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Conservation Prioritisation for the Murray-Darling Basin: Representation Gap Analysis and Vulnerability Assessment

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Executive Summary

This report presents the key findings from a comprehensive evaluation of representation gaps for high conservation value aquatic species, ecosystems and habitats (biodiversity assets) in the Murray-Darling Basin. The study aimed to assess the protection status of biodiversity assets within existing conservation measures and identify gaps that require urgent attention. The analysis focused on the representation of biodiversity assets, the correlation between asset size and protection, and a vulnerability assessment of assets to climate change. The results provide valuable insights for prioritising conservation efforts and guiding future management decisions.

Part 1: Representation Gap Analysis

The evaluation revealed that the Murray-Darling Basin demonstrates low protection, with 14% of the area falling within existing protected areas, Key Biodiversity Areas (KBA), or Ramsar wetlands. Additionally, 24% of the basin is potentially waterable, and 4% falls into both protected and waterable categories. The study found a significant correlation between biodiversity asset size and protection, with larger assets exhibiting higher representation within protected areas, KBA, or Ramsar wetlands.

Certain biodiversity asset types showed better representation within conservation measures. Wetlands classified as Directory of Important Wetlands in Australia (DIWA) demonstrated relatively higher representation compared to other asset types. The overall protection equality metric (PE) for Important Wetlands (DIWA) was 0.55, indicating a low to average level of protection equality. Specific wetland types, such as streams and transition streams classified under Australian National Aquatic Ecosystems (ANAE) framework, were poorly represented in the Basin.

The evaluation identified specific catchments with varying levels of representation. The Condamine catchment exhibited the lowest representation, despite its significant species richness, particularly reptiles and mammals.

Ecological Communities of National Significance exhibited low representation, with only 16% of likely to occur classes being adequately protected. Catchments such as Hamilton, Murrumbidgee, and Upper Murray demonstrated relatively higher representation, while the Otway and Lake Frome catchments lacked designated protected and managed areas.

Furthermore, the analysis revealed major representation gaps across most of the Basin, particularly in the Condamine, Border Rivers, and Macquarie catchments, which had minimal to no representation within protected areas, KBA, or Ramsar wetlands. The assessment highlighted the Mid-Murray catchment as having the highest proportion (60-80%) of potentially waterable area, followed by the Condamine, Murrumbidgee, and Goulburn-Loddon catchments (20-40%).

ANAE wetland classes, particularly permanent stream systems, were significantly underrepresented within protected areas, KBA, or Ramsar wetlands. While 68% of important wetlands (DIWA) were represented within conservation measures, several wetlands remained unprotected or inadequately represented.

These findings emphasise the need for targeted conservation efforts to address the representation gaps and enhance the protection of important biodiversity assets within the Murray-Darling Basin. The detailed analysis, maps, and metrics provided in this study offer valuable tools for informed decision-making, assisting stakeholders in prioritising conservation and management strategies. Access to the interactive map developed on Google Earth Engine further facilitates the use of these findings in future conservation initiatives and sustainable management practices in the region.

Part 2: Vulnerability Analysis

In this study, we assessed the vulnerability of biodiversity assets to climate change within the MDB using Climate Velocity as an indicator. Climate velocity layers, derived from reliable gridded datasets for monthly mean temperatures and precipitation, were obtained and analysed. Our analysis focused on understanding the projected shifts in climate conditions across the landscape in terms of kilometres per year (km/yr).

By performing zonal statistics, we evaluated the average change in climate velocity for various biodiversity assets within the MDB, including the ANAE Wetlands, DIWA, SNES, ECNES, Darling River floodplain vegetation and NVIS.

Our findings highlighted areas where significant climate shifts are expected to occur. We identified biodiversity assets within these regions that are likely to experience notable climate changes. For example, the Darling River floodplain vegetation is projected to undergo average changes in mean monthly temperature ranging from 3.43 to 3.99 km/year and mean monthly precipitation ranging from 3.21 to 5.16 km/year.

This vulnerability analysis provides valuable insights into the potential impacts of climate change on biodiversity assets within the MDB. The results can guide future conservation efforts and inform management strategies aimed at mitigating the risks associated with climate change. This information provides a vital insight that will be utilised as a penalty layer in the Basin-wide prioritisation analysis that will follow on from this study.

Table of Contents

Project Introduction

Environmental watering aims to help protect and restore biodiversity, including many plants and animals that depend on Basin water resources. This includes representative populations and communities of native biota, which refer to species typical of a particular ecosystem or region and often involves protecting a subset of species representative of the biodiversity area. Not all wetlands will be of equal value in protecting biodiversity and with declining water resources and increasing threats to ecosystems, it is important to prioritise protection for those ecosystems with the potential to make the greatest contribution to the Basin Plan objectives. **This project aims to help the Murray–Darling Basin Authority (MDBA) to identify places of high conservation value and prioritise management actions to conserve the critical biodiversity assets in these areas.** This information will be vital to inform the Basin Plan review in 2026, which strongly focuses on climate adaptation. Through stakeholder engagement and spatial analysis, this project will produce fit-for-purpose maps and guidelines for management in the Murray-Darling Basin (Figure 1). These guidelines will reflect co-designed objectives and provide the basis for evidence-based policy to inform Basin Plan 2.

More specifically this project aims to:

1. Evaluate representation gaps for biodiversity assets in the existing network of protected and managed areas.
2. Estimate the vulnerability of biodiversity assets to climate change.
3. Co-design and conduct conservation prioritisation with significant input from MDBA, Commonwealth Environmental Water Office (CEWO), Basin states and other Stakeholders.

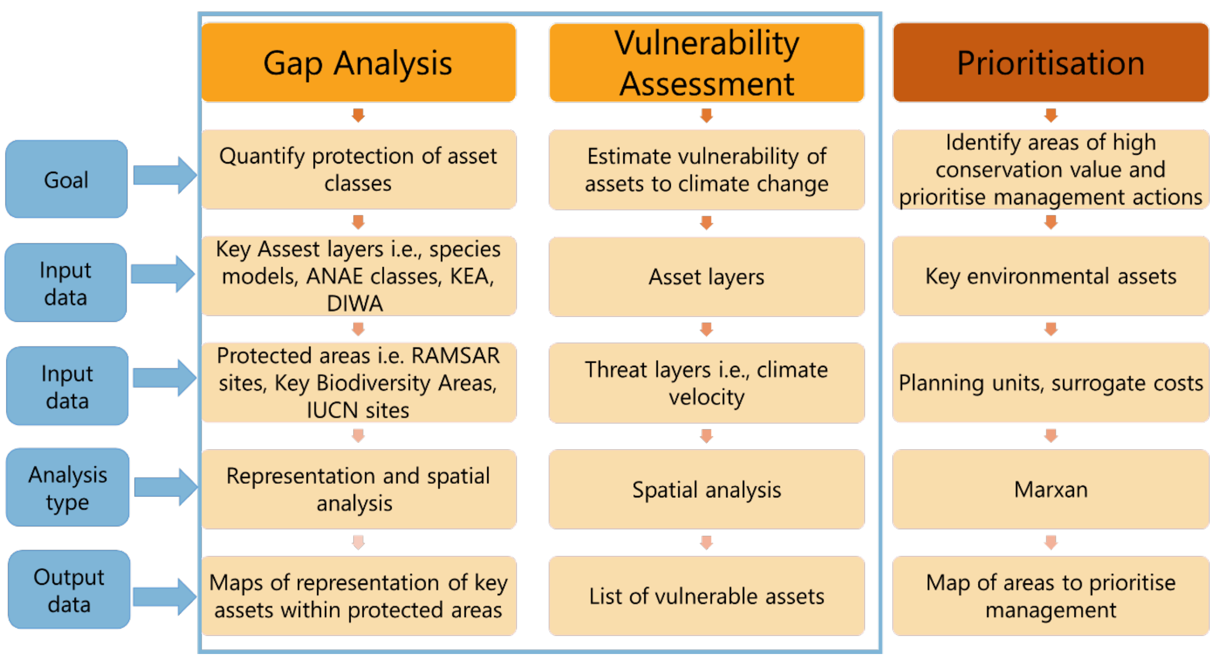

Figure 1. Project workflow for the three main tasks including data inputs and outputs. The content in the blue box is available in this report.

Part one: Representation Gap Analysis

Introduction

A gap or representation analysis is often conducted in systematic conservation planning prior to spatial prioritisation analysis to identify major gaps in the protection of important species, habitats or other important environmental assets. The resulting gaps in protection can then be used to inform future conservation and management decisions. This can include identifying priority areas for the establishment of new protected areas, the expansion of existing ones or planning appropriate management efforts such as environmental watering.

The Murray-Darling Basin provides habitat for many important species including fish, birds, mammals, reptiles and frogs among many others. It also contains key habitats and ecosystems for these species, for example, important waterbird wetlands, threatened fish habitat and endangered plant communities. However, how represented these biodiversity assets are within protected areas or other area-based conservation measures is currently unknown.

This study aims to evaluate representation gaps for high conservation value aquatic species, ecosystems and habitats (biodiversity assets) in the existing protected and managed area network. More specifically this study will 1) assess how represented biodiversity assets in the Murray-Darling Basin are within protected and other area-based conservation measures using protection equality metrics, 2) highlight major gaps in protection for the biodiversity assets through spatial analysis, 3) determine if there is a correlation between the size of the biodiversity asset (ha) and protection using statistical analysis.

The resulting output and data will then be used in a vulnerability assessment, followed by prioritisation analysis.

Methods

Data

Key stakeholders including the WERP theme 3 User Advisory Group and other external stakeholders were consulted to determine the biodiversity assets, spatial units and protected area datasets to be in the gap analysis. Through various workshops and meetings, biodiversity assets were identified and included in the analysis (Table 1).

Table 1. List of data to be included in the representation gap analysis

Variable type	Variable name	Dataset name	Reference
Spatial Unit	Geofabric Catchment Pfafstetter (v2.1.1).	Geofabric Catchment Pfafstetter (v2.1.1).	Australian Bureau of Meteorology. (2014)
	Geofabric ANAE waterways layer	Australian National Aquatic Ecosystem (ANAE)	Brooks (2021)
Biodiversity asset	ANAE Wetland classes	Australian National Aquatic Ecosystem (ANAE) classification for the Murray Darling Basin Version 3	Brooks et al (2013)
	DIWA	Directory of Important Wetlands in Australia (DIWA) Spatial Database	Australian Government (2010)
	SNES	Species of National Environmental Significance Distributions (public grids)	Australian Government (2022a)
	ECNES	Ecological Communities of National Significance	Australian Government (2022b)
	Murray-Darling Basin floodplain vegetation mapping	DarlingMDB_2016_PCT_E_4454	Murray-Darling Basin Authority (2015)
	NVIS	National Vegetation Information System Version 6.0	Australian Government (2020)
Protected area & other area-based conservation measures	CAPAD	The Collaborative Australian Protected Areas Database 2020	Australian Government (2022c)
	Ramsar	National dataset of Australia's Ramsar Wetlands	Australian Government (2023)
	KBA	World Database of Key Biodiversity Areas, including Australian Important Bird Areas	Birdlife Australia (2018)
Waterable areas	Areas potentially able to be watered by managed flow release from dams	Original_potentially_waterable_areas	Bunn et al (2014)

Data wrangling

Each environmental asset (Table 1) was reprojected to EPSG:3577 - GDA94 / Australian Albers, and each of the geometries were fixed prior to analysis. The catchment layer, Species and Ecological Communities of National significance and fish models required further data wrangling.

Catchments

To analyse the different landforms of each catchment the ANAE waterways layer and Geofabric Catchment Pfafstetter (v2.1.1) layer were projected, and geometries were fixed. Vertices were created for the ANAE Waterways (V3) layer to identify landform types along each river and stream. A spatial join was conducted for the ANAE waterway's vertices and Geofabric Catchment Pfafstetter layer. The joined layer was then aggregated by Australian Water Resources Council (AWRC) name and used for further analyses.

Species of National Environmental Significance

Multiple steps were taken to separate out each species from the Species of National Environmental Significance (SNES) dataset as it was provided as a single shapefile with 484 layers.

The Linux Subsystem was used due to the size of the dataset and the spatial tools required. Code was written using the Orfeo toolbox in Bash to convert each polygon (species) to a standard 30m raster file. BandMathx was then used to stack the rasters and count the number of species per 30m grid cell to enable zonal statistics in QGIS. This step was repeated for each taxonomic group (plants, reptiles, birds, frogs, fish, mammals, others).

Ecological Communities of National Environmental Significance

The Ecological Communities of National Environmental Significance (ECNES) dataset was provided as a single shapefile with 32 layers. The multi-polygon shapefile was split into 32 separate shapefiles for analysis. The distribution data for ECNES is provided in two groups; likely to occur and may occur.

Protected area and other area-based conservation measures

As this study focuses on evaluating the representation of important biodiversity assets within existing conservation and management frameworks, it was decided, with the expertise of our stakeholders, to use multiple protected and managed area tenures. The Collaborative Australian Protected Areas Database (CAPAD) categories were used as well as Key Biodiversity Areas (KBA) and Ramsar wetlands. These were chosen as they are sites that have a significant level of protection, management or are likely to be designated protected in the future. While acknowledging the inherent complexities of ecological functionality across protected and non-protected habitats, our study is primarily focused on evaluating the representation of important biodiversity assets within existing conservation frameworks.

The three protected area and other area-based conservation layers (CAPAD, Ramsar and KBA) were spatially joined in QGIS to create a single protected area layer projected to EPSG:3577 - GDA94 / Australian Albers (Figure 2).

We acknowledge the value of considering privately held lands managed under agreements with Catchment Management Authorities (CMAs) and Local Land Services (LLSs) to enhance the study's comprehensiveness. Our primary goal is to pinpoint concentrated areas of biodiversity assets, including important species, communities, and habitats, to provide valuable insights for strategic management actions by entities like CMA's and LLSs. However, the inclusion of such data is currently beyond the scope of our study due to inherent challenges related to data accessibility.

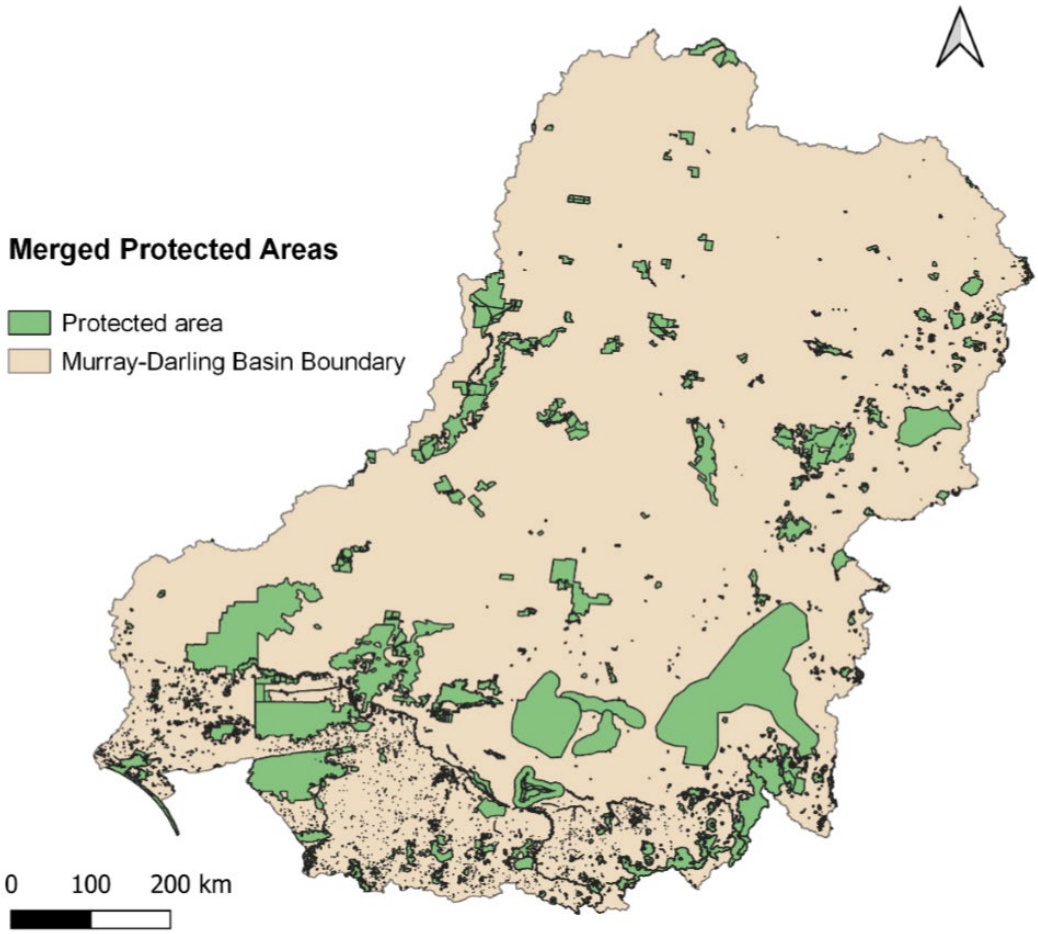

Figure 2. A map showing the merged protected and managed area layer including CAPAD, KBA and Ramsar protected areas within the Murray-Darling Basin Boundary.

Potentially Waterable Areas

Recognising that ecological functionality can vary widely across different areas, and environmental watering is a key management action within the basin we have included the potential to be environmentally watered. A spatial layer showing areas potentially able to be watered by managed flow releases from dams was provided by Bunn et al 2014 and was projected to EPSG:3577 - GDA94 / Australian Albers (Figure 3). This was based on a simple set of rules that included identifying those parts of the Basin that are downstream of large reservoirs (i.e. that can store > 50% of mean annual runoff) and are within the lateral extent of a 10 year return interval flood event, and assumes there are no other constraints to water delivery (e.g. floodplain infrastructure, roads and bridges, etc). It is important to note that the spatial extent of areas identified as potentially able receive the benefits of managed flow releases from dams is likely to be overestimated given constraints on water delivery. This also does not imply that there would be sufficient water to meet the environmental flow needs for the entire area or for environmental assets in particular areas.

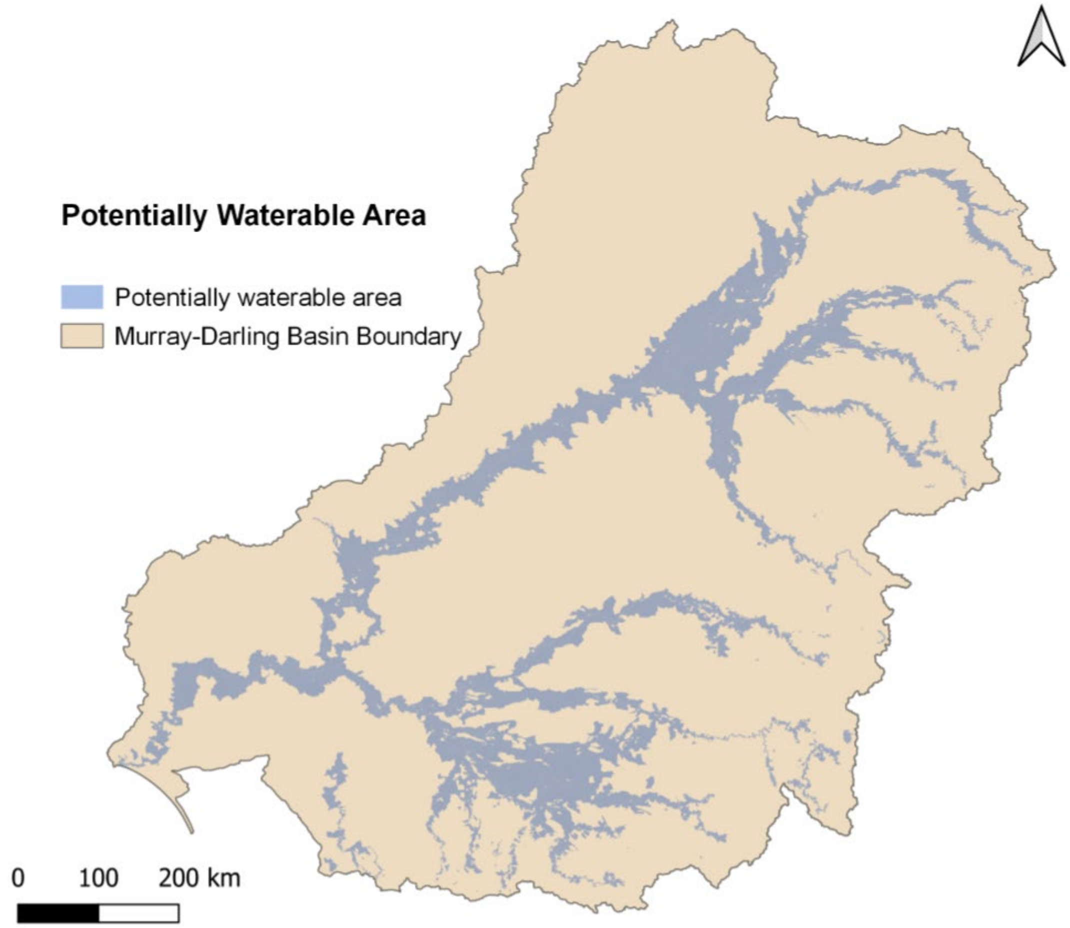

Figure 3. Areas potentially able to be watered by managed flow release from dams, adapted from Bunn et al 2014.

Spatial Analysis

Overlap Analysis

Overlap analysis is a powerful spatial analysis tool in QGIS that identifies and measures the degree of spatial intersection between two or more vector datasets. This analysis was conducted for each biodiversity asset and the spatially joined protected area, KBA and Ramsar wetlands layer. The percentage for area within the protected area, KBA and Ramsar wetlands layer was then calculated, mapped and reported.

Understanding the representation of biodiversity assets within potentially waterable areas holds significant importance in determining the feasibility of allocating water for environmental conservation in the Murray-Darling Basin. A secondary overlap analysis was conducted for each biodiversity asset and the potentially waterable layer. The percentage for area within the potentially waterable area layer was calculated, mapped and reported.

Interactive Map

An interactive map was developed to enable stakeholders to visualize gaps in protection for each of the biodiversity assets. The code was written in the JavaScript coding language in Google Earth Engine (Request access to GitHub).

Statistical Analysis

Protection equality metric

Protection equality metrics are used to measure the level of representation of biodiversity assets within a protected or managed area network and are often used in systematic conservation planning. In this study the protection equality metric is used to determine how represented the biodiversity assets including wetlands, significant species and ecological communities and vegetation are within the protected area network.

The Protect Equal R Package (Chauvenet 2017) was used to determine how equally the biodiversity assets within the MDB are protected. The pi (area within a protected area) and ai (total area) were calculated for each biodiversity asset by exporting spatial overlap data from QGIS.

The proportional area was calculated for each biodiversity asset under the protected areas. The output of the analysis is a corrected Protection Equality (PE) metric which measures the ecological representation of each asset where 0 shows no representation and 1 is equal representation.

Linear regression

The biodiversity assets with the Murray-Darling Basin vary significantly in size for example some assets cover over 1000 ha while others just 1ha and are sporadically scattered across the landscape. To understand trends in the data it was important to determine whether the size of the assets have an impact on their representation within protected areas.

Linear regression models were conducted to determine whether there is a correlation between the original area (ha) of the asset and the proportion within protected areas. Models were run for each asset using the ‘lm’ package in R Version 3.6.3 with default settings.

Results

Summary

- A total of 14% of the Murray-Darling Basin is within either CAPAD, KBA or Ramsar wetlands, 24% of the Basin is potentially waterable with 4% both represented and potentially waterable (Table 2).
- There is a significant correlation between the area (hectares) of each biodiversity asset and representation within a protected area, KBA or Ramsar wetlands, where the larger the area the greater the representation.
- Important wetlands (DIWA) are more represented in protected areas, KBA or Ramsar wetlands than other assets (Figure 4).
- ANAE wetland types are not well represented, particularly streams (Rp1), transition streams (Rp1.2), lowland streams (Rp1.4), low energy upland streams (Rp1.3) and high energy upland streams (Rp1.1).
- Native vegetation is poorly represented in protected areas, KBA or Ramsar wetlands across the Basin.
- The Condamine has the least representation but is relatively high in significant species richness, particularly for reptiles and mammals.
- Ecological Communities of National Significance are not well represented (16% of likely to occur are represented).

To visualize the area represented within protected areas, KBA or Ramsar wetlands for these assets, visit the interactive map [on Google Earth Engine.]

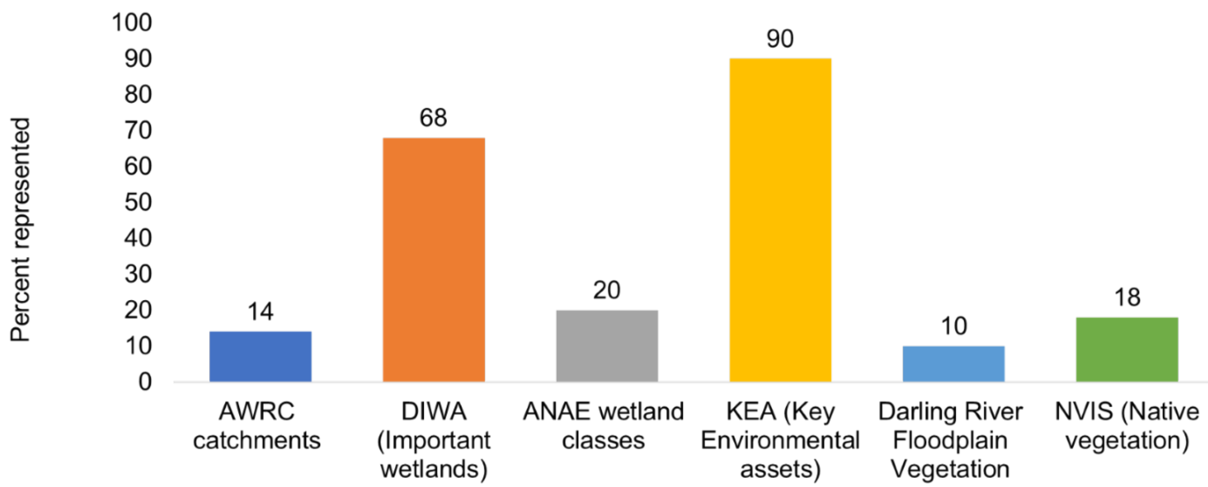

Figure 4. Percent of each biodiversity asset represented within a protected area, KBA or Ramsar wetland.

Table 2. Summary of representation in protected areas, KBA or Ramsar wetlands for catchments and each biodiversity asset area in hectares (ha)

Asset name	Total Area (ha)	Area Protected (ha)	% Area protected	Protection Equality Metric	% Area potentially waterable
AWRC catchments	106202477	15202258	14	0.52	15
ANAE wetland classes	8139700	1667505	20	0.56	46
DIWA Important wetlands	1393319	948892	68	0.55	64
SNES Species of National Environmental Significance	NA			0.38	NA
ECNES (Likely to occur) Ecological Communities of National Environmental Significance	NA			0.44	NA
ECNES (May occur) Ecological Communities of National Environmental Significance	NA			0.49	NA
Darling River Floodplain Vegetation	436838	43623	10	0.54	0
NVIS Native vegetation groups 1-11, 13-24, 26-29, 31-32	63648064	11629869	18	0.45	NA
NVIS Non-native or unknown vegetation groups 25, 99	42554315	3569319	8		
Species (fish, plants, macro inverts) models	To be completed when data is made available				

Catchments

The Australian Water Resources Council (AWRC) catchment with the highest representation is Hamilton (68% protected) followed by the Murrumbidgee (37%) and the Upper Murray (27%). The Otway and Lake Frome catchments do not fall within any designated protected or managed area (Figures 5 & 6). Upland AHGF catchments have the highest representation within protected areas (22%), followed by Low Energy Upland catchments (14%), Transitional catchments (11%) and Lowland catchments (11%).

Major gaps in representation are across a large majority of the Basin area. For example, The Condamine has little to no representation within a protected area, KBA or Ramsar wetland with similar representation gaps in the Border Rivers and Macquarie. The Murrumbidgee and Upper Murray have significant representation compared to other catchments with between 24-37% of area within a protected area, KBA or Ramsar wetland. Only 15% of the Murray-darling Basin is potentially waterable with the Mid-Murray having the highest area in a waterable zone (60-80%), followed by the Condamine, Murrumbidgee, and Goulburn-Loddon catchments (20-40%) (Figure 5).

The fixed area protection equality metric (PE) of AWRC catchments was 0.52, indicating average protection equality across catchments.

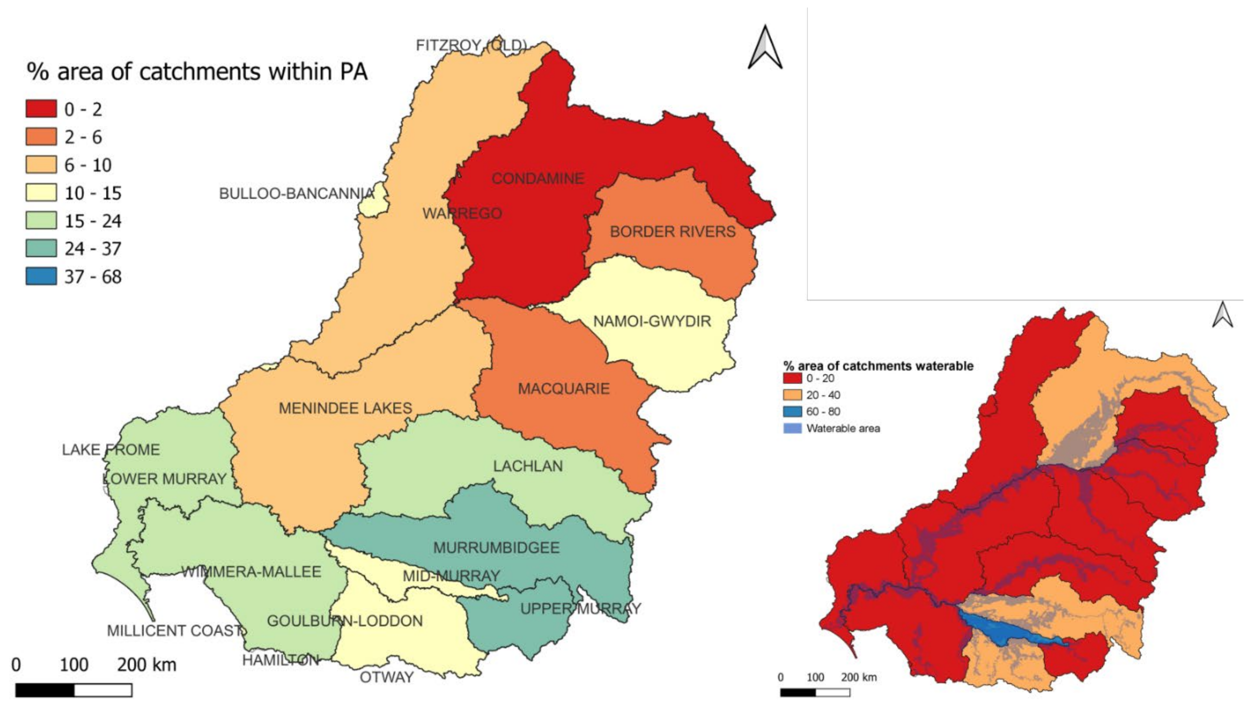

Figure 5. Map of the MDB showing the percentage area of catchments by Australian Water Resources Council name within protected areas, KBA and Ramsar wetlands with the inset showing the percent (%) area of each catchment that is waterable with the waterable area shown in dark blue.

When the areas are broken down into smaller contracted catchments, it is noticeably clear where gaps in protection occur (Figure 6). Protected areas are often small and sparsely scattered across the landscape. For example, only small, sparse, and isolated areas are protected in the northern Murray-Darling Basin (Condamine catchments). The upland systems including both high (22% protected) and low energy (14% protected) are more protected than lowland and transitional systems (Figure 6).

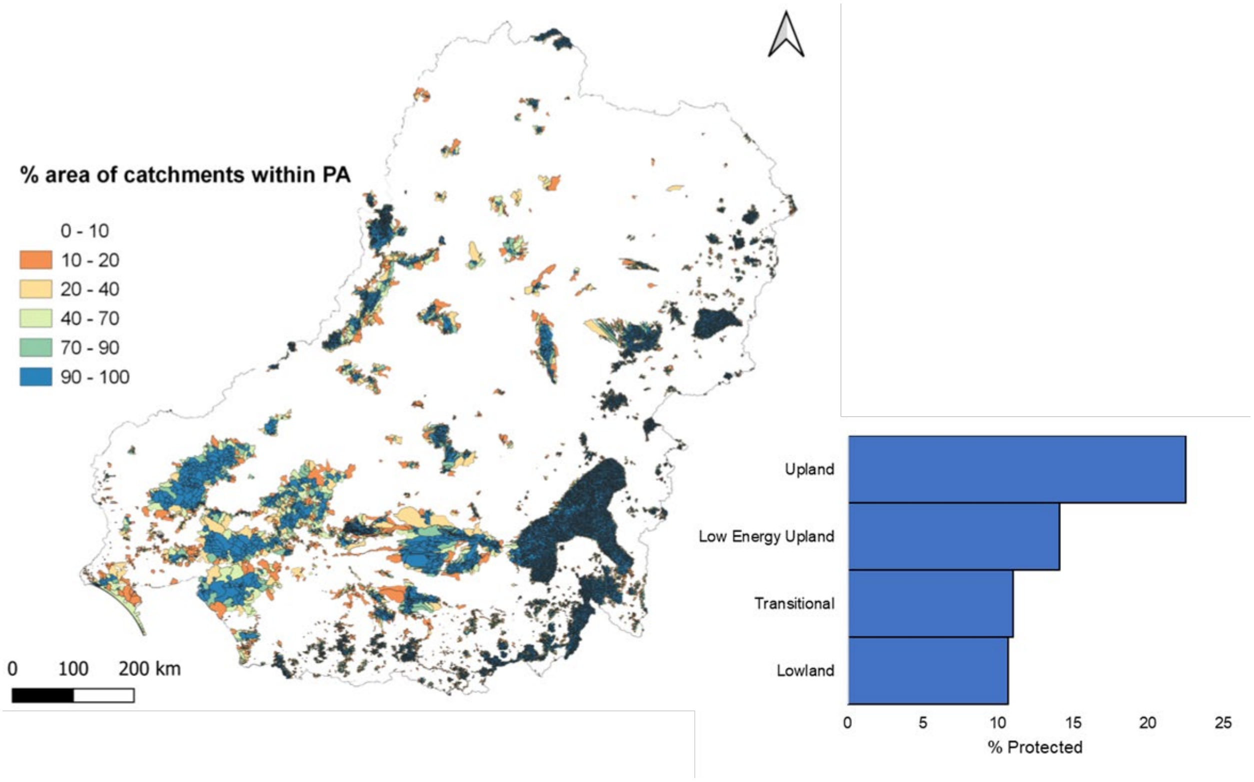

Figure 6. Map of the MDB showing the percentage area of Australian Hydrological Geospatial Fabric (AHGF) catchments within protected areas with the percent protection of each landform type within the basin including Upland, Low energy upland, Transitional and Lowland.

ANAE Wetland Classes

ANAE wetland classes cover ~8,139,700 hectares of which ~20% is represented within protected areas, KBA and Ramsar wetlands. Of the 70 ANAE wetland classes 11 have less 10% of area represented including permanent paper swamp (0% represented), grassland riparian zone (6% represented) and coolibah riparian zone (8% represented).

Permanent stream systems including streams, (Rp1), transition streams (Rp1.2), lowland streams (Rp1.4), low energy upland streams (Rp1.3) and high energy upland streams (Rp1.1) are not well represented within the Basin with an average of 20% area within a protected area, KBA or Ramsar wetland (Figure 7).

Of the 70 classes, 20 have over 60% of total area represented in a protected area, KBA or Ramsar wetland, with many of these tidal and intertidal zones or salt lakes (Figure 7). A total of 46% of ANAE wetland classes are in a potentially waterable area.

Overall, the ANAE classes are not well represented with protected with a proportional area protection equality metric (PE) of 0.56. There is a significant correlation between the size of the wetland and whether it is protected as the larger the area, the more likely it is to fall within a protected area ($P<0.05$, R Squared 0.645).

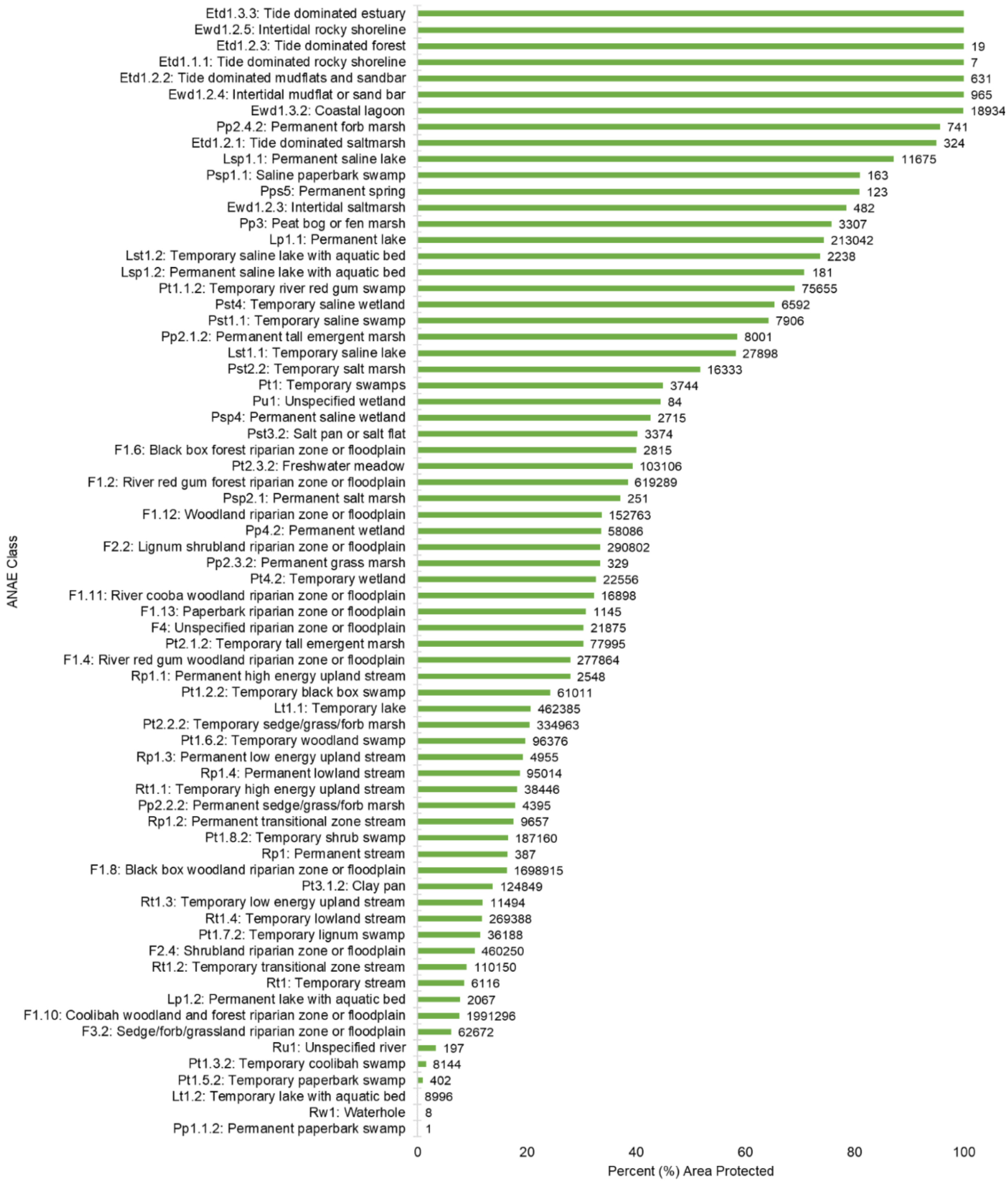

Figure 7. The percentage of area within a protected area, KBA or Ramsar wetland for each ANAE wetland class including the total area of the asset in hectares (right).

Important Wetlands (DIWA)

A total of 68% of the Important Wetlands listed on the Directory of Important Wetlands in Australia (DIWA) within the Murray-Darling basin are within either CAPAD, KBA or Ramsar wetlands. Of the 202 important wetlands, 68 had no representation in a protected area, KBA or Ramsar wetland. Of the 202 wetlands, 14 ranged between 1-20% of the area represented, 19 wetlands with 20-80% represented and the remaining 101 had 81-100% of their area within a protected area, KBA or Ramsar wetland (Figure 8).

Many of the unrepresented wetlands are isolated and often small for example, Bethungra Dam Reserve, Yarran Swamp, Taylors Lake, Great Artesian Basin Springs, Morella Watercourse, Boobera Lagoon, Pungbougal Lagoon, Green Creek Swamp, and Coopers Swamp are all under a hectare in size and have no representation in protected areas, KBA's or Ramsar wetlands. Others such as Lake George, Lake Buloke Wetlands, Talyawalka Anabranch, Teryawynia Creek, Lake Cowal Wilbertroy Wetlands, Balonne River Floodplain and Lake Hume are large in area but are also not well represented.

Approximately, 64% of the wetlands are in a potentially waterable area and 52% are both represented in protected area, KBA or Ramsar wetland and potentially waterable.

Although some larger wetlands are not well represented, there is a significant correlation between the size of the wetland and whether it is represented, where larger the area, the more likely it is to fall within a protected area ($P<0.05$, R Squared 0.911). The overall protection equality metric (PE) for Important Wetlands was 0.55, indicating a low to average protection equality.

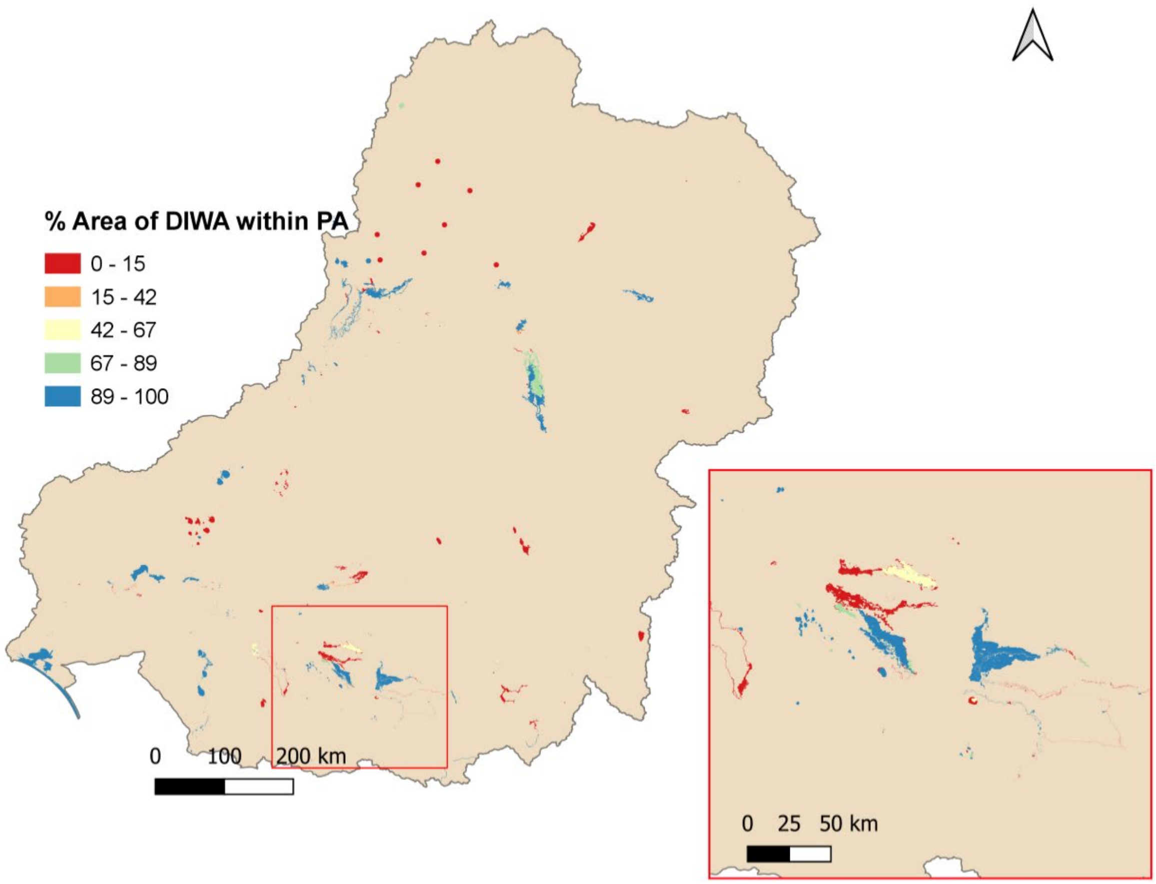

Figure 8. Map of the MDB showing the percentage area of DIWA within protected areas, KBA's or Ramsar wetlands with an inset to show an example of the wetlands.

Species of National Environmental Significance

A total of 484 species are listed as a Species of National Significance (SNES) and modelled within the Murray-Darling Basin, with birds and plants the most common taxonomic groups (Figure 10). A high number of bird species are also unrepresented in the Loddon River, Upper Murray River, Millicent Coast, Murray-Riverina, Avoca River and the Murrumbidgee River catchments (Table 3). The Border Rivers, in particular the New England area, has a high number of unprotected mammals and reptiles as does the Condamine and Fitzroy River catchments (Figure 9).

The proportional protection equality metric (PE) of Species of National Environmental Significance was 0.38, indicating below-average protection equality. There is a significant correlation between the size of the likely distribution and whether it is protected as the larger the area, the more likely it is to fall within a protected area; however, the relationship is not as linear as other assets ($P<0.05$, R Squared 0.363).

Table 3. The total and taxonomically grouped mean number of species of national significance (SNES) not represented in protected areas, KBAs or Ramsar wetlands (in **bold**) and represented (not bold) per 30m grid cell within each AWRC catchment.

Catchment name	All sp	Birds	Fish	Frogs	Mammals	Plants	Reptiles	Other
Loddon River	**31**/32	**17**/17	**2**/2	**2**/2	**3**/3	**6**/6	**2**/2	**1**/1
Upper Murray River	**30**/29	**16**/14	**2**/2	**2**/2	**4**/5	**4**/5	**2**/1	**1**/1
Millicent Coast	**29**/31	**16**/17	**1**/1	**1**/1	**1**/1	**10**/11	**1**/1	**0**/0
Murray-Riverina	**29**/31	**17**/17	**3**/3	**1**/2	**3**/2	**5**/5	**1**/1	**1**/1
Murrumbidgee River	**28**/27	**16**/16	**2**/2	**2**/1	**3**/3	**4**/4	**2**/2	**1**/1
Moonie River	**26**/37	**14**/17	**1**/1	**1**/1	**4**/7	**5**/9	**3**/4	**1**/0
Gwydir River	**25**/28	**14**/15	**1**/1	**1**/1	**5**/6	**5**/6	**2/2**	**0**/0
Avoca River	**24**/24	**16**/18	**1**/1	**1**/1	**1**/1	**5**/3	**2**/1	**1**/1
Fitzroy River (Qld)	**24**/33	**13**/17	**0**/0	**0**/0	**5**/5	**2**/6	**4**/5	**1**/0
Lachlan River	**24**/26	**15**/16	**2**/1	**1**/1	**3**/4	**3**/3	**1**/2	**1**/1
Macquarie-Bogan Rivers	**22**/24	**14**/14	**1**/1	**2**/2	**4**/4	**3**/5	**2**/2	**1**/1
Lower River Murray	**20**/23	**15**/17	**1**/1	**1**/1	**1**/2	**3**/2	**1**/2	**0**/0
Condamine-Culgoa Rivers	**19**/19	**12**/12	**1**/1	**1**/1	**3**/3	**3**/6	**2**/2	**2**/2
Lake Frome	**18**/0	**12**/0	**1**/0	**0**/0	**0**/0	**3**/0	**2**/0	**0**/0
Darling River	**15/18**	**12**/13	**1**/1	**1**/1	**1**/1	**2**/3	**0**/0	**0**/0
Lake Bancannia	**14**/15	**11**/11	**1**/0	**0**/0	**1**/2	**2**/2	**1**/1	**0**/0
Paroo River	**14**/14	**10**/10	**1**/1	**0**/0	**2**/2	**1**/2	**1**/2	**0**/0

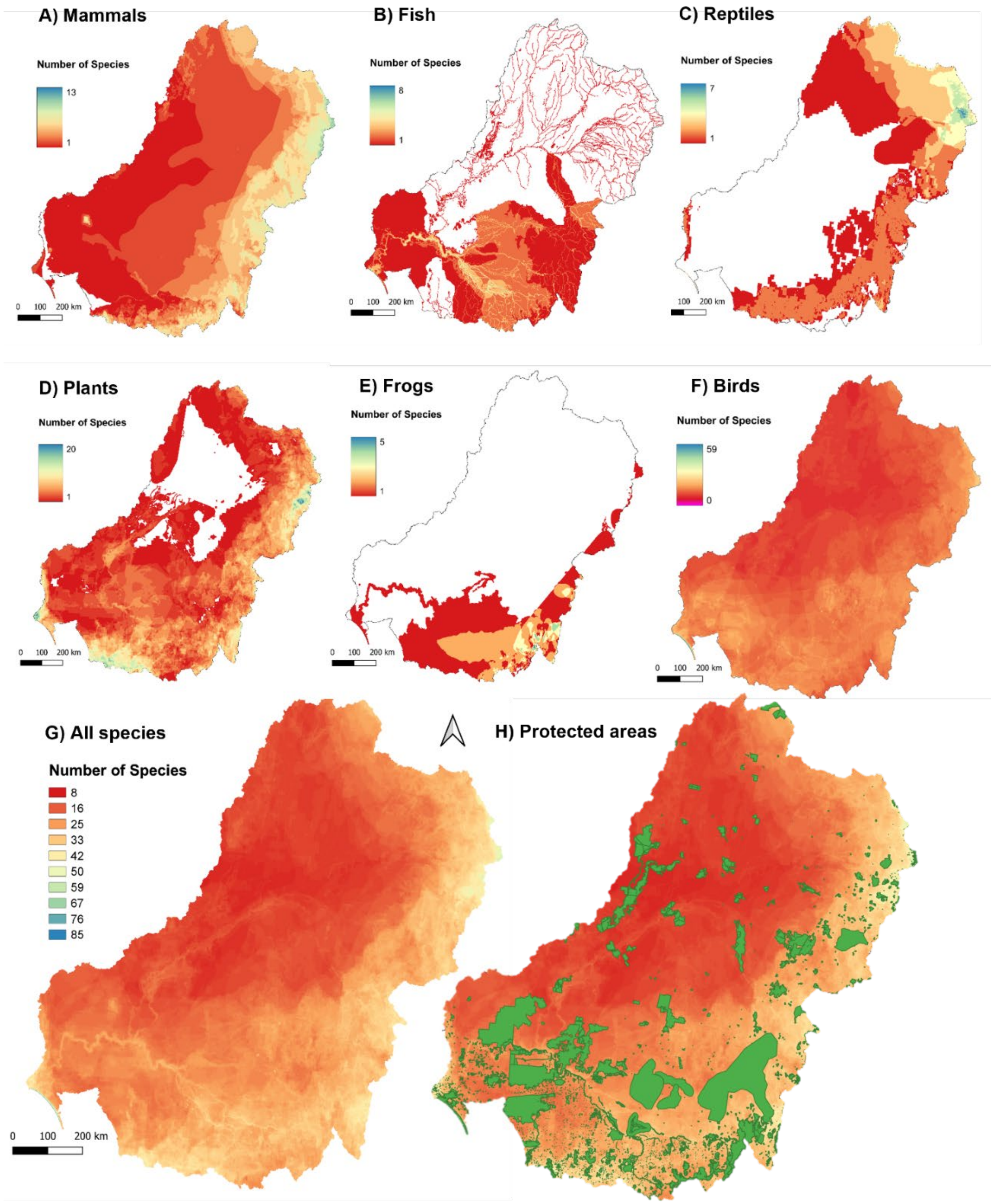

Figure 9. The total number of Species of National Significance within each 30m grid cell across the Murray-Darling Basin where white represents no data and green represents protected areas, KBAs and Ramsar wetlands.

Ecological Communities of National Environmental Significance

Approximately 16% of the total area of likely to occur ECNES are represented within a protected area, KBA or RAMSAR wetland, while communities that may occur are more represented (36%).

Of the 32 ecological communities of national environmental significance (likely to occur) only 6 have more than 50% of area represented within a protected area, KBA or RAMSAR wetland, including Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains (56%), Mallee Bird Community of the Murray Darling Depression Bioregion (57%), Alpine Sphagnum Bogs and Associated Fens (58%), Swamps of the Fleurieu Peninsula (60%), Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion (84%), Subtropical and Temperate Coastal Saltmarsh (98%) (Figure 10).

The overall protection equality metrics (PE) were 0.44 for ECNES that are likely to occur and 0.49 for ECNES that may occur, indicating relatively low protection equality.

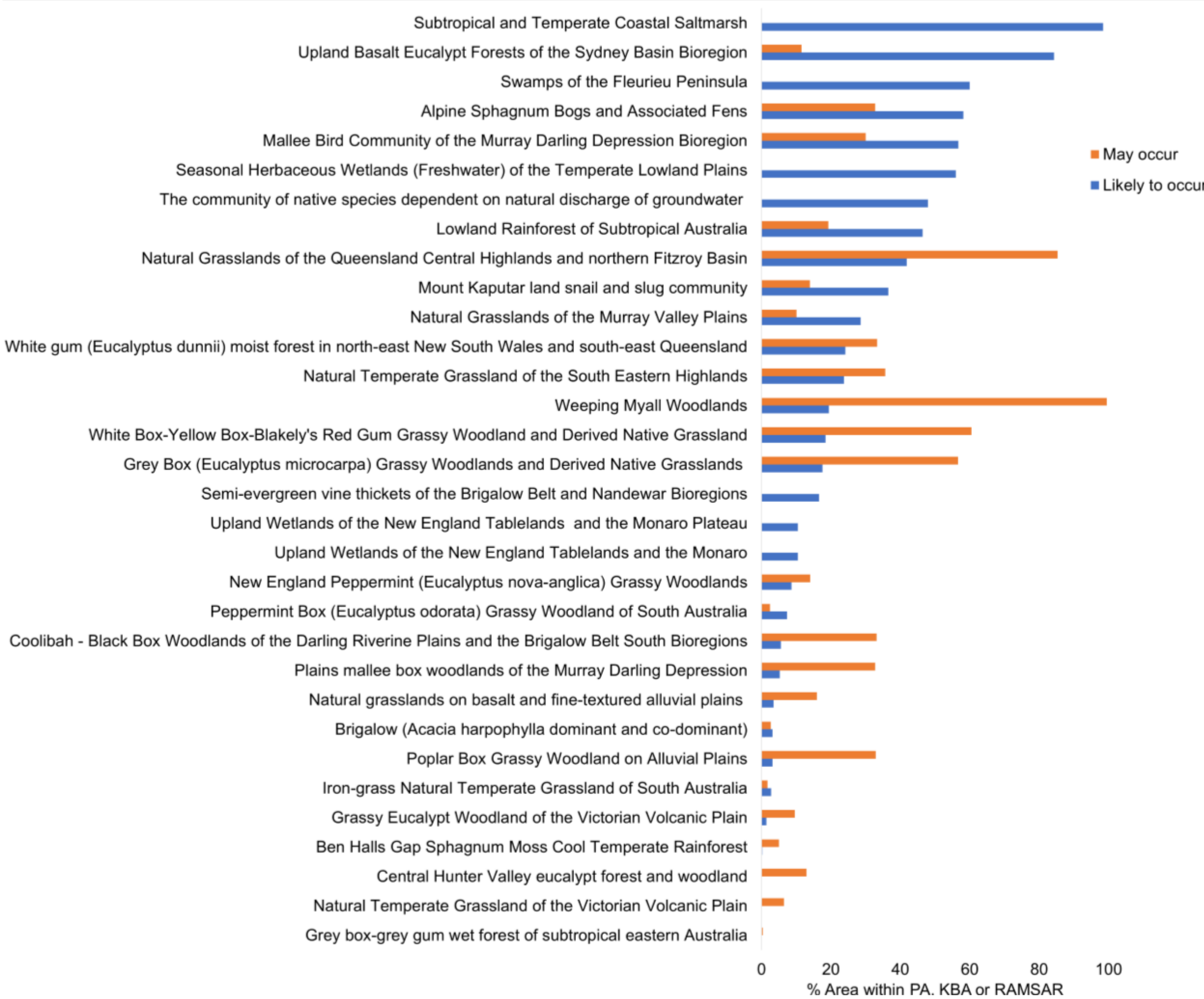

Figure 10. The percentage of area within a protected area, KBA or Ramsar wetland for each ecological community of national environmental significance with likely to occur communities in blue and may occur communities in orange.

Murray-Darling Basin floodplain vegetation

There are major gaps in representation for the floodplain vegetation of the Darling River, particularly in the northern area. A total of 10% of the Darling River floodplain vegetation is within two protected areas, the Paroo-Darling State Conservation Area, and National Park (Figure 11). The River Red Gum is the least represented vegetation group, with less than 5% within a protected area, KBA or Ramsar wetland. The Coolibah species is also scarcely represented with ~6% of area represented, followed closely by Floodplain Grassland (<10% represented) and Lignum (<15% represented) (Figure 12). The Non-woody water dependent and ephemeral wetlands had the highest percentage of area represented (~34%).

There is a significant correlation between size (area ha) and whether it is represented within a protected area, KBA or Ramsar wetland, where the larger the area, the more likely it is to be represented (P<0.05, R Squared 0.858). The proportional protection equality metric (PE) of Darling River floodplain vegetation was 0.54, indicating an average protection equality.

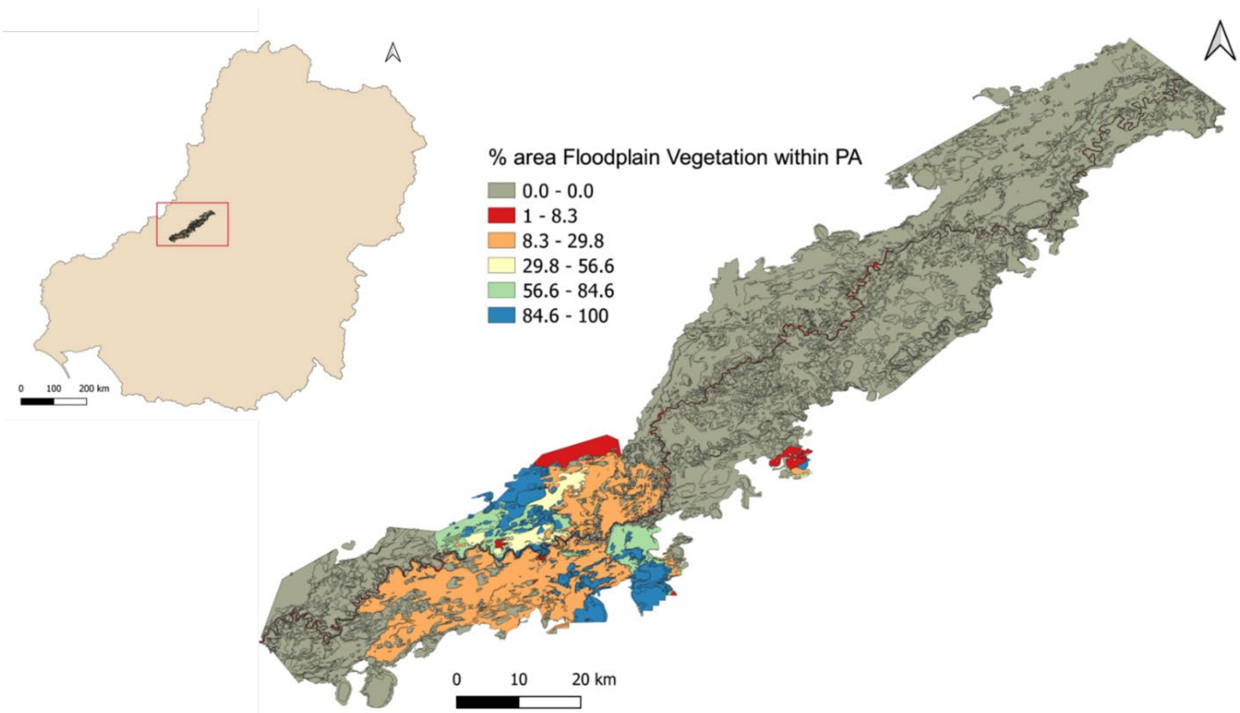

Figure 11. The percentage of area of the Darling River Floodplain Vegetation within protected areas, KBAs or Ramsar wetlands.

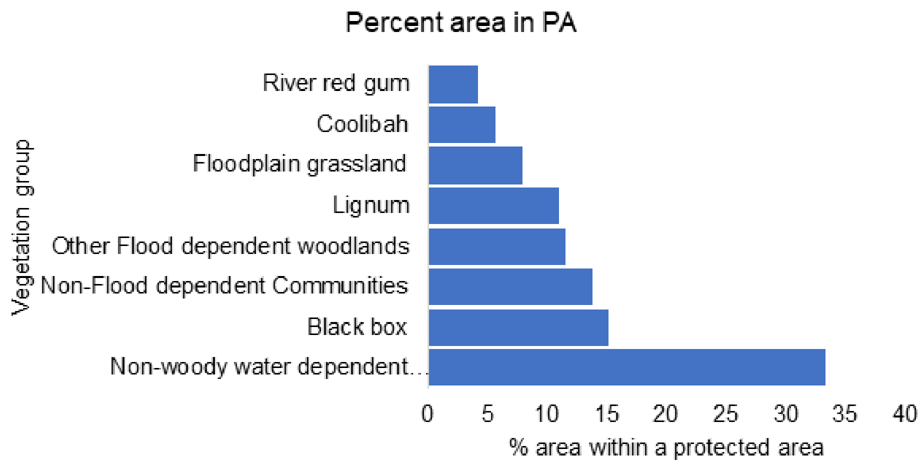

Figure 12. The percentage area represented within protected areas, KBAs or Ramsar wetlands for each of the broad vegetation groups within the Darling River floodplain.

National Vegetation Information System

Overall native vegetation is not well protected across the basin, with all major native vegetation groups with less than 57% of area represented within a protected area, KBA or Ramsar wetland, except for two categories; Heathlands (80% protected) and Seas and Estuaries (97% protected). The least represented native NVIS categories within the Basin are Other Forests and Woodlands, Acacia Open Woodlands, Hummock Grasslands, Acacia Shrublands, Acacia Forests and Woodlands, Chenopod Shrublands, Samphire Shrublands and Forblands which have less than 10% of area protected (Figure 13).

The proportional protection equality metric (PE) of the NVIS broad vegetation groups was 0.45, indicating a less than average protection equality. There is a significant correlation between the area of each vegetation group and whether it is represented, with the larger the area, the more likely it is to fall within a protected area, KBA or Ramsar wetland; however, the relationship is not as strong as other assets ($P<0.05$, R Squared 0.643).

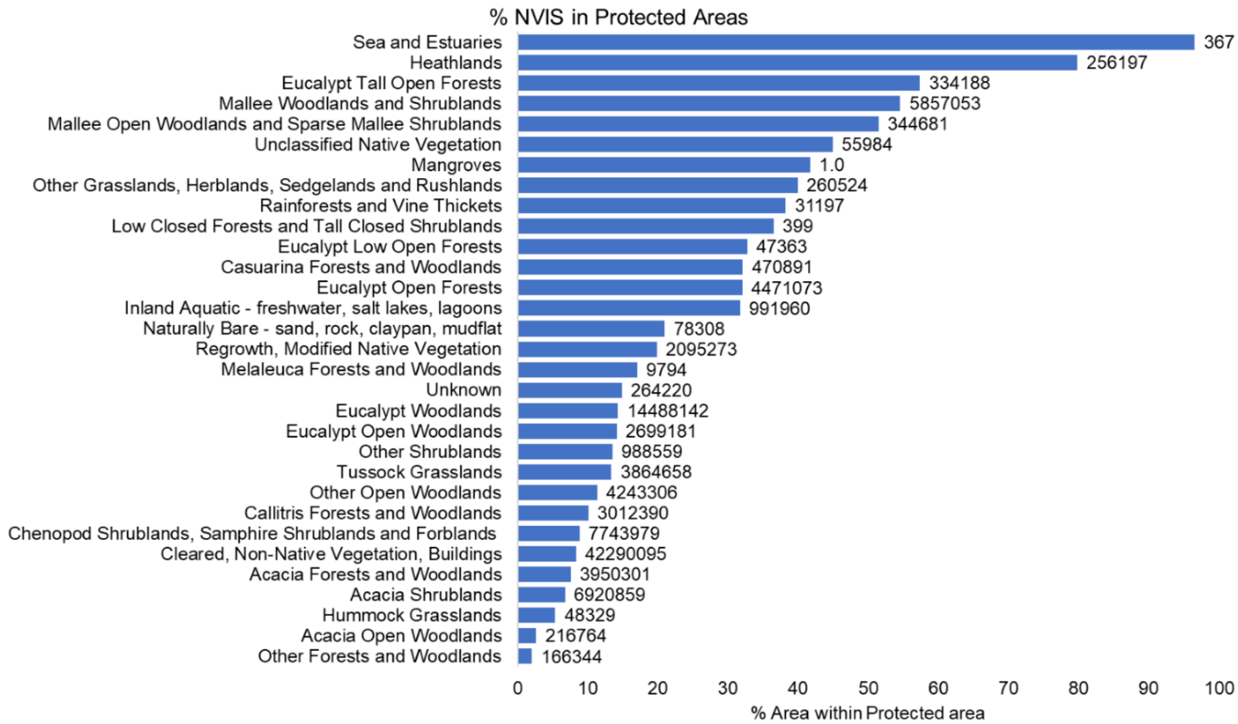

Figure 13. The percentage area represented within protected areas, KBAs or Ramsar wetlands (blue) for each NVIS major vegetation group within the Murray-Darling Basin and the corresponding size in hectares.

References

Australian Government (2010). Directory of Important Wetlands in Australia (DIWA) Spatial Database. Accessed August 2022. [Online] Available at: http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BED248FC1-7237-4A74-91AC-2DA3FC277E0A%7D

Australian Government (2020). National Vegetation Information System V6.0. Accessed October 2022. [Online] Available at: https://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B991C36C0-3FEA-4469-8C30-BB56CC2C7772%7D

Australian Government (2022a). Australia - Species of National Environmental Significance Distributions (public grids). Accessed October 2022. [Online] Available at: http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B337B05B6-254E-47AD-A701-C55D9A0435EA%7D

Australian Government (2022b). Australia - Ecological Communities of National Environmental Significance Distributions (public grids). Accessed March 2023. [Online] Available at: http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B184A3793-2526-48F4-A268-5406A2BE85BC%7D

Australian Government (2022c). Collaborative Australian Protected Areas Database (CAPAD) 2022 – Terrestrial. Accessed October 2022. [Online] Available at: https://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B4448CACD-9DA8-43D1-A48F-48149FD5FCFD%7D

Australian Government (2023). Ramsar Wetlands of Australia. Accessed October 2021. [Online] Available at: http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B3F208CDF-28ED-4B1F-B965-A733EB58D952%7D

Australian Bureau of Meteorology (2014). Geofabric Hydrology Reporting Catchments - V2.1.1. Accessed October 2022. [Online] Available at: http://www.bom.gov.au/metadata/19115/ANZCW0503900107

Birdlife Australia (2018). Key Biodiversity Areas and Important bird areas Australia. Accessed March 2023. [Online] Available at: https://www.keybiodiversityareas.org.au/resources

Brooks S., Cottingham P., Butcher R., Hale J. (2013). Murray-Darling Basin aquatic ecosystem classification: Stage 2 report. Peter Cottingham & Associates report to the Commonwealth Environmental Water Office and Murray-Darling Basin Authority, Canberra.

Brooks, S. (2021). Australian National Aquatic Ecosystem (ANAE) Classification of the Murray-Darling Basin: Technical Report, Revision 3.0, March 2021. Report for the Commonwealth Environmental Water Office, Department of Agriculture, Water and the Environment, Australia., Canberra, Australia.

Bunn, S.E., Kennard, M.J., Bond, N.R., Ward, D.P., Tews, K., Sims, N.C. & Peterson, E.E. (2014) Flow regimes and ecological assets. A technical report from the Ecological Responses to Altered Flow Regimes Flagship Research Cluster (SubProject 2). CSIRO Water for a Healthy Country Flagship, Australia. http://doi.org/10.4225/08/584d953656970

Chauvenet, A.L.M., Kuempel, C.D., McGowan, J., Beger, M., Possingham, H.P. (2017). Methods for calculating Protection Equality for conservation planning. PLoS ONE 12(2): e0171591. https://doi.org/10.1371/journal.pone.0171591

Chauvenet, A.L.M. (2023). The conservation potential of protected areas over time measured through design and ecological integrity indicators is affected by land conversion. Biological Conservation 279, 109908. https://doi.org/10.1016/j.biocon.2023.109908

García Molinos, J., Schoeman, D.S., Brown, C.J., Burrows, M.T. (2019). VoCC: An r package for calculating the velocity of climate change and related climatic metrics. Methods in Ecology and Evolution 10, 2195–2202. https://doi.org/10.1111/2041-210X.13295

Murray-Darling Basin Authority (2015). Murray-Darling Basin floodplain vegetation mapping, Darling - VIS_ID 4454. Accessed October 2022. [Online] Available at: https://datasets.seed.nsw.gov.au/dataset/mdb-darling-vegetation-map-vis_id-4454

GitHub code repository

https://github.com/wrawra90/WERP_10.2.git (Request access from j.wraith@griffith.edu if needed).

Part two: Vulnerability Analysis

To assess the vulnerability of climate change within the basin we used Climate Velocity as a proxy. Climate velocity measures how fast selected climate indicators, such as average temperature or precipitation, are shifting spatially over time. It is calculated using past gridded climate data (the Climate Research Unit (v4.05), covering the period from 1901 to 2020; Chauvenet 2023), and a time series analysis that is looking for trends in the data. The results represent an estimate of how far from each focal cell will the same climatic conditions be found in a year, and the unit is in km per year. This measure is particularly relevant to living organisms as it shows how far a species would have to shift their range to follow their preferred temperature or precipitation conditions, for example. Climate velocity can be positive if the trend for temperature or precipitation shows an increase, or negative if it shows a decrease. In the MDB, the average temperature has been increasing, and the average precipitation has been decreasing (Figure 14).

Climate velocity was calculated using the VoCC package in R developed by García Molinos et al. (2019a, 2019b). Subsequently, the climate velocity was resampled from its original resolution of 0.5 arc degrees.

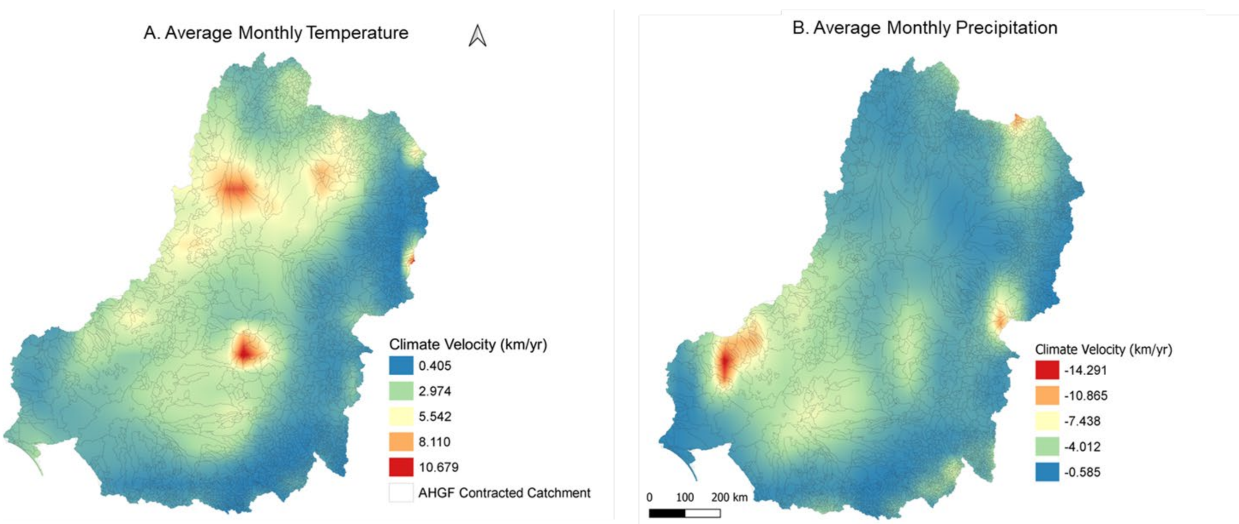

Figure 14. Climate velocity (km/yr) across the MDB including monthly mean temperatures (A) and monthly precipitation (B). A negative velocity indicates a decrease in the climate variable, e.g. lower precipitation.

To assess the average change in climate velocity for individual biodiversity assets, zonal statistics were executed using R Studio. This analysis aimed to elucidate the projected shifts in climate conditions across the landscape in terms of kilometers per year (km/yr), utilising the available dataset.

ANAE Wetlands

ANAE wetlands are expected to occur in areas where the climate will undergo significant shifts, particularly in terms of mean temperature, and precipitation (Figure 15). Based on the velocity data, it is anticipated that the following species will occur in areas that will experience the most substantial climate shifts:

Under the influence of monthly mean temperature fluctuations:

- F3.2: Sedge/forb/grassland riparian zone or floodplain: 4.79 km/yr
- F1.10: Coolibah woodland and forest riparian zone or floodplain: 4.55 km/yr
- Pt1.3.2: Temporary coolibah swamp: 4.55 km/yr
- Pt2.1.2: Temporary tall emergent marsh: 4.37 km/yr
- Pp2.1.2: Permanent tall emergent marsh: 4.25 km/yr
- F1.13: Paperbark riparian zone or floodplain: 4.14 km/yr
- Lsp1.1: Permanent saline lake: 3.99 km/yr
- Pt1.6.2: Temporary woodland swamp: 3.99 km/yr
- Lp1.2: Permanent lake with aquatic bed: 3.91 km/yr
- Pt1.8.2: Temporary shrub swamp: 3.89 km/yr

Impacted by precipitation variations:

- F2.4: Shrubland riparian zone or floodplain: 4.63 km/yr
- F1.6: Black box forest riparian zone or floodplain: 4.46 km/yr
- Lst1.1: Temporary saline lake: 4.42 km/yr
- Pt1.8.2: Temporary shrub swamp: 4.25 km/yr
- Lt1.1: Temporary Lake: 4.18 km/yr
- Psp2.1: Permanent salt marsh: 4.16 km/yr
- Lst1.2: Temporary saline lake with aquatic bed: 4.11 km/yr
- Pu1: Unspecified wetland: 3.95 km/yr
- Pst2.2: Temporary salt marsh: 3.79 km/yr
- Pt1.7.2: Temporary lignum swamp: 3.64 km/yr

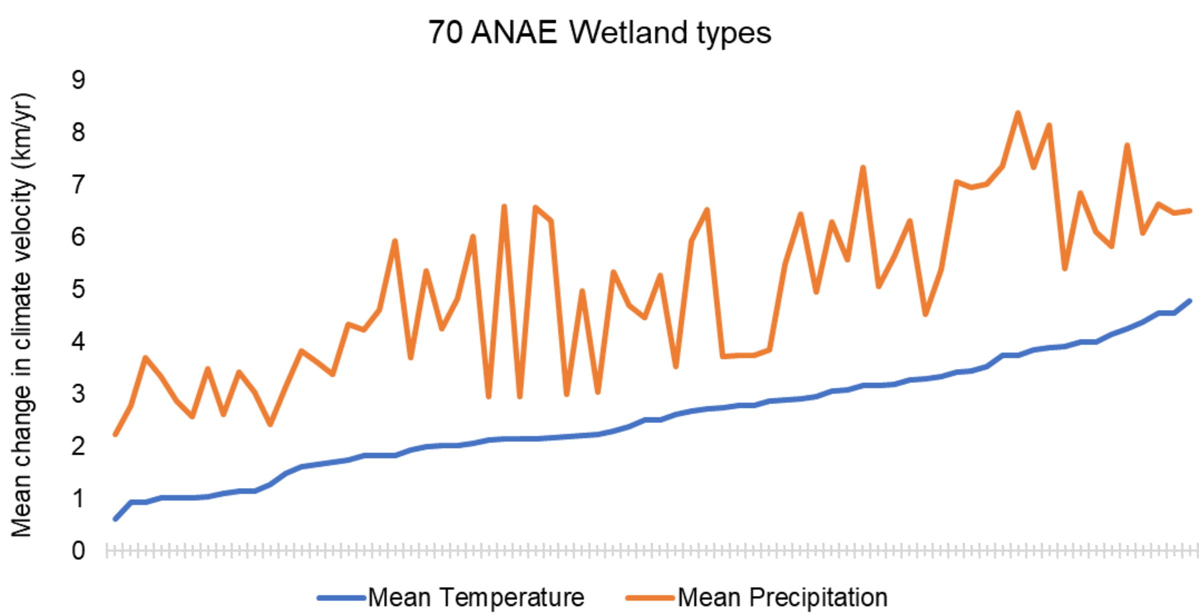

Figure 15. Average change in climate velocity (km/yr) for each 70 ANAE wetland class for the mean monthly temperature and mean month precipitation.

DIWA

The wetlands identified and listed on the Directory of Important Wetlands (DIWA) are in regions where notable climate shifts are anticipated (Figure 16). Analysis of the velocity data indicates that the following species will inhabit areas experiencing the most pronounced climate changes:

Under the influence of monthly mean temperature fluctuations:

- New England Wetlands: 9.16 km/yr
- "Murrawondah" Lakes: 8.24 km/yr
- Warrego River Distributary System: 8.13 km/yr
- Balonne River Floodplain: 6.30 km/yr
- Lake Nichebulka: 6.15 km/yr
- "Myola"-"Mulga Downs" Salt Lake and Claypans: 6.07 km/yr
- Lake Burkanoko: 6.03 km/yr
- Gypsum Swamp: 5.93 km/yr
- Eulo Artesian Springs Supergroup: 5.81 km/yr
- Calbocaro Billabong: 5.79 km/yr

Assets impacted by precipitation variations:

- Lowbidgee Floodplain: 6.40 km/yr
- Heywoods Lake: 6.12 km/yr
- Major Mitchell Lagoon: 5.96 km/yr
- Great Cumbungi Swamp: 5.78 km/yr
- Menindee Lakes: 5.77 km/yr
- Darling Anabranch Lakes: 5.76 km/yr
- Belsar Island: 5.66 km/yr
- Coona Coona Lake: 5.47 km/yr
- Kosciusko Alpine Fens, Bogs, and Lakes: 5.27 km/yr
- Lachlan Swamp (Part of mid Lachlan Wetlands): 5.24 km/yr

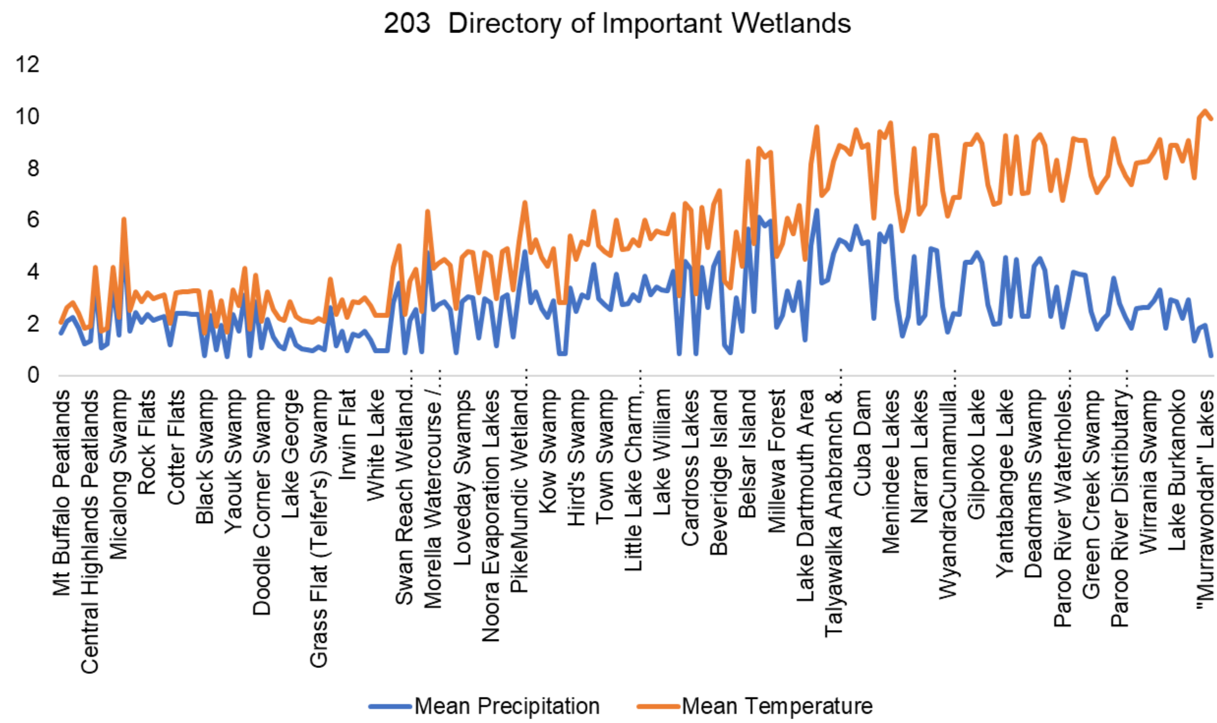

Figure 16. Average change in climate velocity (km/yr) for each of the 203 DIWA in the MDB for the mean monthly temperature and mean month precipitation.

SNES

All Species of National Environmental Significance (SNES) are located in areas that will see a change in climate based on the climate velocity data (Figure 17).

The SNES found in regions with the most significant changes in average temperature are:

- Amytornis barbatus barbatus (Gould's Barbet): 5.55 km/yr
- Xerothamnella parvifolia (Small-leaved Xerothamnella): 5.47 km/yr
- Acacia curranii (Curran's Wattle): 5.37 km/yr
- Diuris eborensis (Ivory Diuris): 5.23 km/yr
- Acacia ammophila (Sandhill Wattle): 5.09 km/yr
- Sclerolaena walkeri (Walker's Sclerolaena): 4.83 km/yr
- Eriocaulon carsonii (Carson's Pipewort): 4.77 km/yr
- Macrotis lagotis (Greater Bilby): 4.50 km/yr
- Calotis moorei (Moore's Daisy): 4.24 km/yr
- Hakea maconochieana: 3.96 km/yr

Species in areas with a change in precipitation are:

- Calytrix gurulmundensis (Gurulmundi Starflower): 8.84 km/yr
- Onychogalea fraenata (Bridled Nail-tail Wallaby): 8.18 km/yr

- Leporillus conditor (Greater Stick-nest Rat): 8.15 km/yr
- Bettongia lesueur lesueur (Lesueur's Bettong): 7.95 km/yr
- Homoranthus decumbens (Sticky Homoranthus): 7.54 km/yr
- Myrmecobius fasciatus (Numbat): 7.48 km/yr
- Acacia carneorum (Flesh-colored Wattle): 6.41 km/yr
- Acacia handonis (Handon's Wattle): 6.09 km/yr
- Bettongia penicillata ogilbyi (Brush-tailed Bettong): 6.07 km/yr
- Solanum karsense (Kar's Nightshade): 5.69 km/yr

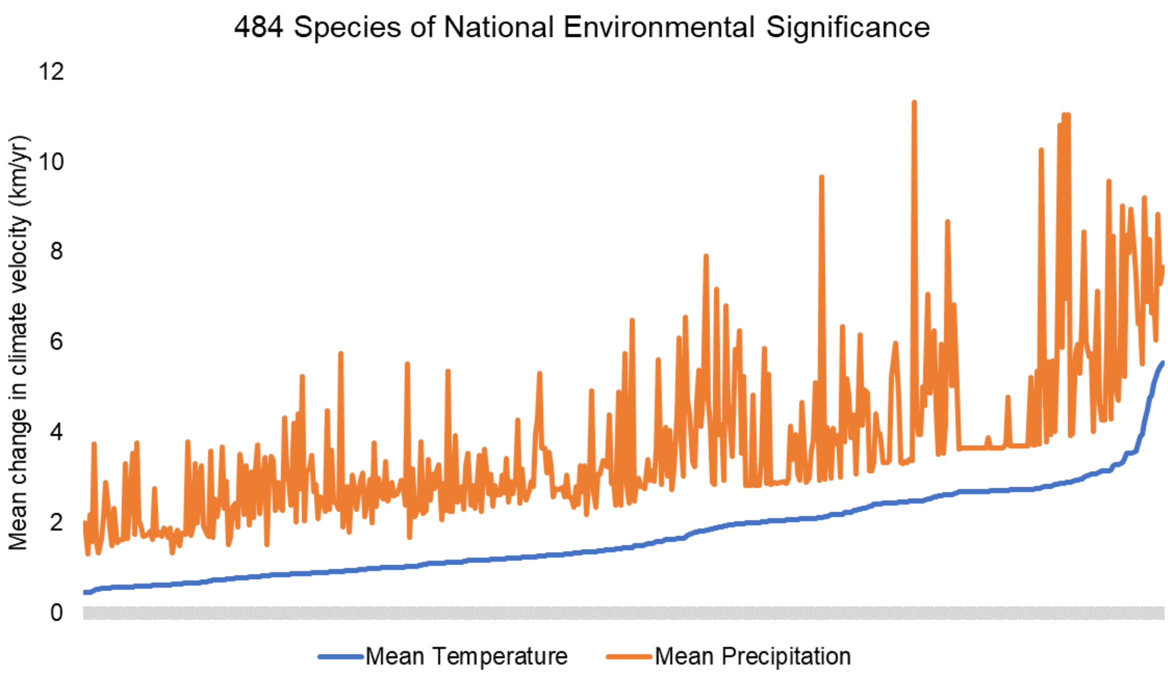

Figure 17. Average change in climate velocity (km/yr) for each of the 484 Species of National Environmental Significance (SNES) in the MDB for the mean monthly temperature and mean month precipitation.

ECNES

The Ecological Communities of National Environmental Significance (ECNES) are all in regions where notable climate shifts are anticipated (Figure 18). Analysis of the velocity data indicates that the following species will inhabit areas experiencing the most pronounced climate changes:

The ECNES found in regions with the most significant changes in average temperature are:

- The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin: 5.17 km/yr
- Brigalow (Acacia harpophylla dominant and co-dominant): 3.59 km/yr

- New England Peppermint (Eucalyptus nova-anglica) Grassy Woodlands: 3.58 km/yr
- Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions: 3.47 km/yr
- Weeping Myall Woodlands: 3.16 km/yr
- Poplar Box Grassy Woodland on Alluvial Plains: 2.77 km/yr
- Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions: 2.66 km/yr
- Subtropical and Temperate Coastal Saltmarsh: 2.51 km/yr
- Swamps of the Fleurieu Peninsula: 2.05 km/yr
- Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin: 1.90 km/yr

The ECNES found in regions with the most significant changes in average precipitation are:

- Central Hunter Valley eucalypt forest and woodland: 4.14 km/yr
- Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin: 3.56 km/yr
- Brigalow (Acacia harpophylla dominant and co-dominant): 2.98 km/yr
- Plains mallee box woodlands of the Murray Darling Depression, Riverina and Naracoorte Coastal Plain Bioregions: 2.77 km/yr
- Mallee Bird Community of the Murray Darling Depression Bioregion: 2.72 km/yr
- Weeping Myall Woodlands: 2.59 km/yr
- Natural Temperate Grassland of the Victorian Volcanic Plain: 2.50 km/yr
- Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions: 2.49 km/yr
- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland: 2.48 km/yr
- Poplar Box Grassy Woodland on Alluvial Plains: 2.41 km/yr

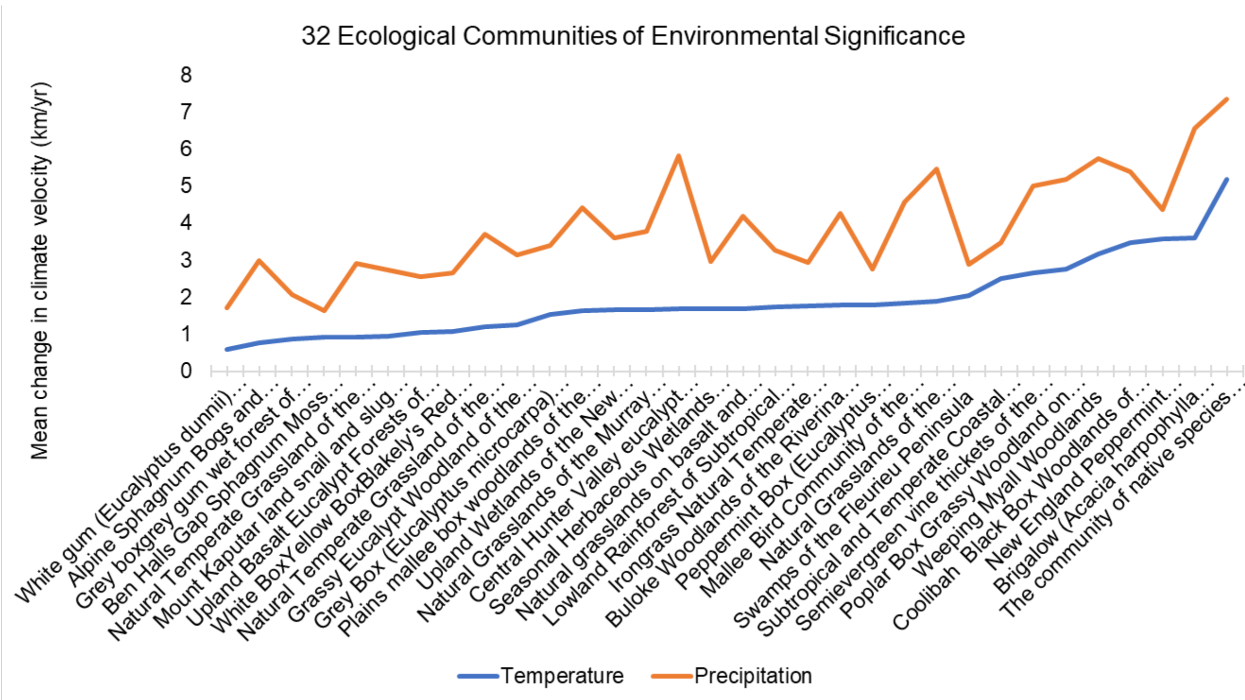

Figure 18. Average change in climate velocity (km/yr) for each of the 32 Ecological Communities of National Environmental Significance (ECNES) in the MDB for the mean monthly temperature and mean month precipitation.

Darling River floodplain vegetation

The Darling River Floodplain vegetation groups occupy a relatively small area which will see an average change of 3.43 to 3.99 km/year for mean monthly temperature and –3.21 to -5.16 km/year for mean monthly precipitation.

NVIS Major Vegetation Groups

Major native vegetation groups occupy areas that will see a significant shift in climate. For example NVIS Major Vegetation Groups with the most significant changes in average temperature are:

- Mallee Woodlands and Shrublands: 3.12 km/yr
- Acacia Open Woodlands: 3.22 km/yr
- Callitris Forests and Woodlands: 3.30 km/yr
- Eucalypt Tall Open Forests: 3.35 km/yr
- Mangroves: 3.39 km/yr
- Other Forests and Woodlands: 3.48 km/yr
- Acacia Forests and Woodlands: 3.57 km/yr
- Eucalypt Low Open Forests: 4.29 km/yr
- Hummock Grasslands: 4.64 km/yr
- Rainforests and Vine Thickets: 4.69 km/yr

NVIS Major Vegetation Groups with Notable Changes in Average Precipitation:

- Mangroves: 4.60 km/yr
- Mallee Woodlands and Shrublands: 4.44 km/yr
- Naturally Bare areas (sand, rock, claypan, mudflat): 4.07 km/yr
- Other Open Woodlands: 3.77 km/yr
- Regrowth, Modified Native Vegetation: 3.55 km/yr
- Acacia Shrublands: 3.54 km/yr
- Eucalypt Low Open Forests: 3.20 km/yr
- Heathlands: 3.12 km/yr
- Callitris Forests and Woodlands: 3.06 km/yr
- Acacia Forests and Woodlands: 3.04 km/yr

References

Chauvenet, A.L.M. (2023). The conservation potential of protected areas over time measured through design and ecological integrity indicators is affected by land conversion. Biological Conservation 279, 109908. https://doi.org/10.1016/j.biocon.2023.109908

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