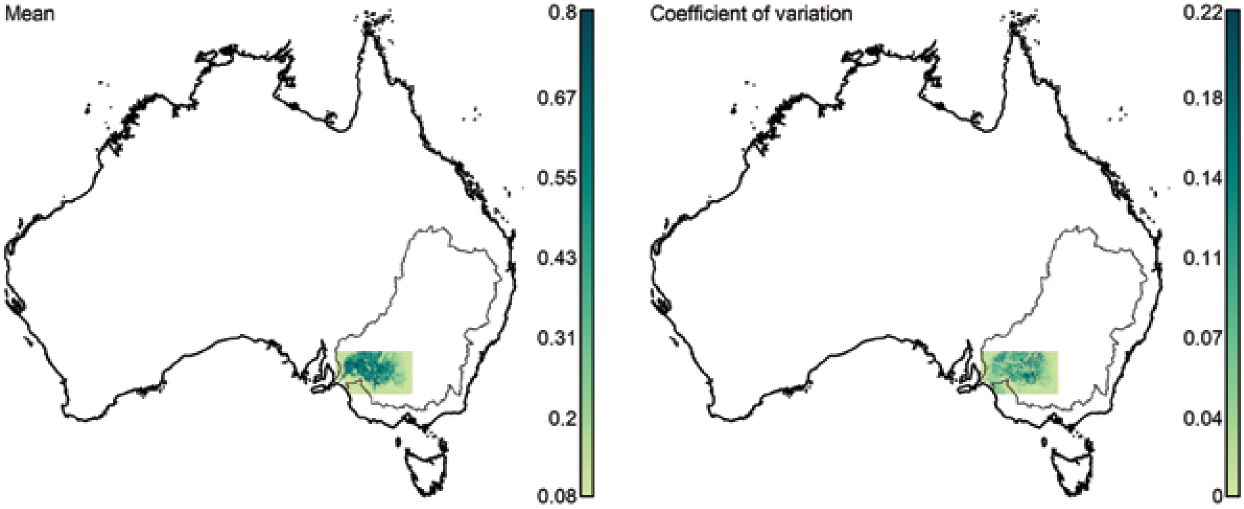
Red-capped robin non-breeding



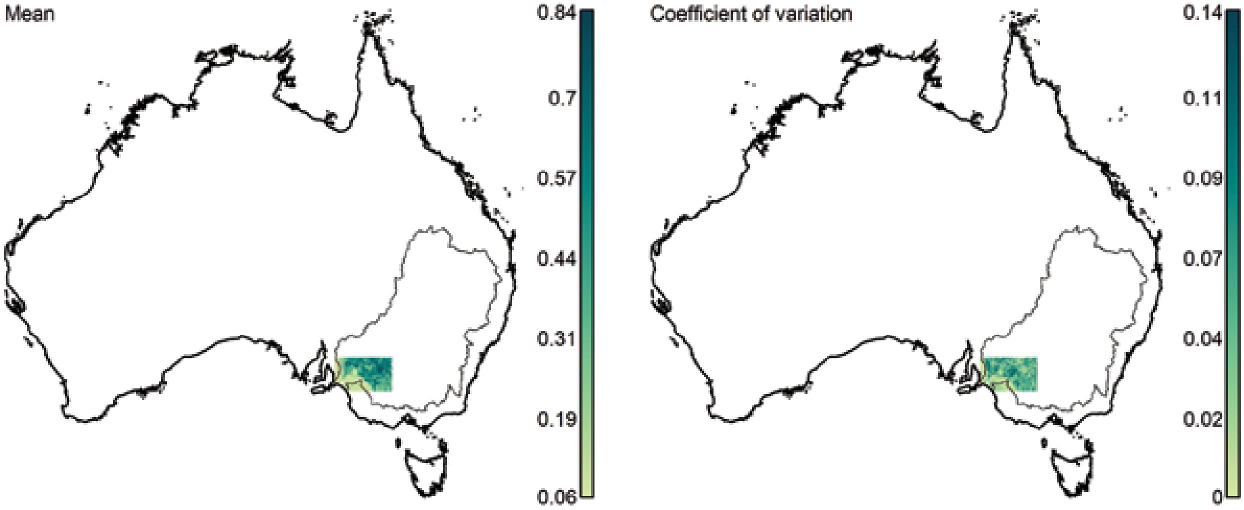
Red-rumped parrot breeding



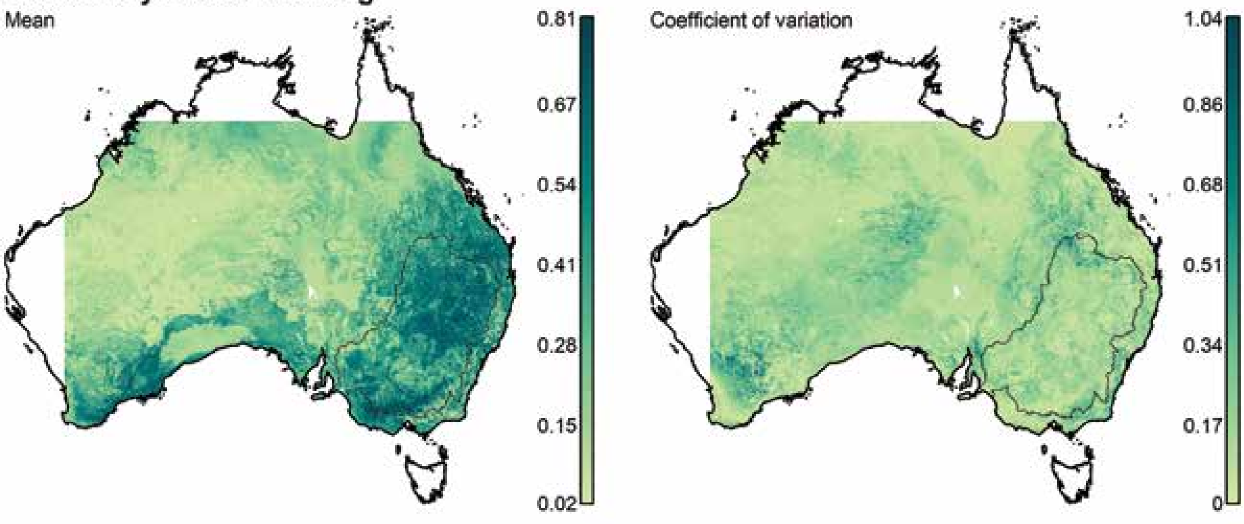
Regent parrot breeding



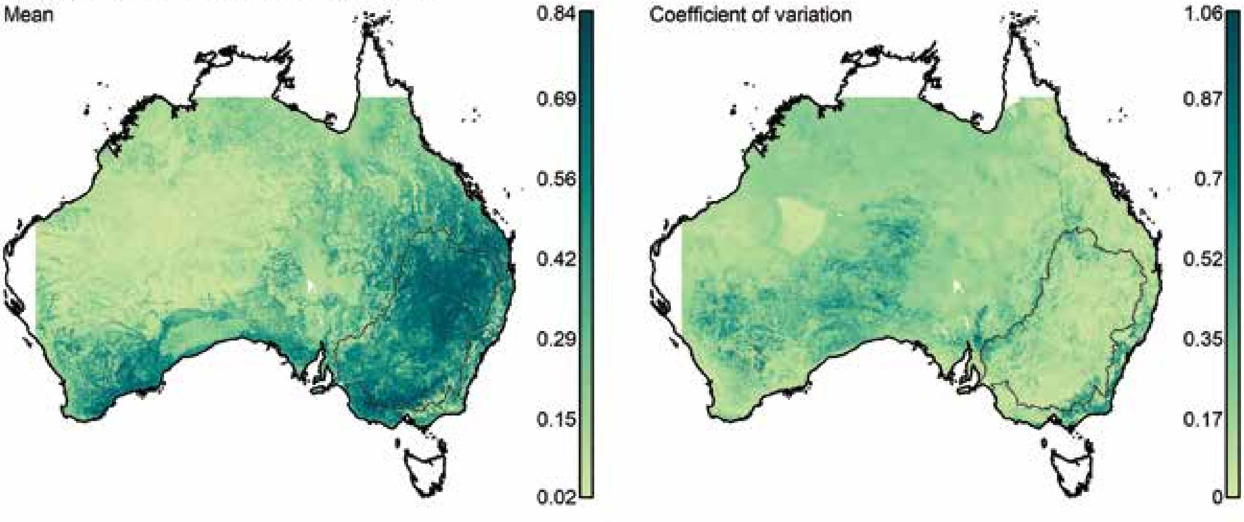
Regent parrot non-breeding



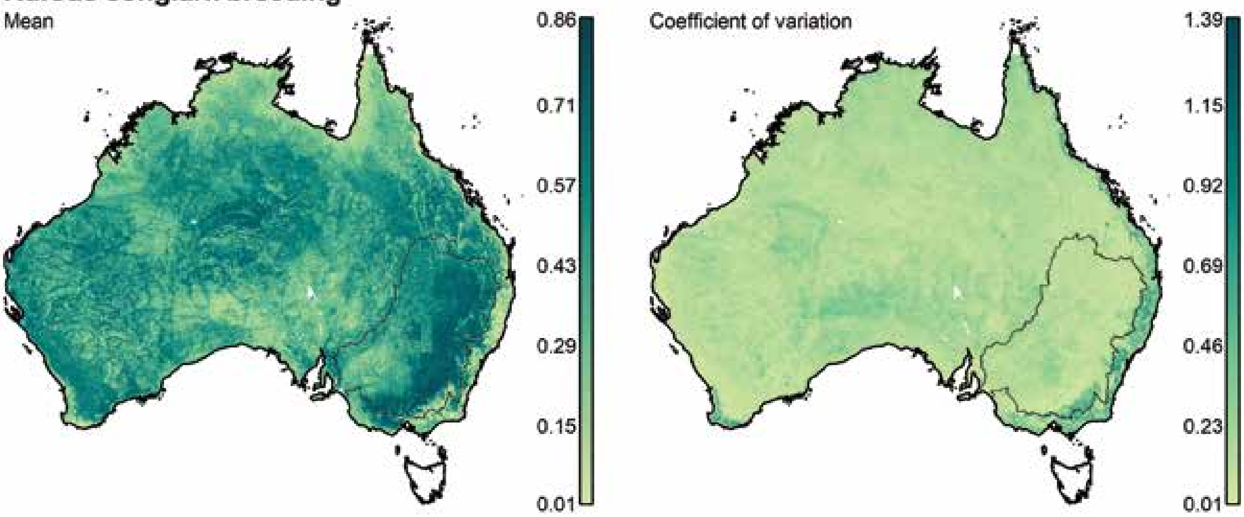
Restless flycatcher breeding



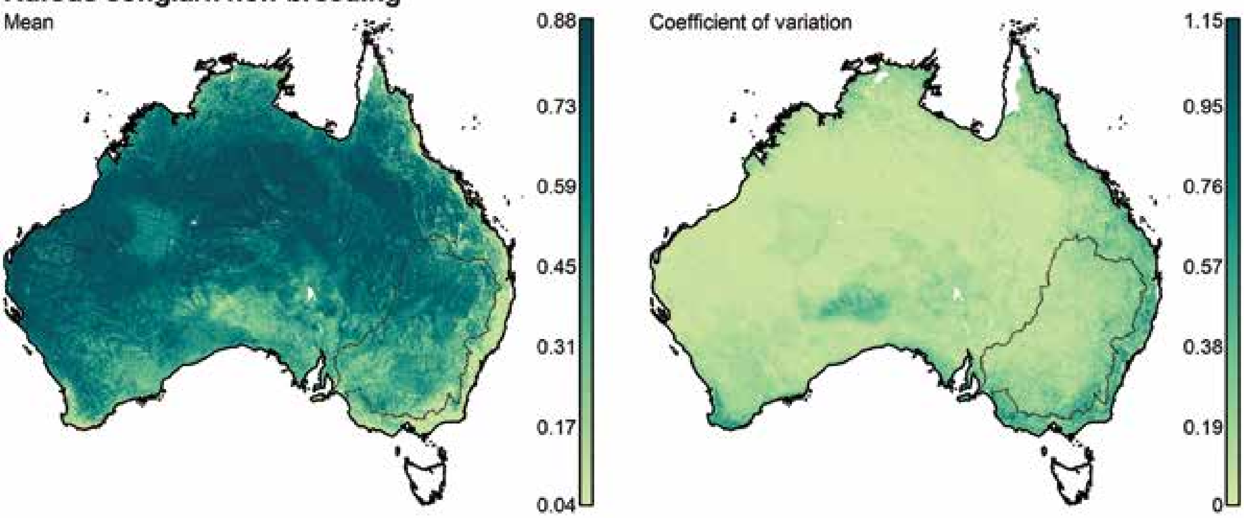
Restless flycatcher non-breeding

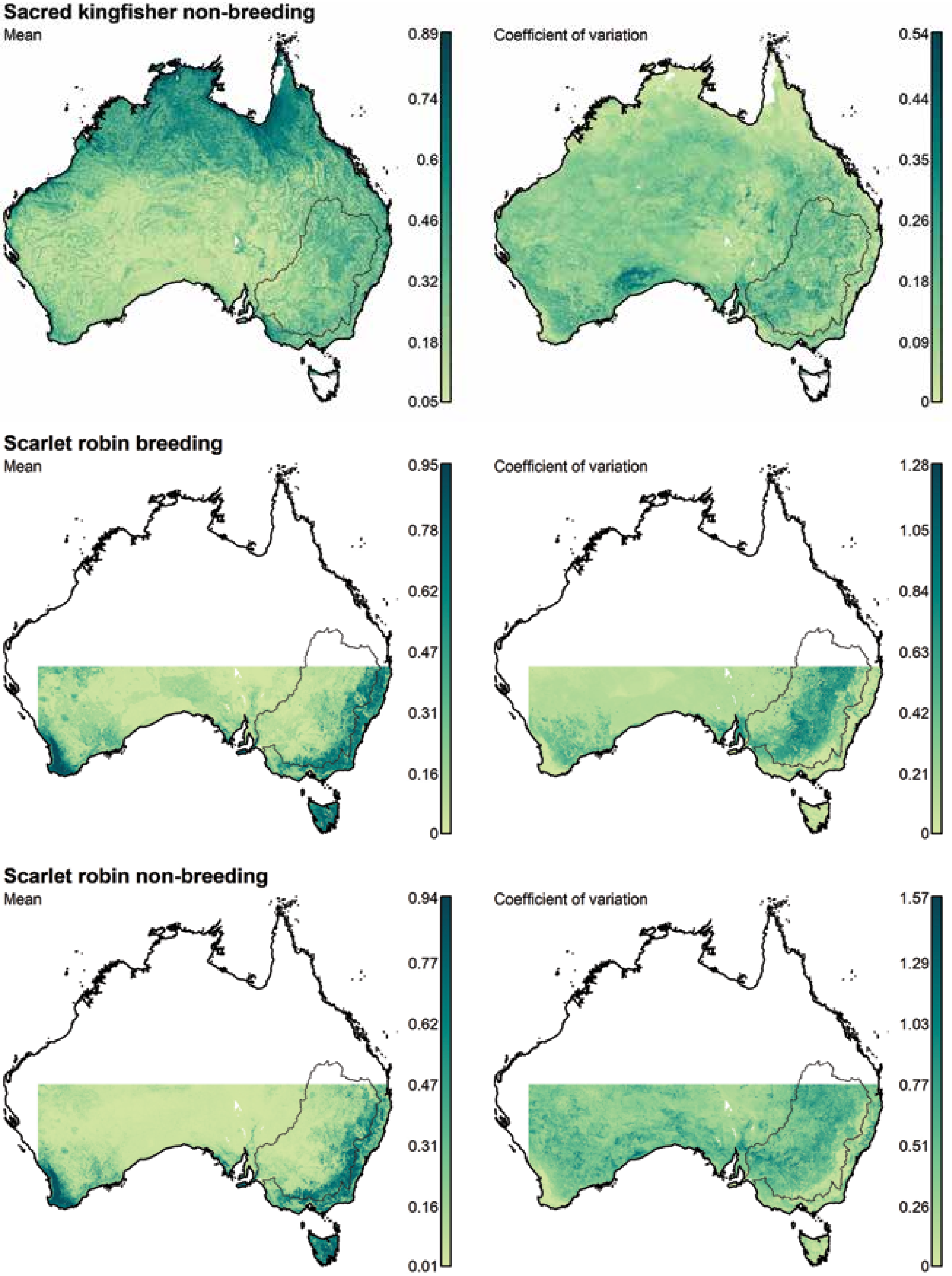


Rufous songlark breeding

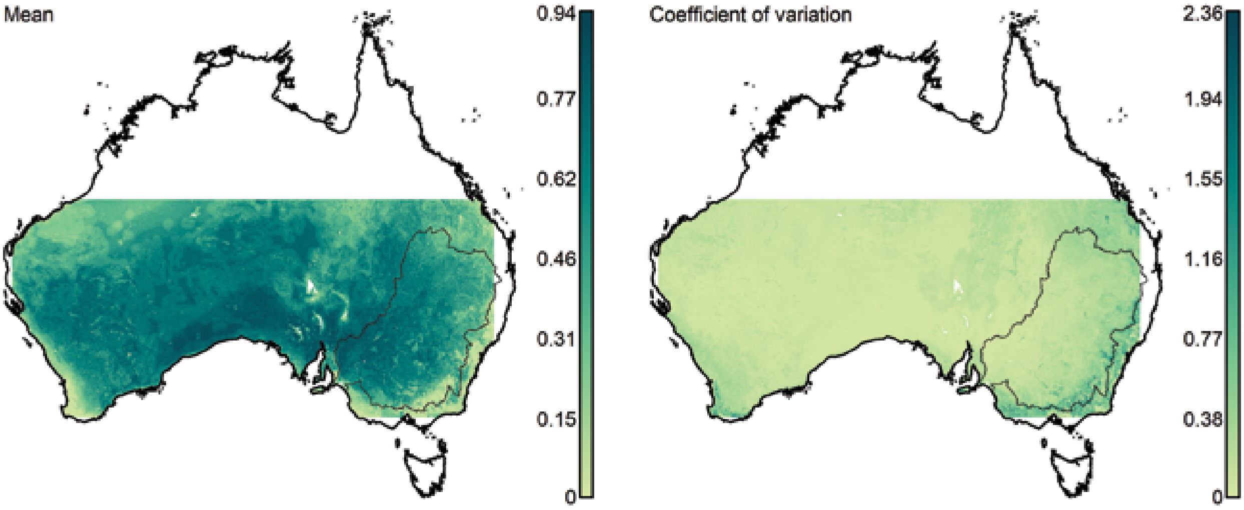


Rufous songlark non-breeding

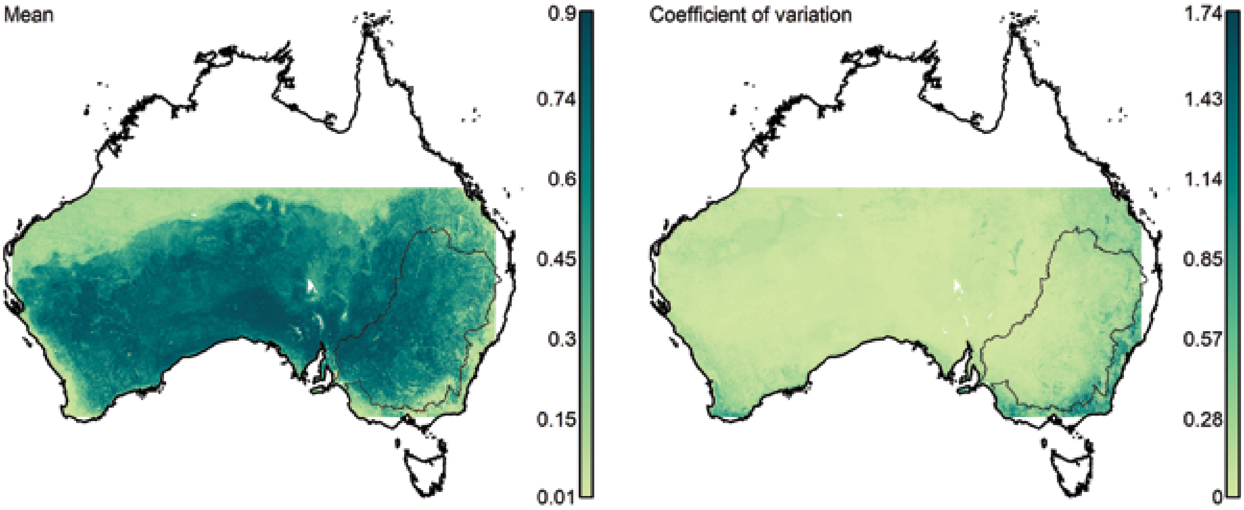



Sacred kingfisher non-breeding
Mean
0.89
0.74
0.6
0.46
0.32
0.18
0.05
Coefficient of variation
0.54
0.44
0.35
0.26
0.18
0.09
0
Scarlet robin breeding
Mean
0.95
0.78
0.62
0.47
0.31
0.16
0
Coefficient of variation
1.28
1.05
0.84
0.63
0.42
0.21
0
Scarlet robin non-breeding
Mean
0.94
0.77
0.62
0.47
0.31
0.16
0.01
Coefficient of variation
1.57
1.29
1.03
0.77
0.51
0.26
0

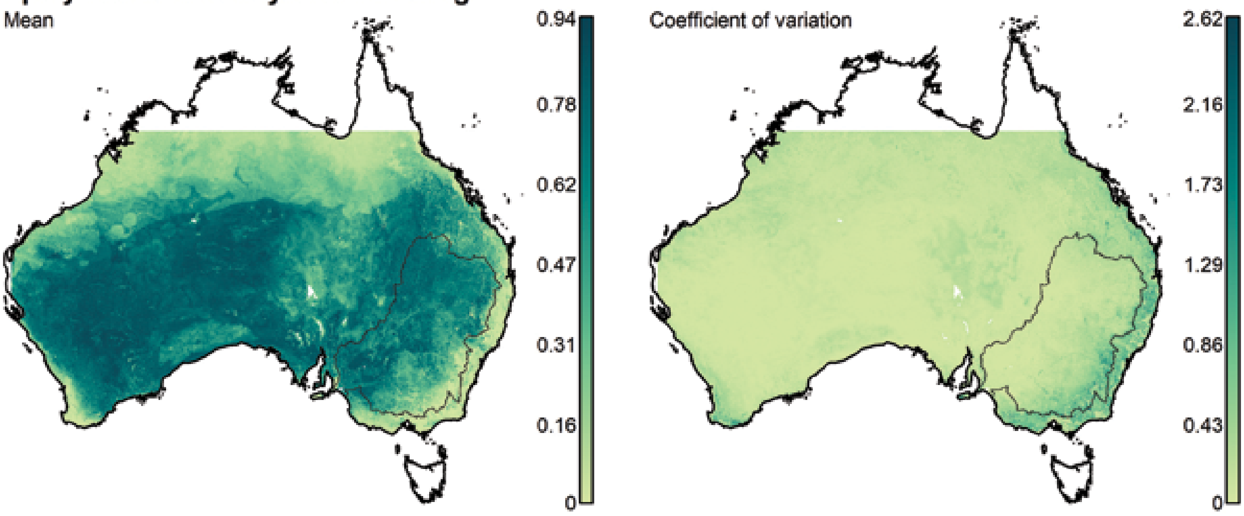
Southern whiteface breeding



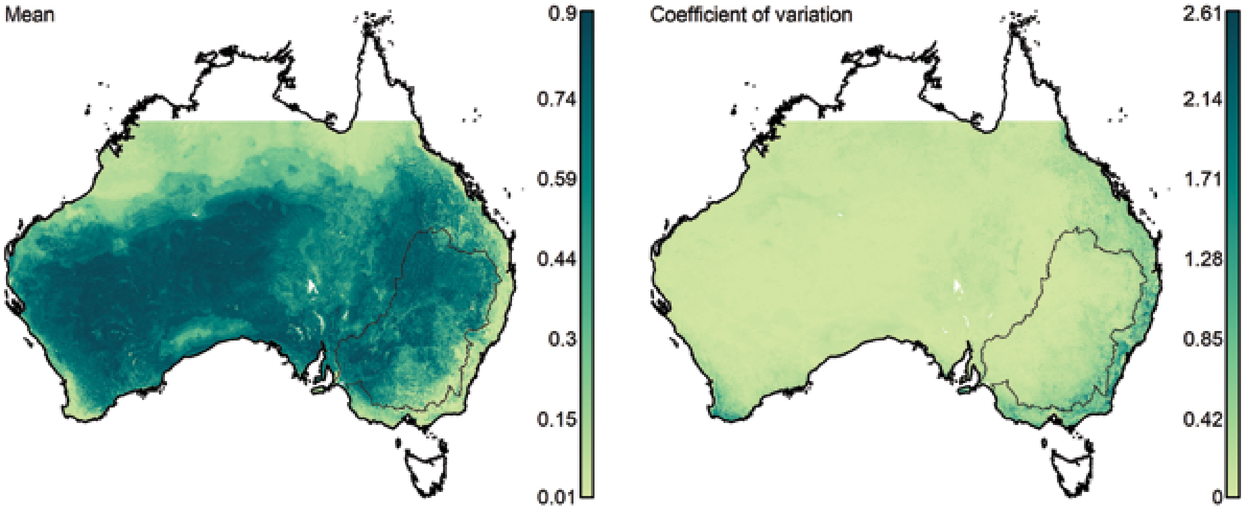
Southern whiteface non-breeding



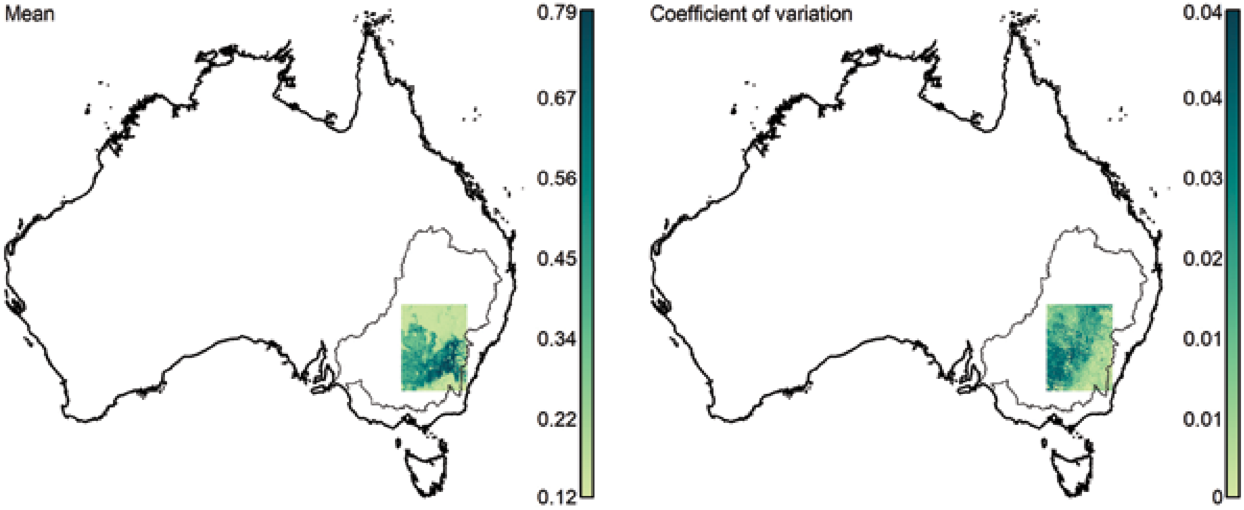
Spiny-cheeked honeyeater breeding



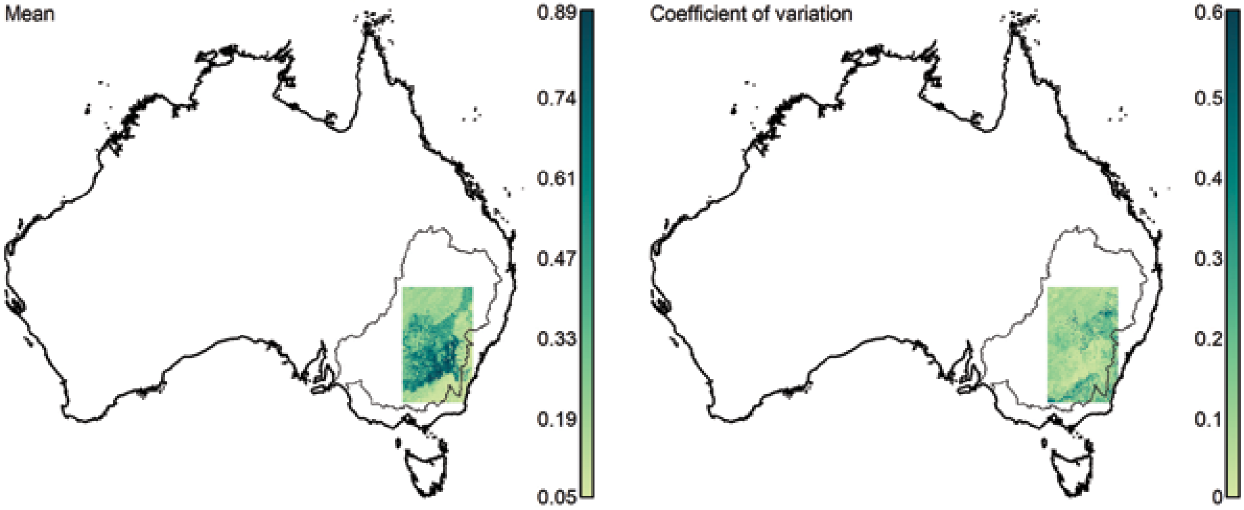
Spiny-cheeked honeyeater non-breeding



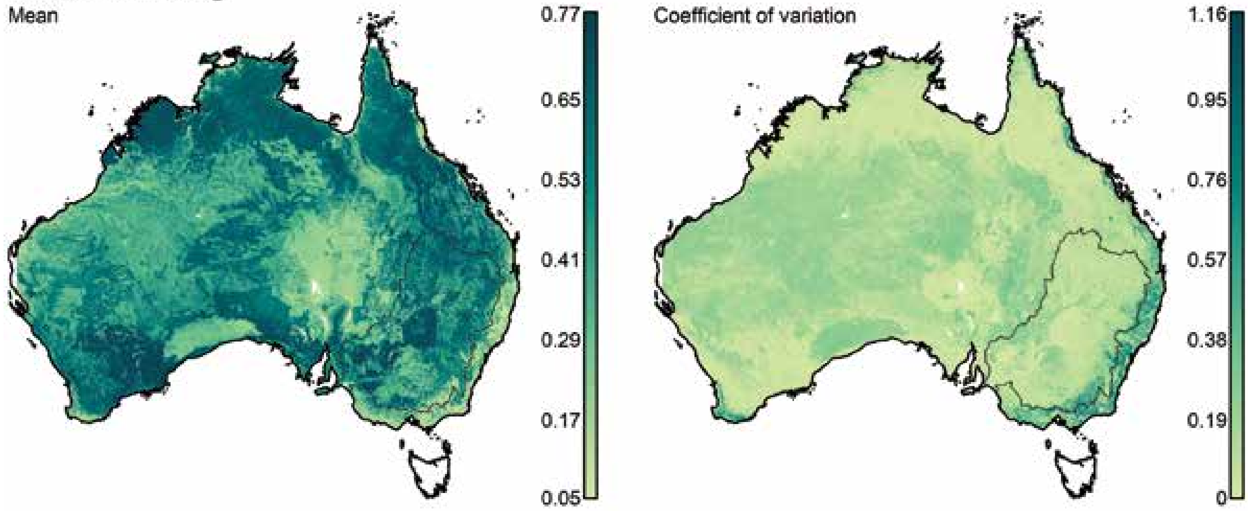
Superb parrot breeding



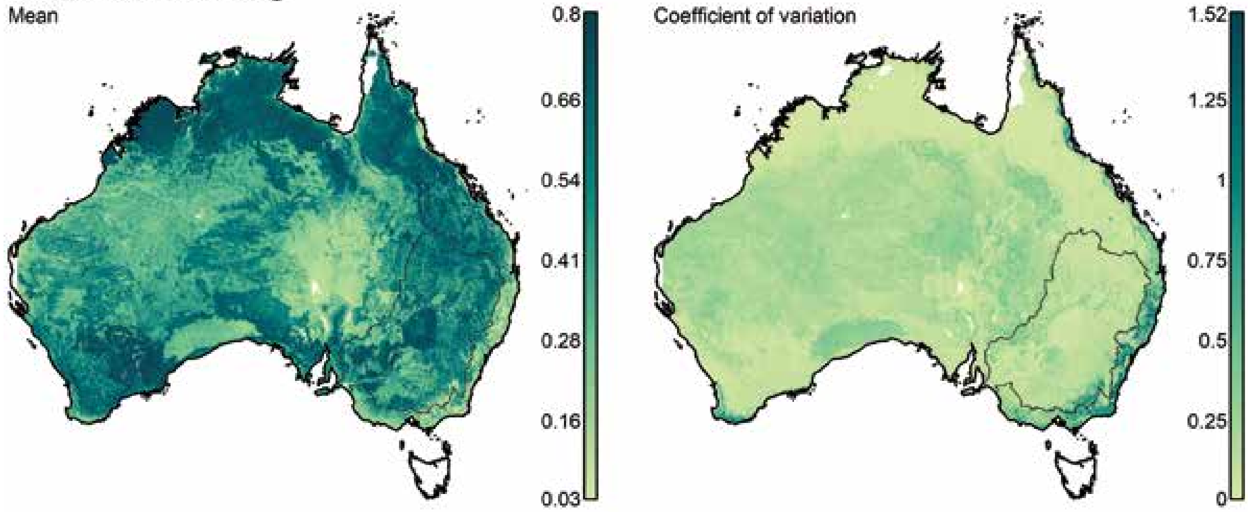
Superb parrot non-breeding



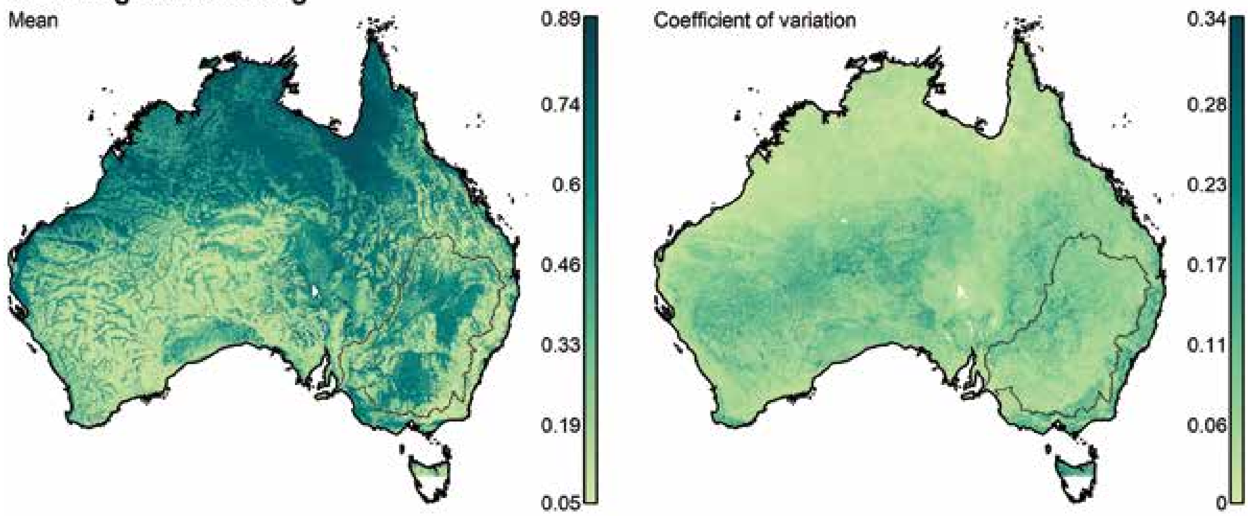
Weebill breeding



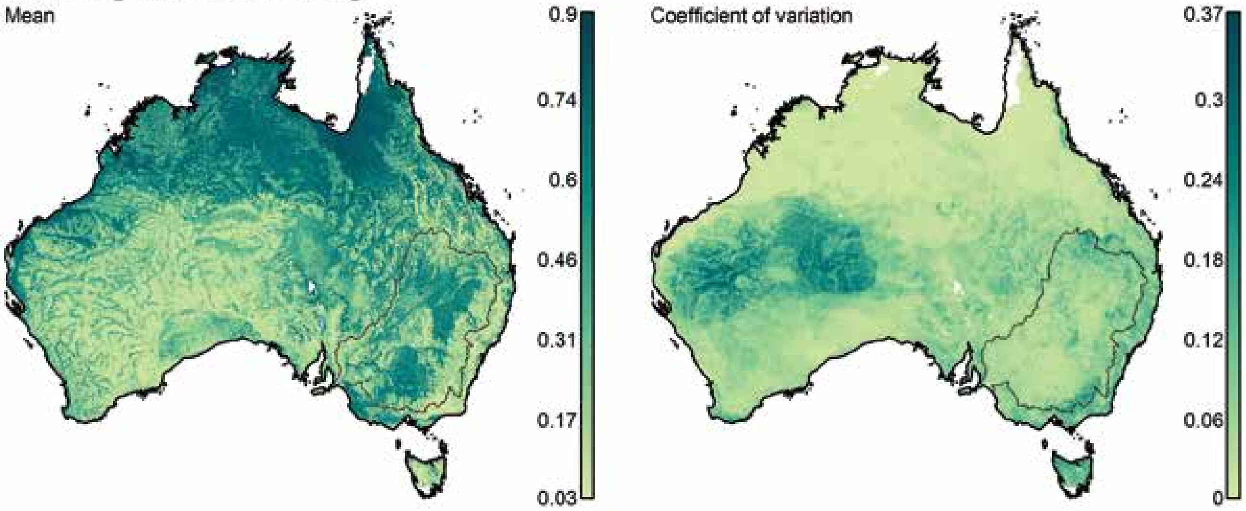
Weebill non-breeding



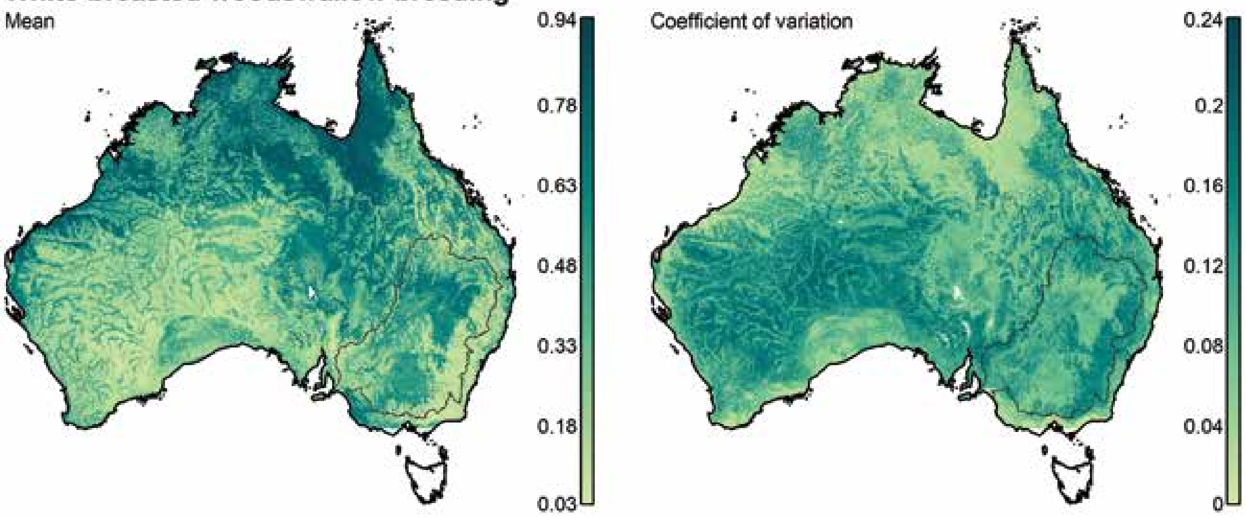
Whistling kite breeding



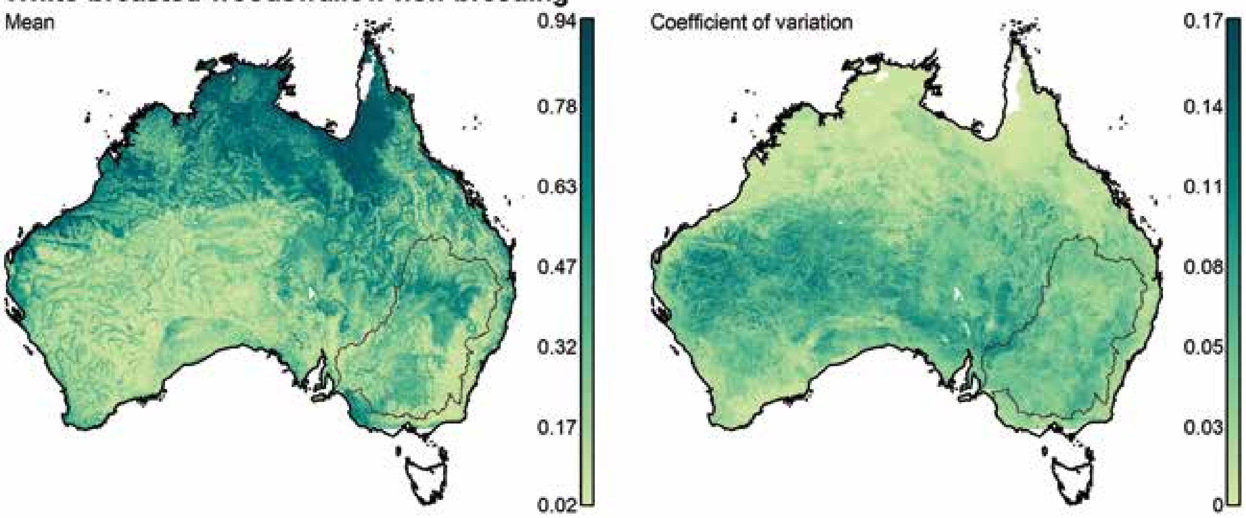
Whistling kite non-breeding



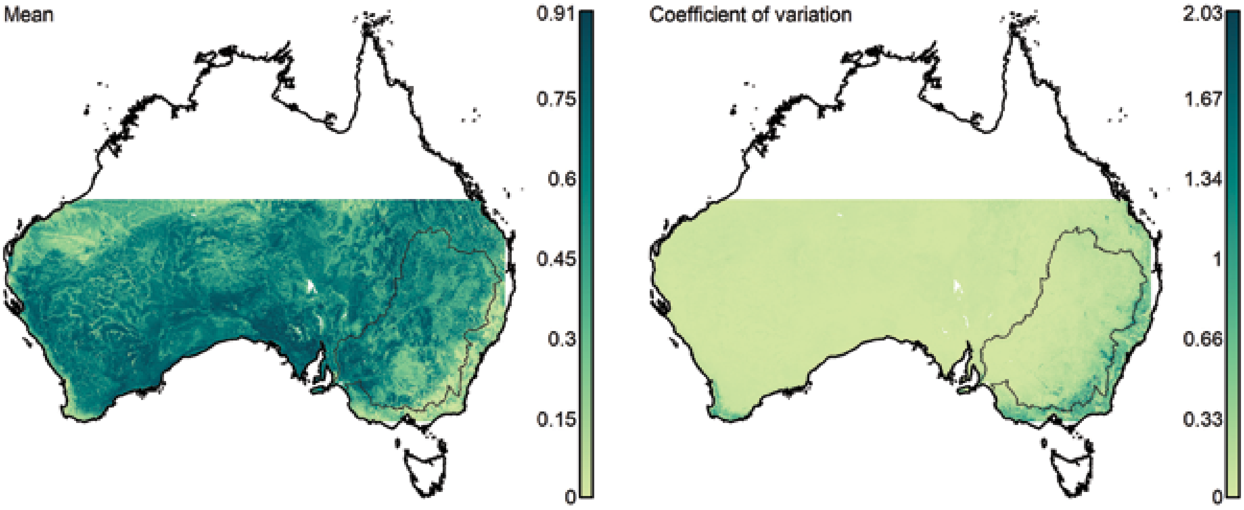
White-breasted woodswallow breeding



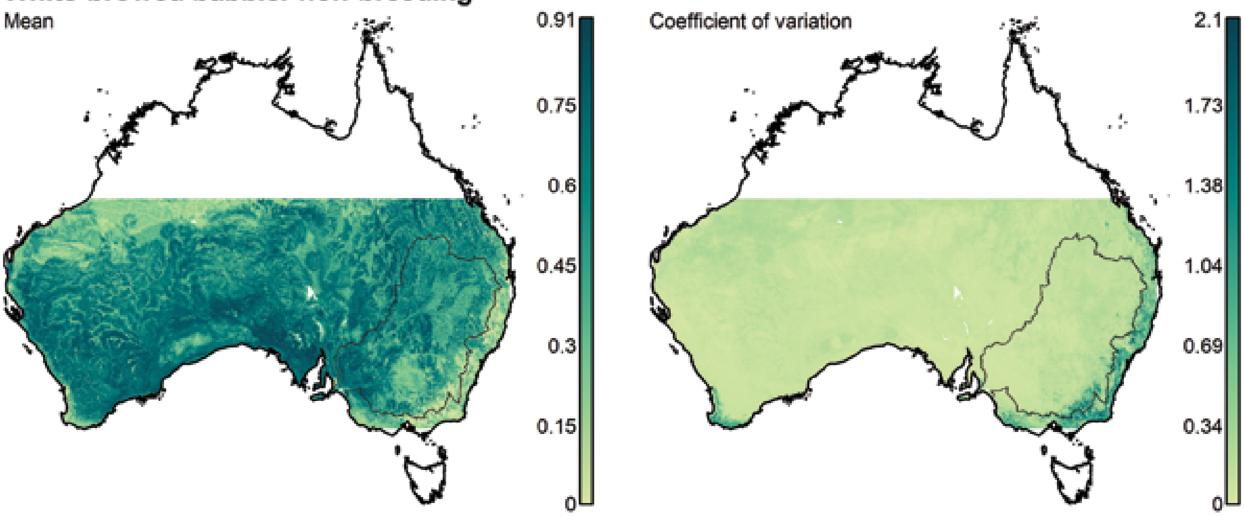
White-breasted woodswallow non-breeding



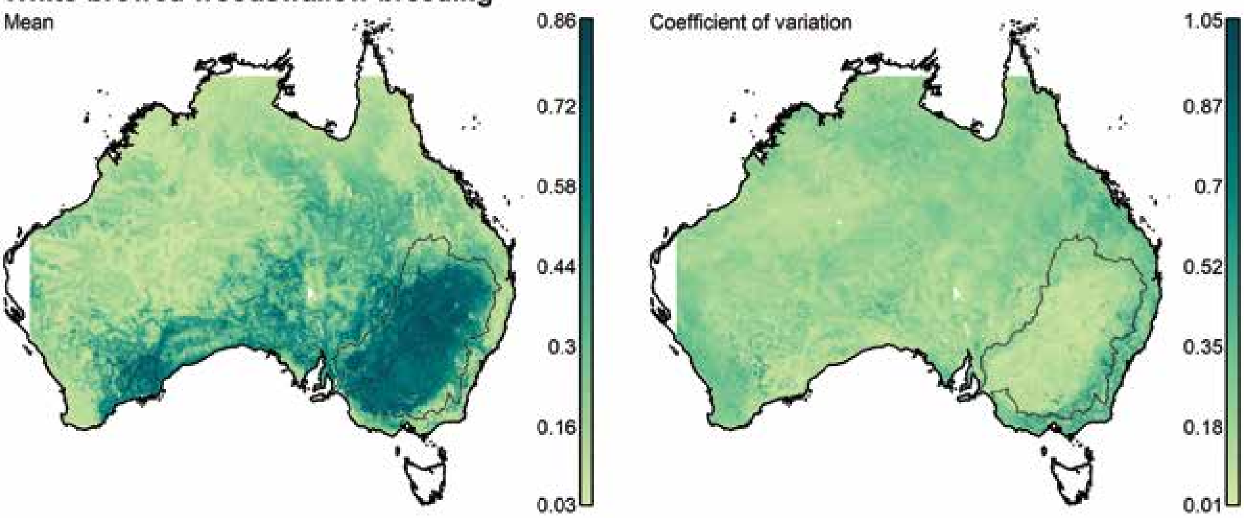
White-browed babbler breeding



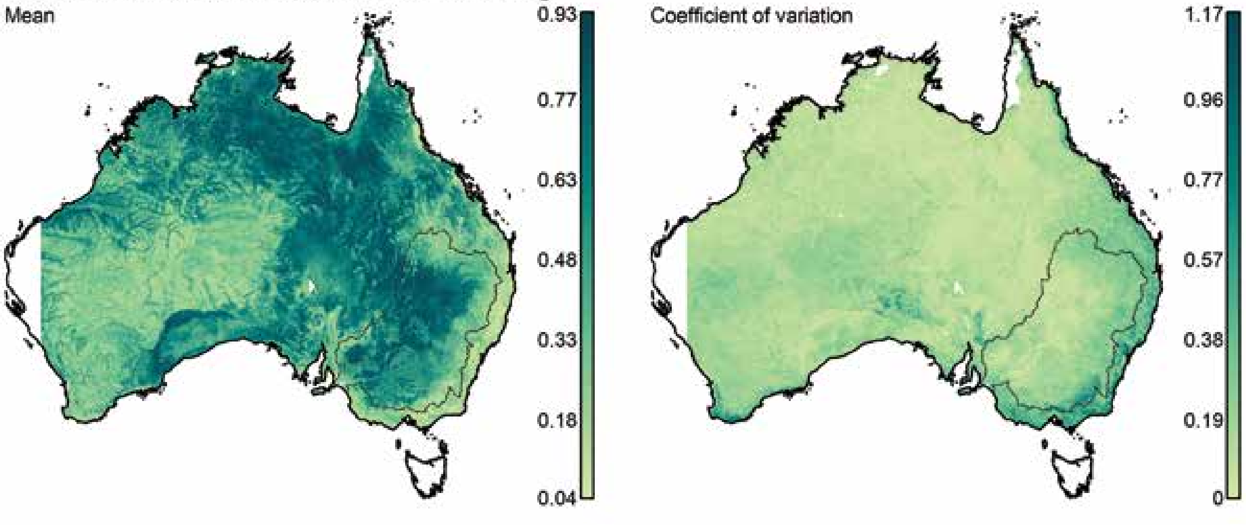
White-browed babbler non-breeding



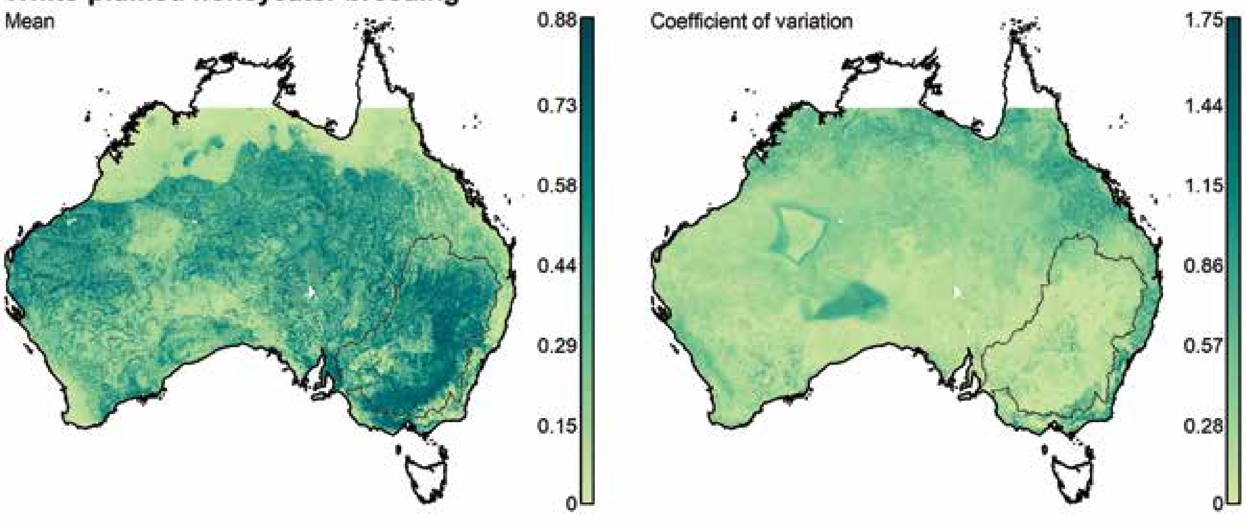
White-browed woodswallow breeding



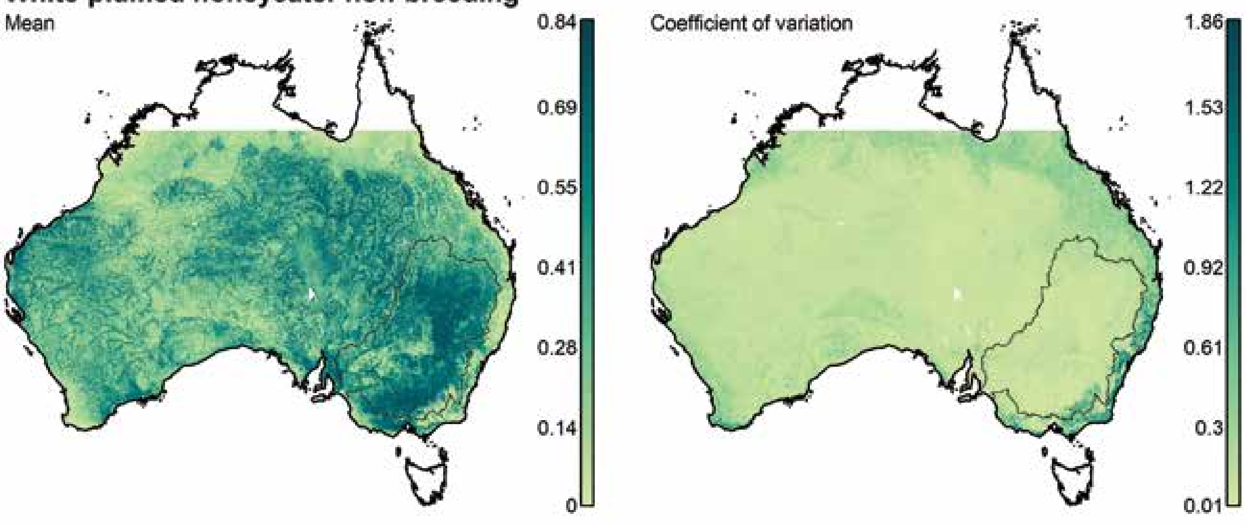
White-browed woodswallow non-breeding



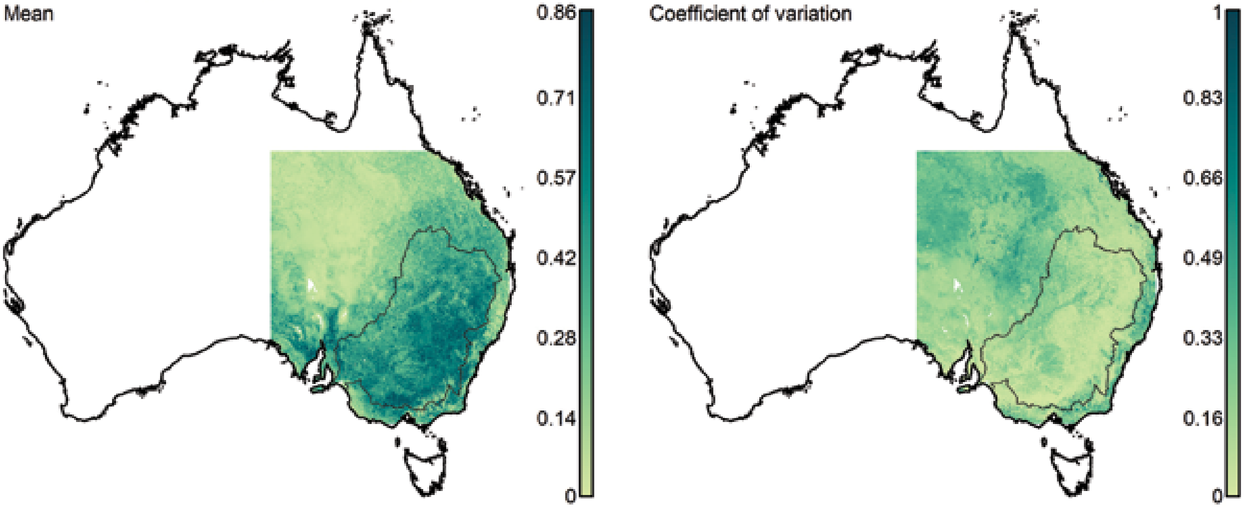
White-plumed honeyeater breeding



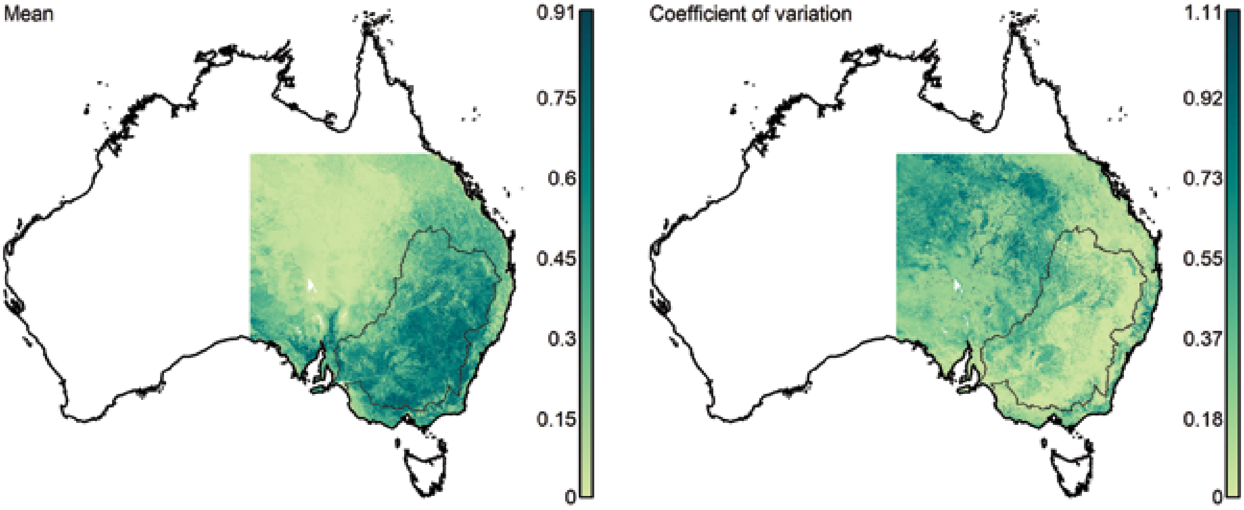
White-plumed honeyeater non-breeding



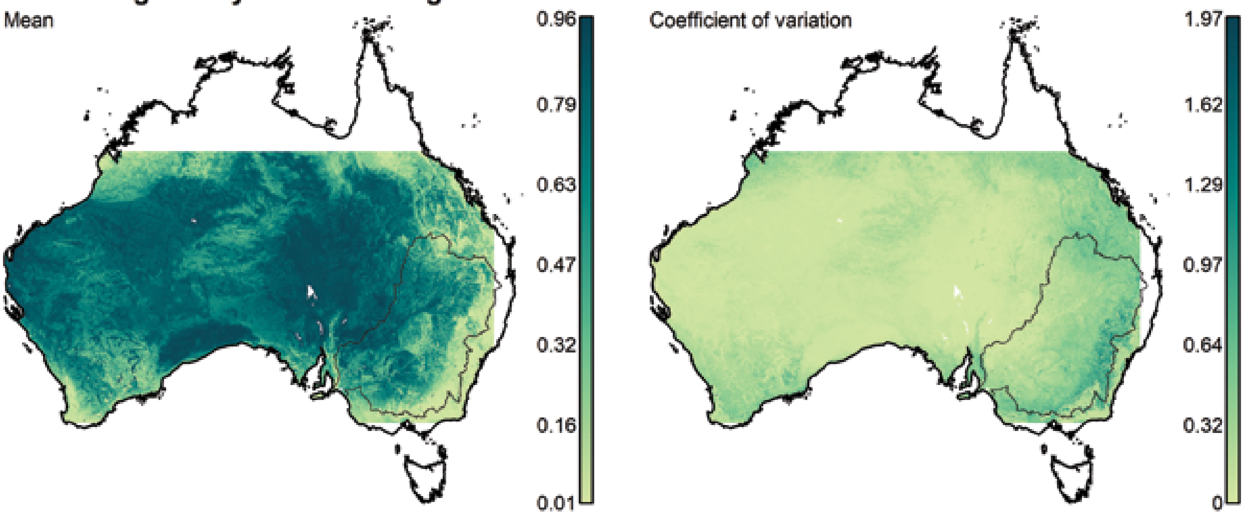
White-winged chough breeding

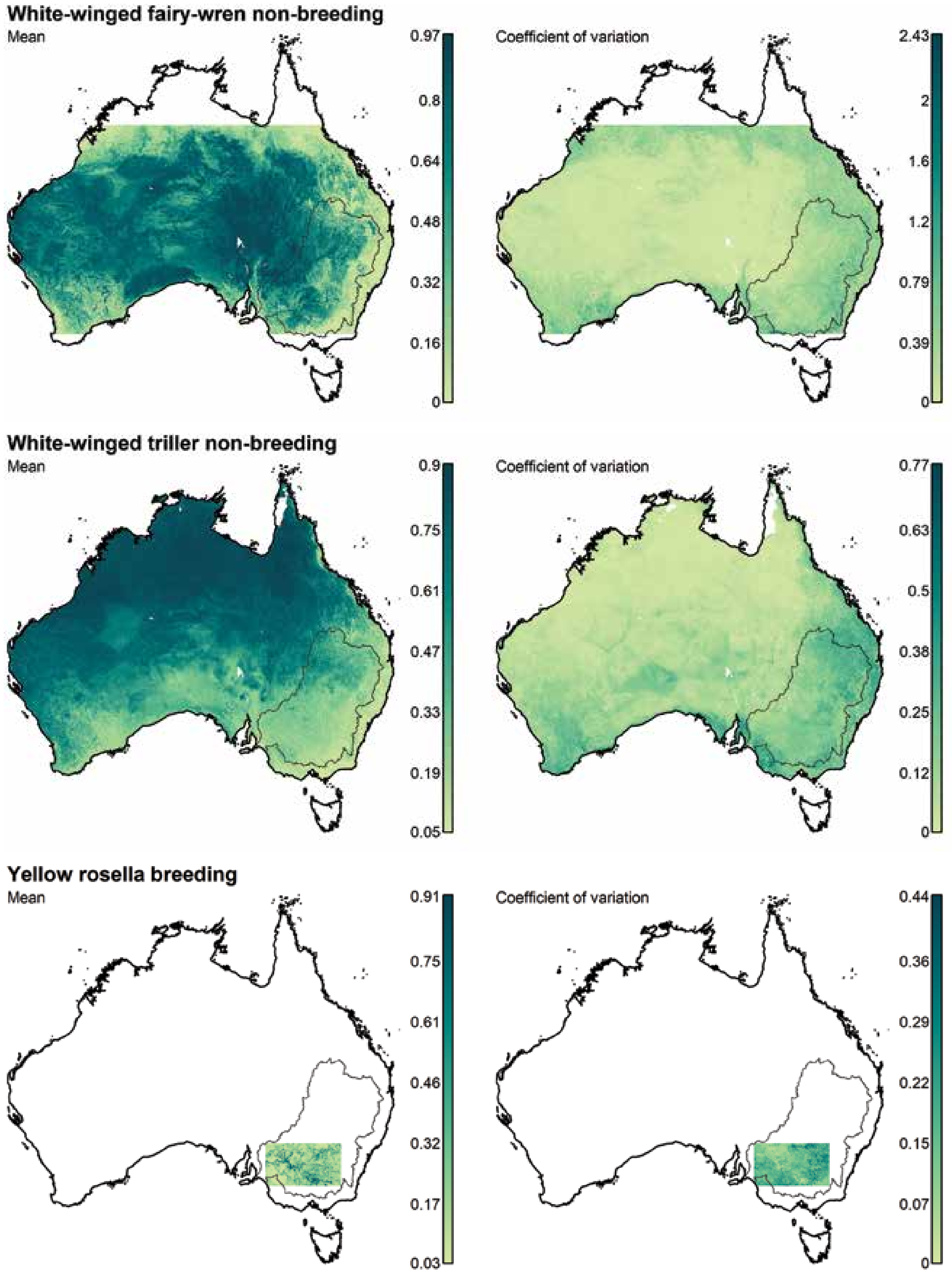


White-winged chough non-breeding

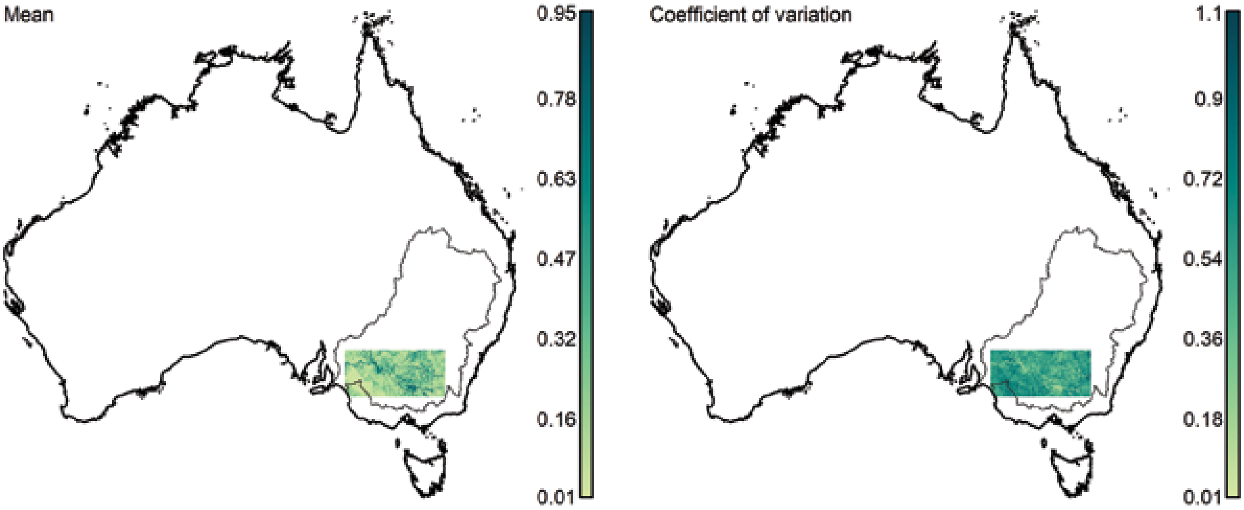


White-winged fairy-wren breeding

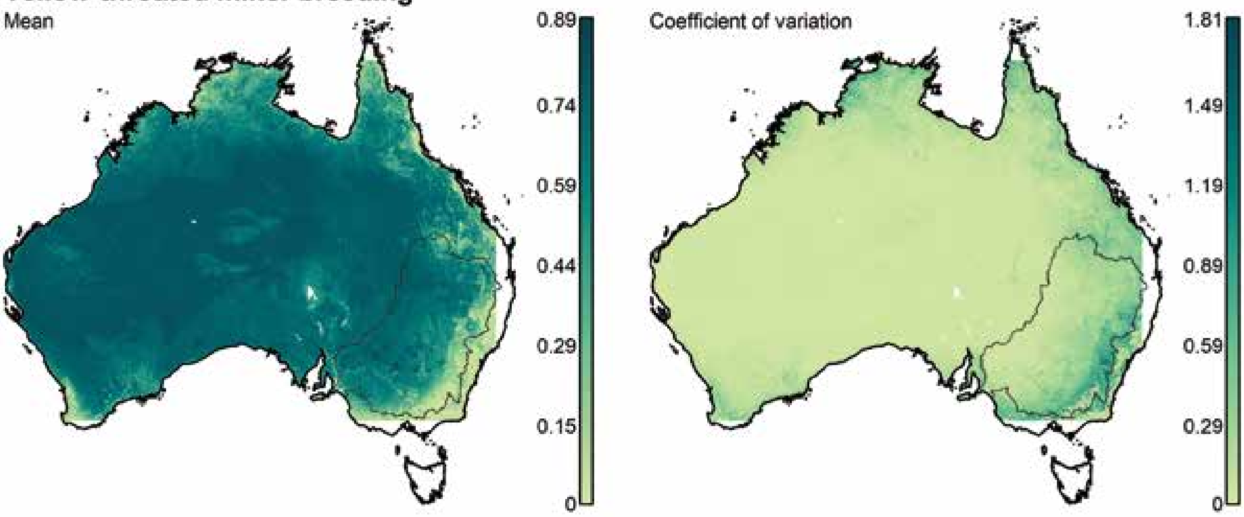



White-winged fairy-wren non-breeding
Mean
0.97
0.8
0.64
0.48
0.32
0.16
0
Coefficient of variation
2.43
2
1.6
1.2
0.79
0.39
0
White-winged triller non-breeding
Mean
0.9
0.75
0.61
0.47
0.33
0.19
0.05
Coefficient of variation
0.77
0.63
0.5
0.38
0.25
0.12
0
Yellow rosella breeding
Mean
0.91
0.75
0.61
0.46
0.32
0.17
0.03
Coefficient of variation
0.44
0.36
0.29
0.22
0.15
0.07
0

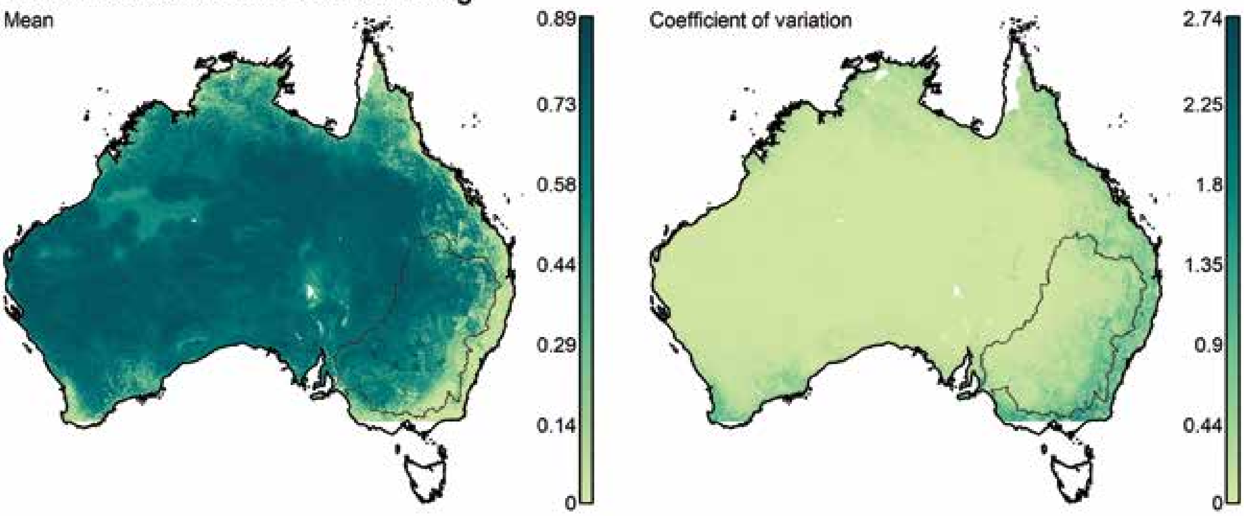
Yellow rosella non-breeding

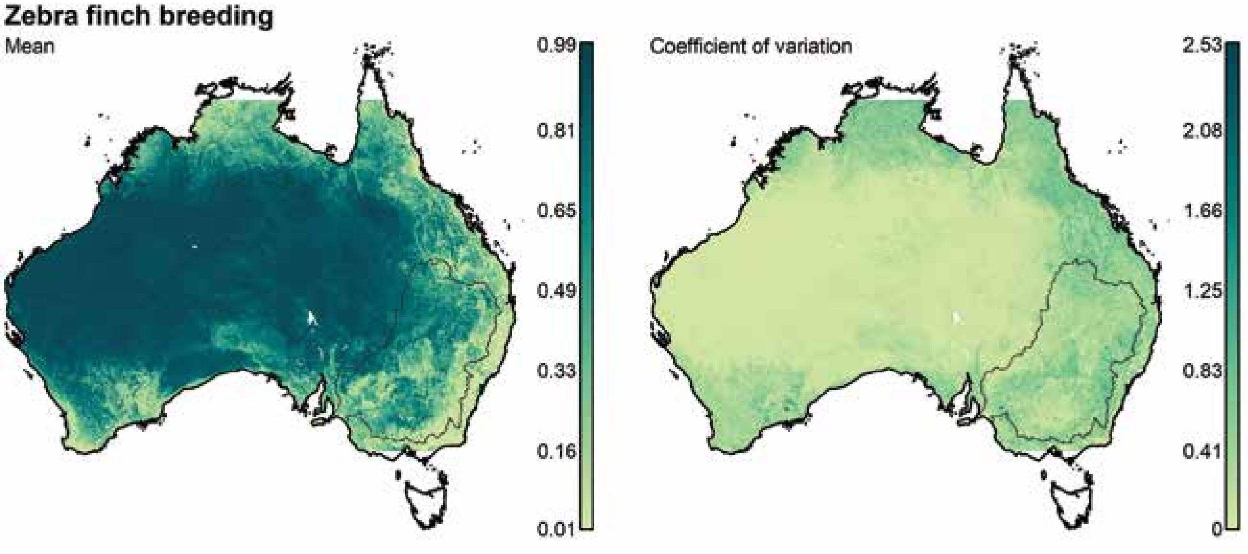


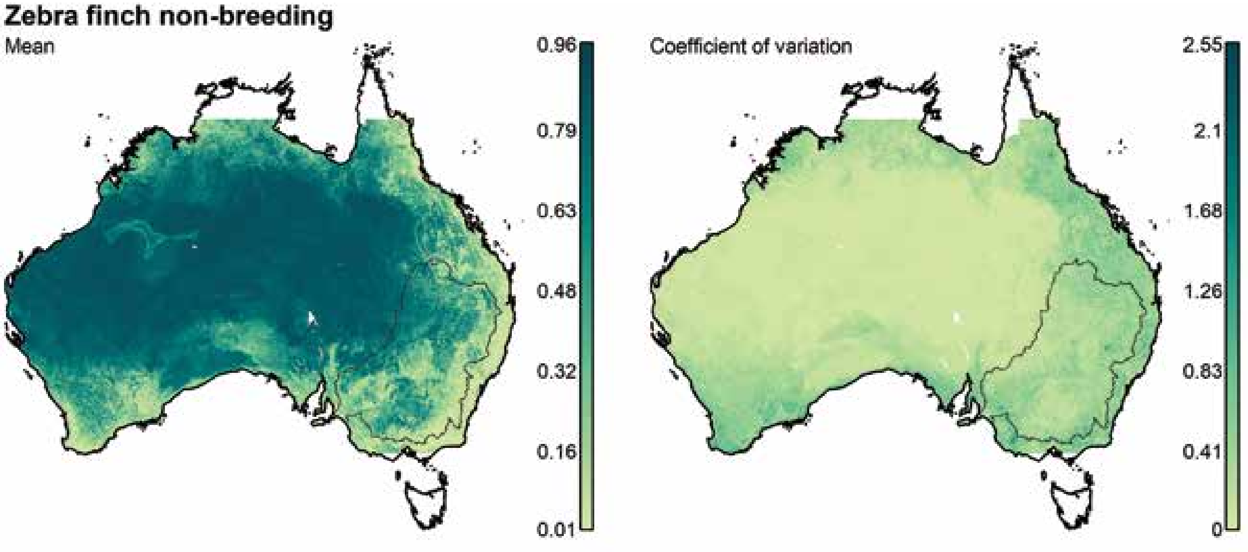
Yellow-throated miner breeding



Yellow-throated miner non-breeding







Dispersive little friarbird. Image: Rowan Mott

Appendix 5. Species that use Ramsar wetlands

Species that use (e.g., for foraging, shelter, dispersal) and potentially breed in each Ramsar Wetland of International Importance within the Murray-Darling Basin (MDB) are shown in this table. A species was classified as present in a Ramsar wetland by identifying whether there was at least one presence record for each species in each of the MDB's Ramsar wetlands. A species was classified as breeding in a Ramsar site if there was at least one presence record for that species in at least one breeding season of the 21-year study period. This is best considered as an indicator of potential breeding because there is not necessarily any direct observation of breeding in these cases. Ramsar wetlands are specified by the following abbreviations: BS = Banrock Station Wetland Complex; BF = Barmah Forest; BL = Blue Lake; CL = Currawinya Lakes (Currawinya National Park); Coo = The Coorong, and Lakes Alexandrina and Albert Wetland; FTS = Fivebough and Tuckerbil Swamps; GiFl = Ginini Flats Wetland Complex; GuFo = Gunbower Forest; GW = Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses; HKL = Hattah-Kulkyne Lakes; KW = Kerang Wetlands; LA = Lake Albacutya; MM = The Macquarie Marshes; NL = Narran Lake Nature Reserve; CMSF = NSW Central Murray State Forests; PR = Paroo River Wetlands; Riv = Riverland.

Species	Present in Ramsar site	Breeding in Ramsar site
Apostlebird	BS, CL, FTS, GuFo, HKL, NL, PR, Riv, MM	BS, CL, FTS, GuFo, HKL, NL, PR, Riv, MM
Australasian pipit	BS, BF, CL, FTS, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	CL, FTS, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Australian hobby	BS, BF, CL, FTS, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, FTS, HKL, KW, CMSF, PR, Riv, Coo, MM
Australian magpie	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Australian pratincole	CL, KW, PR, Riv, Coo	CL, PR, Riv, Coo
Australian raven	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Australian ringneck	BS, CL, FTS, HKL, KW, NL, PR, Riv, Coo, MM	BS, CL, HKL, KW, NL, PR, Riv, Coo, MM
Banded lapwing	CL, FTS, HKL, KW, NL, Riv, Coo	CL, FTS, HKL, KW, NL, Riv, Coo
Barking owl	CL, GuFo	
Black-chinned honeyeater	BF, CL, FTS, GuFo, KW, CMSF, Coo, MM	BF, CL, FTS, GuFo, CMSF, Coo, MM
Black-faced cuckoo-shrike	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Black-faced woodswallow	BS, CL, KW, NL, CMSF, PR, Riv, Coo, MM	CL, KW, CMSF, PR, MM
Black-shouldered kite	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Black-tailed native-hen	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Black honeyeater	CL, NL, CMSF, PR	CL, NL, CMSF, PR
Black kite	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, CL, FTS, GuFo, HKL, KW, CMSF, PR, Riv, Coo, MM
Blue bonnet	CL, GW, HKL, KW, LA, NL, PR, Riv, Coo, MM	CL, HKL, KW, NL, PR, Riv, Coo, MM
Brown-headed honeyeater	BF, CL, GiFl, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo	BF, CL, GiFl, GuFo, HKL, CMSF, Riv, Coo
Brown falcon	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Brown songlark	BS, CL, FTS, GuFo, KW, NL, CMSF, Coo, MM	CL, FTS, GuFo, KW, NL, CMSF, Coo, MM
Brown treecreeper	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM
Budgerigar	BS, CL, HKL, KW, CMSF, PR, Riv, Coo, MM	BS, CL, HKL, KW, PR, Riv, Coo, MM
Buff-rumped thornbill	BF, CL, GuFo, KW, CMSF, Riv	BF, CL, GuFo, KW, CMSF
Bush stone-curlew	CMSF, Riv, Coo	Riv
Chestnut-crowned babbler	BS, CL, HKL, PR, Riv, MM	BS, CL, HKL, PR, Riv, MM
Chestnut-rumped thornbill	BS, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM	BS, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM

Species	Present in Ramsar site	Breeding in Ramsar site
Chirruping wedgebill	CL, NL, PR	CL, PR
Cockatiel	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, CMSF, PR, Riv, Coo, MM
Collared sparrowhawk	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, PR, Coo	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, Coo
Common bronzewing	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Crested pigeon	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Crested shrike-tit	BF, FTS, GuFo, KW, CMSF, Coo	BF, GuFo, KW, CMSF
Crimson chat	CL, FTS, KW, NL, CMSF, PR	CL, FTS, KW, NL, CMSF
Diamond dove	BF, CL, GuFo, NL, CMSF, PR, Riv	CL, NL, PR, Riv
Diamond firetail	BS, BF, GuFo, CMSF	BF, GuFo, CMSF
Dusky woodswallow	BS, BF, CL, GuFo, HKL, KW, NL, CMSF, Riv, Coo, MM	BS, BF, CL, GuFo, HKL, KW, CMSF, Riv, Coo, MM
Eastern rosella	BF, FTS, GuFo, HKL, KW, CMSF, Riv, Coo	BF, FTS, GuFo, HKL, KW, CMSF, Coo
Emu	BF, CL, GuFo, HKL, LA, NL, CMSF, PR, Riv, Coo, MM	BF, CL, GuFo, HKL, LA, NL, CMSF, PR, Riv, Coo, MM
Fairy martin	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo, MM
Galah	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Golden whistler	BF, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo	BF, GuFo, HKL, LA, NL, CMSF, Coo
Grey-crowned babbler	BF, CL, GuFo, GW, KW, NL, CMSF, PR, MM	CL, GuFo, GW, KW, NL, CMSF, MM
Grey butcherbird	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, CL, FTS, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Grey currawong	GiFl, HKL, Riv, Coo	GiFl, HKL, Coo
Grey fantail	BS, BF, CL, FTS, GiFl, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Grey shrike-thrush	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Ground cuckoo-shrike	CL, FTS, HKL, NL, PR, Riv	CL, HKL, NL, Riv
Hooded robin	BS, BF, CL, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GuFo, HKL, KW, CMSF, PR, Riv, Coo, MM
Horsfield's bronze-cuckoo	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Jacky winter	BS, BF, CL, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, GuFo, HKL, KW, NL, CMSF, Riv, Coo, MM
Laughing kookaburra	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Little corella	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo, MM
Little eagle	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo, MM
Little friarbird	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, MM
Little raven	BS, BF, FTS, GiFl, GuFo, GW, HKL, KW, LA, CMSF, Riv, Coo, MM	BS, BF, FTS, GiFl, GuFo, GW, HKL, KW, CMSF, Riv, Coo, MM
Magpie-lark	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Major Mitchell's cockatoo	CL, HKL, NL, PR, Riv	CL, HKL, NL, PR

Species	Present in Ramsar site	Breeding in Ramsar site
Mallee ringneck	BS, CL, HKL, PR, Coo, MM	BS, CL, HKL, PR, Coo, MM
Masked woodswallow	BF, CL, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BF, CL, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Mistletoebird	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, CMSF, PR, Riv, Coo, MM
Nankeen kestrel	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Noisy friarbird	BF, CL, FTS, GuFo, HKL, KW, CMSF, PR, MM	BF, CL, FTS, GuFo, HKL, KW, CMSF, PR, MM
Noisy miner	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, CMSF, Riv, Coo, MM
Olive-backed oriole	BS, BF, CL, GuFo, KW, CMSF, Riv, MM	BF, CL, GuFo, KW, CMSF, MM
Painted button-quail	BF, GuFo, CMSF, Coo	BF, GuFo, CMSF, Coo
Painted honeyeater	BF, CL, FTS, GW, HKL, CMSF	BF, CL, GW, HKL, CMSF
Pallid cuckoo	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GuFo, HKL, KW, NL, CMSF, PR, Coo, MM
Peaceful dove	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, CMSF, PR, Riv, Coo, MM
Pied butcherbird	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, MM
Pied currawong	BF, CL, GiFl, GuFo, CMSF	BF, GiFl, GuFo, CMSF
Rainbow bee-eater	BS, BF, CL, FTS, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Red-backed kingfisher	BS, BF, CL, FTS, KW, PR, Riv, Coo	BS, BF, CL, FTS, KW, PR, Riv, Coo
Red-browed pardalote	CL, Riv	CL
Red-capped robin	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM
Red-rumped parrot	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, Riv, Coo, MM	BS, BF, FTS, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo, MM
Regent parrot	BS, HKL, LA, Riv	BS, HKL, LA, Riv
Restless flycatcher	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, Riv, MM
Rufous songlark	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, NL, CMSF, PR, Riv, Coo, MM
Rufous whistler	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Sacred kingfisher	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, MM
Scarlet robin	BF, GuFo, CMSF, Coo	BF, GuFo, CMSF, Coo
Southern boobook	BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BF, CL, GuFo, HKL, KW, CMSF, PR, Riv, MM
Southern whiteface	BS, CL, GuFo, HKL, KW, LA, CMSF, PR, Riv, MM	BS, CL, GuFo, HKL, KW, LA, CMSF, PR, Riv, MM
Spiny-cheeked honeyeater	BS, CL, FTS, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, CL, FTS, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Striated pardalote	BS, BF, CL, FTS, GiFl, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GiFl, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo, MM
Sulphur-crested cockatoo	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, CMSF, Riv, Coo, MM
Superb fairy-wren	BS, BF, FTS, GuFo, GW, KW, LA, CMSF, Riv, Coo, MM	BS, BF, FTS, GuFo, GW, KW, CMSF, Riv, Coo, MM

Species	Present in Ramsar site	Breeding in Ramsar site
Superb parrot	BF, FTS, CMSF	BF, FTS, CMSF
Tawny frogmouth	BF, CL, FTS, GuFo, HKL, KW, CMSF, PR, Riv, MM	BF, CL, GuFo, HKL, KW, CMSF, Riv, MM
Tree martin	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Varied sittella	BF, CL, GuFo, HKL, KW, LA, CMSF, Riv, Coo	BF, CL, GuFo, CMSF, Riv
Variegated fairy-wren	BS, CL, FTS, GW, HKL, KW, LA, NL, PR, Riv, Coo, MM	BS, CL, FTS, HKL, KW, LA, NL, PR, Riv, Coo, MM
Wedge-tailed eagle	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Weebill	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Whistling kite	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
White-breasted woodswallow	BS, BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, MM	BF, CL, FTS, GuFo, GW, HKL, KW, NL, CMSF, PR, Riv, MM
White-browed babbler	BS, BF, CL, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo	BS, BF, CL, GuFo, HKL, KW, LA, CMSF, PR, Riv, Coo
White-browed woodswallow	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
White-plumed honeyeater	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
White-winged chough	BS, BF, CL, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, MM	BS, BF, CL, GuFo, HKL, KW, LA, CMSF, PR, Riv, MM
White-winged fairy-wren	BF, CL, FTS, KW, NL, PR, Riv, MM	BF, CL, FTS, KW, NL, PR, Riv, MM
White-winged triller	BS, BF, CL, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Willie wagtail	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, GW, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Yellow-rumped thornbill	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM	BS, BF, CL, FTS, GuFo, HKL, KW, LA, NL, CMSF, PR, Riv, Coo, MM
Yellow-throated miner	BS, CL, FTS, GW, HKL, KW, LA, NL, PR, Riv, MM	BS, CL, FTS, HKL, KW, LA, NL, PR, Riv, MM
Yellow rosella	BS, BF, FTS, GuFo, HKL, KW, CMSF, Riv	BS, BF, GuFo, HKL, KW, CMSF, Riv
Yellow thornbill	BS, BF, FTS, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo, MM	BF, FTS, GuFo, HKL, KW, LA, NL, CMSF, Riv, Coo, MM
Zebra finch	BS, CL, FTS, GuFo, KW, NL, PR, Riv, Coo, MM	BS, CL, FTS, GuFo, KW, PR, Coo, MM

Appendix 6. Spatial priorities in relation to Ramsar sites

The figures in this appendix display the spatial priorities in relation to sites designated as Ramsar Wetlands of International Importance for each of the three prioritisation scenarios (threatened species, floodplain-dependent species, and floodplain-associated species). Each Ramsar site that intersected with Murray-Darling Basin Authority-defined floodplains (MDBA 2008) is shown in its own panel. White areas of each map are not classified as floodplains by the Murray-Darling Basin Authority and as such have not been allocated a priority ranking. Note the differing scale in each panel.

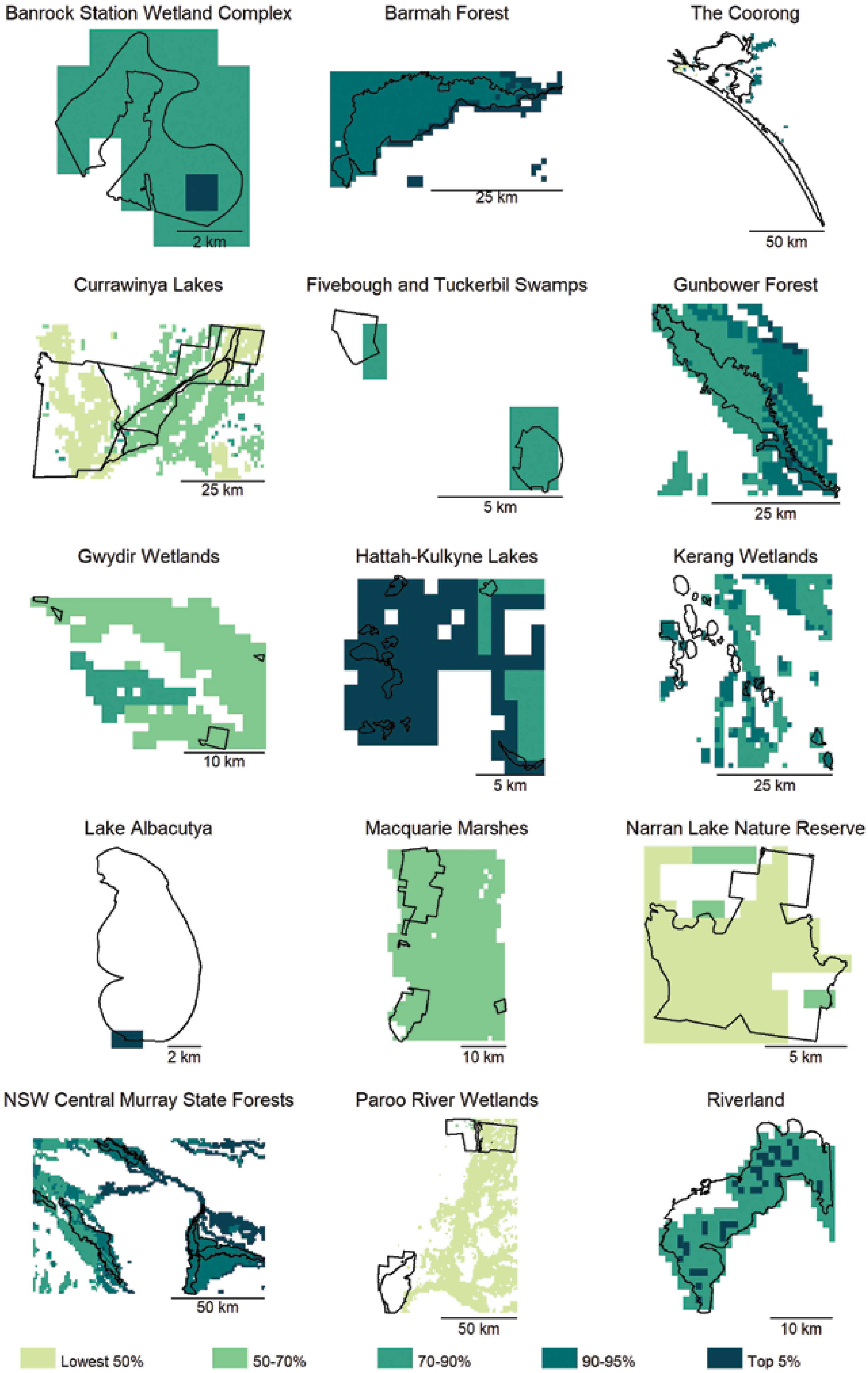


Figure A6.1 Threatened species (scenario 1).

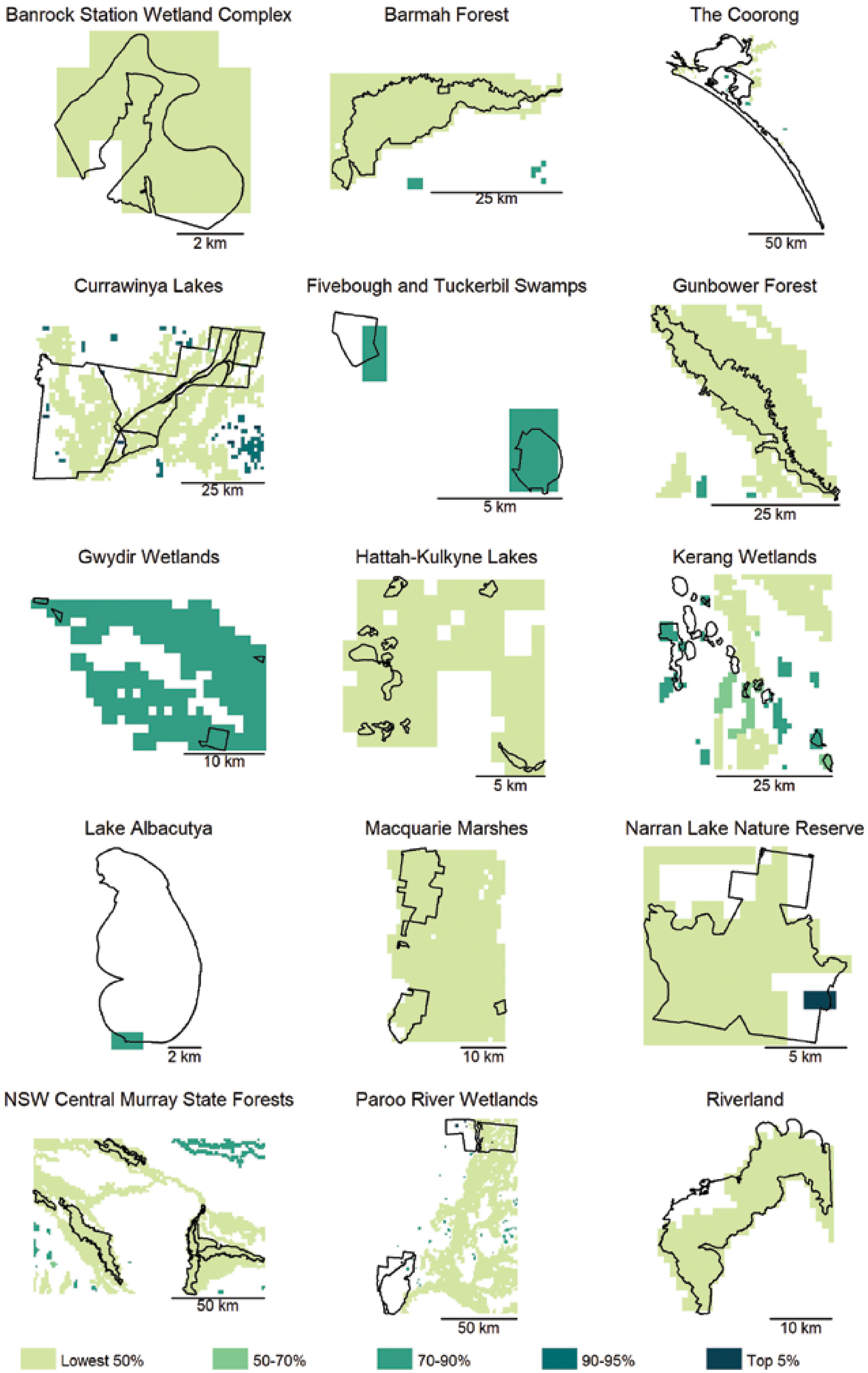


Figure A6.2 Floodplain-dependent species (scenario 2).

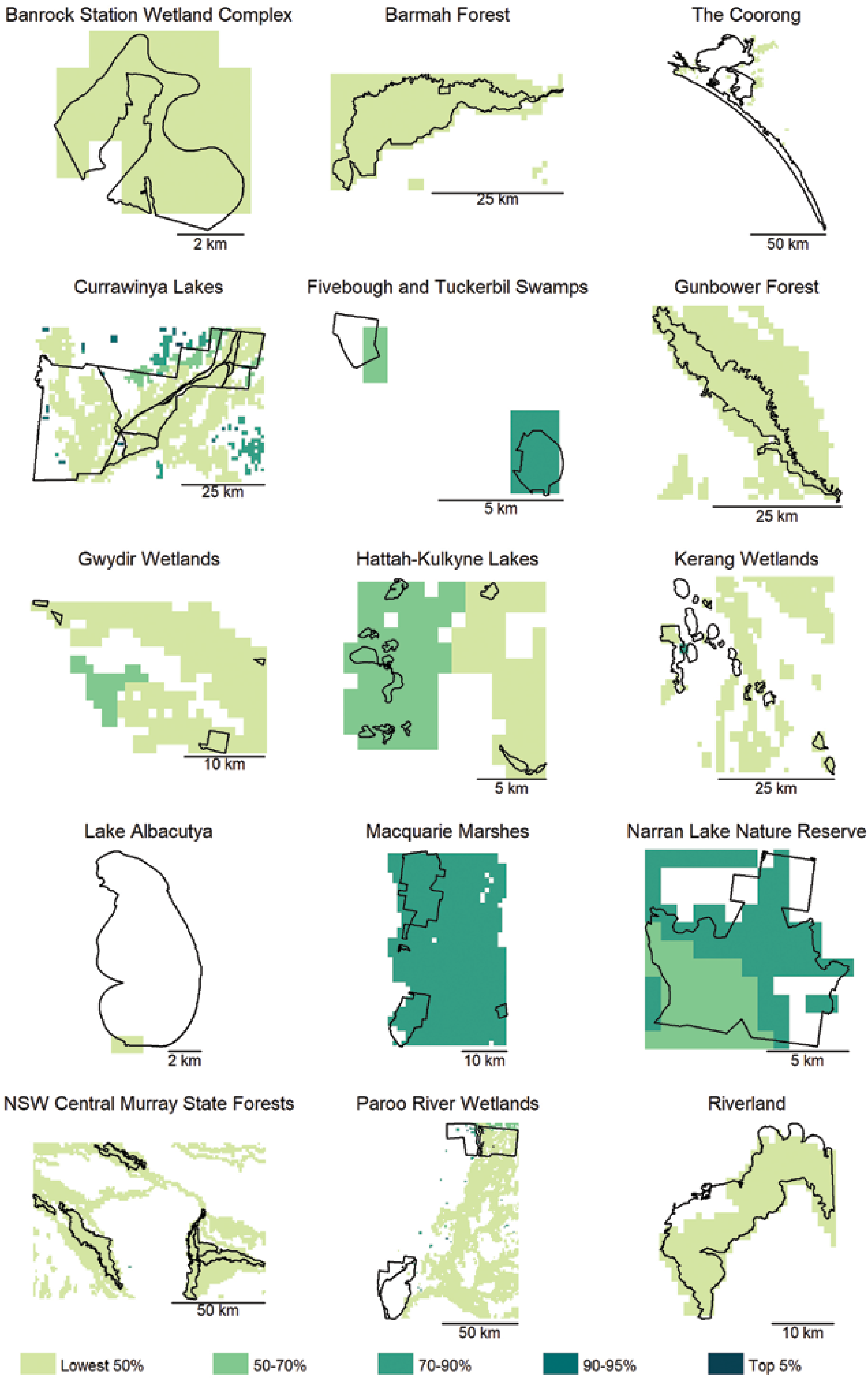


Figure A6.3 Floodplain-associated species (scenario 3).

Further information:

http://www.nespthreatenedspecies.edu.au

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Threatened Species Recovery Hub

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