# Beetaloo GBA Region Baseline Survey Program

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**Cover Photograph**

Bitter Springs, Elsey National Park. BESA. August 2020. Credit: Jenny Davis (RIEL).



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The following people provided assistance with various components of the individual programs as follows.

Terrestrial Biodiversity – Mapping and Vegetation: Donna Lewis, Ian Cowie, Brian Lynch & Jenny Petturson; Threatened Species Data: Laura Ruykys; Ants Nicholas Cuff (NT Herbarium), Rhys Arnott (Elsey National Park), Alan Schmidt (Forrest Hill Station), Justin Dyer (Hayfield-Shenandoah Station), Ruben Andersen, Grace Fuller, Prakash Gaudel, Cassie and François Brassard. Mark Kennard contributed to the development of the wetland mapping and typology.

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Aquatic Biodiversity: Michala Shaw, Nicola Stromsoe, Alea Rose, Dionisia Lambrinidis & Niels Munksgaard (CDU), Richard Willan & Michael Hammer (NTMAG), Arthur Georges (UC).

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# Summary

The Beetaloo GBA region Baseline Survey Program was undertaken to provide baseline data on the biodiversity of the GBA Beetaloo Extended Survey Area (BESA), Northern Territory. This includes both the Beetaloo Sub-basin and the area immediately beyond (as defined by the Beetaloo GBA Stage 2 report) where potential environmental and hydrological impacts associated with the emerging shale gas industry may occur. Relatively few surveys have been undertaken of the plants, animals and ecosystems of the region so this program was designed to collect baseline information for the Beetaloo GBA. COVID-19 delayed some fieldwork, resulting in the provision of draft material for some groups. The program also supported the development of further surveys to be undertaken as part of the Strategic Regional Environmental and Baseline Assessment (SREBA). The program was delivered through the collaboration of researchers at Charles Darwin University (CDU), Griffith University (GU) and the NT Department of Environment, Parks and Water Security (DEPWS). The work was developed with the Commonwealth GBA program (which included all partners and contracted support) to ensure that it informed the broader SREBA as required by the NT Government.

The program comprised three themes: Environmental Mapping; Terrestrial Biodiversity; and Aquatic Biodiversity. It ran from 1 January 2020 to 30 June 2021, with a three-month delay in fieldwork imposed by COVID travel restrictions from late March, 2020. The following key findings are summarised here and presented in greater detail in the following chapters.

- Mapping has been undertaken that provides information on the vegetation classes and surface waterbodies in the BESA. Regional ecosystems have been described and a total of 1,664 plant taxa have been recorded (Chapter 1).
- New field records of EPBC-listed species in the BESA, including the Gouldian finch, crested shrike tit, greater bilby, Gulf snapping turtle and the freshwater sawfish, have been obtained (Chapters 1 and 3).
- Published and unpublished data for waterbirds and migratory waterbirds for Lake Woods, Longreach Waterhole, Sturt Plateau wetlands and the Roper River (at Elsey National Park) have been synthesised, with 81 species recorded to date (Chapter 1).
- A list of terrestrial vertebrates in the BESA, comprising 494 species, has been compiled from the NT Fauna Atlas (Chapter 1).
- Field surveys of ants at 20 BESA sites have recorded 232 ant species from 27 genera and indicated the existence of new species (Chapter 1).
- Species distribution models, showing predicted habitat suitability and occurrence records across Australia and within the BESA, have been developed for 26 Environmentally Protected Matters (EPM) species incorporting new data acquired during this project. Further refinements of these models may be undertaken as part of the SREBA (Chapter 2).
- The 14 surface waterbodies, across four catchments (the Daly, Roper, Limmen Bight and Victoria River-Wiso) that held water in 2020 represent drought refugia (because they are likely to persist through the driest of conditions). Further refugia are likely to be identified by the SREBA (Chapter 3).

- Aquatic fauna surveys detected five species of freshwater turtles, 30 species of fish and 195 species of aquatic invertebrates. More than 20% of the latter appear to be new to science and 40% are new records for the region (Chapter 3).
- Baseline information on stygofauna was collected through a separate project funded by CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) and no additional surveys were undertaken in this program. Results are available at: https://gisera.csiro.au/wp-content/uploads/2021/03/GISERA-Project18-Stygofauna_final-report-20201208.pdf

Overall, the GBA program has made a very valuable contribution to documenting the biodiversity of the BESA. The new and extensive datasets described in this report provide a foundation for further surveys to be undertaken as part of the SREBA. The combined results of the GBA program and the SREBA will provide the information needed to identify areas of high conservation value and to evaluate the potential impacts of resource development on biodiversity within the region. It will inform future environmental impact assessments and support the development of ecological monitoring programs.

# Chapter 1. Environmental Mapping

Baseline environmental mapping at a scale appropriate for the identification of ecological values and the assessment of potential development scenarios is fundamental to the sustainable use of natural resources. Existing vegetation and land resource information for the Beetaloo GBA region is at a scale too coarse (C. 1:1 000 000) in terms of both ground resolution and attribute detail to allow for the accurate identification and survey of potentially important habitats with a high degree of confidence.

The aim of this program was to produce:

1. A preliminary base environmental map of land zones and structural classes to inform the development of regional ecosystems (Sattler and Williams 1999) and associated map products; and
2. A map of surface water features for the purpose of mapping wetlands and Groundwater Dependent Ecosystems (GDE).

As well as providing the base for further development of spatial products associated with the GBA program, these products would also inform the stratification and site selection process for ongoing detailed ecological investigations within the study area. This program was principally a remote sensing exercise supported by desktop analyses from existing data sources, conducted from December 2019 to March 2020.

### 1.1.1. Methods

The study area covered approximately 80,000 km$^2$, located between approximately Mataranka township in the north and Elliott in the south (Figure 1.1). It includes most of the Sturt Plateau bioregion (after Environment Australia 2000) and parts of surrounding bioregions including the Daly Basin, Gulf Fall and Uplands and Mitchell Grass Downs and Davenport Murchison Ranges.

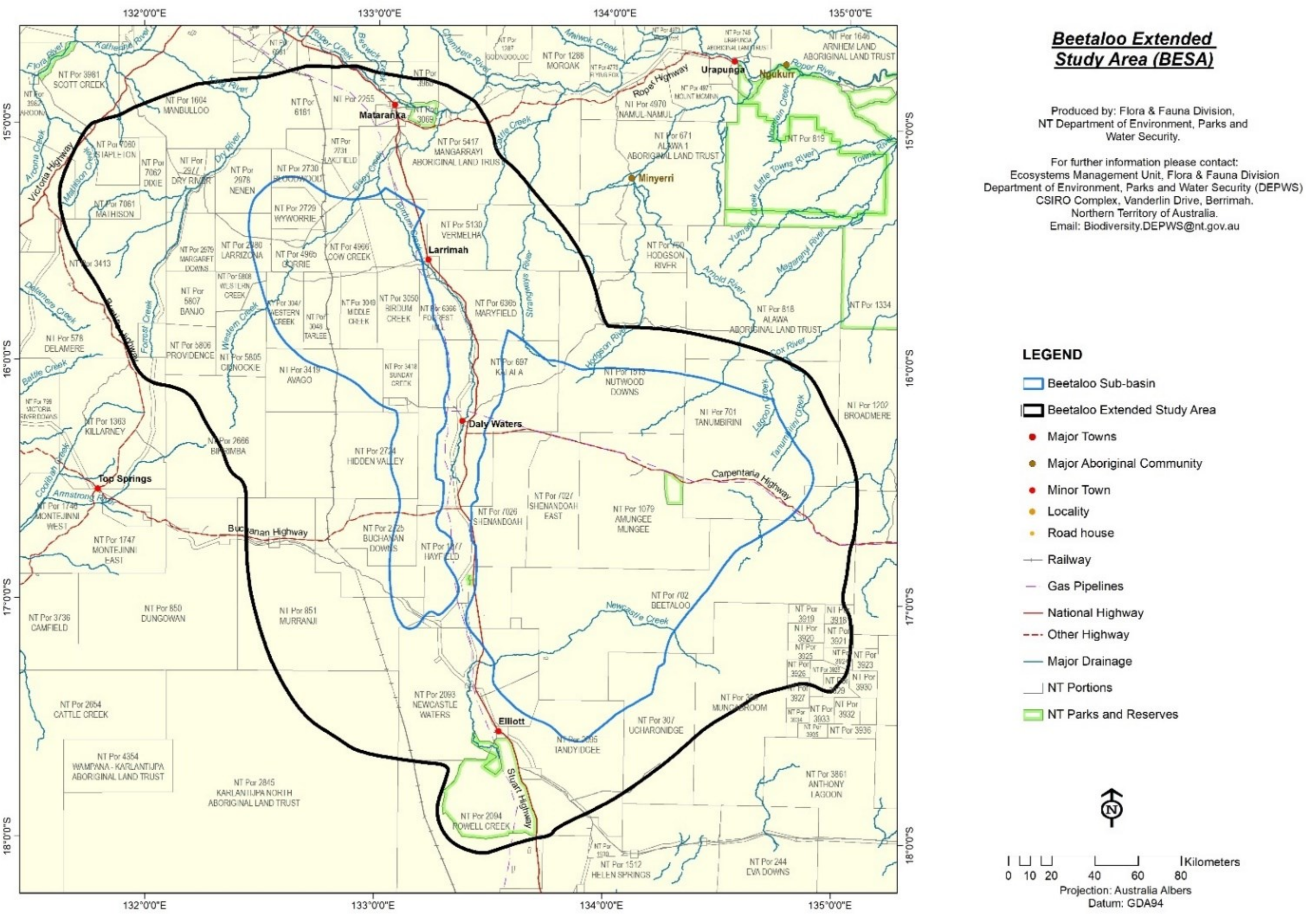



Figure 1.1. The BESA showing the location in relation to the geological basin, major population centres, settlements and pastoral leases.

#### *1.1.1.1. Preliminary land zone and vegetation structural formation mapping*

Map unit boundaries (image objects) were delineated from digital satellite imagery (Sentinel-2 2018 annual composite, 10 m spatial resolution). Preliminary image objects were generated using a multiresolution segmentation with a scale parameter of 200, for each Sentinel-2 tile covering the BESA.

Image objects were then classified with land zones (following Wilson and Taylor 2012) using a Random Trees model in Trimble eCognition Developer 9.4.0 software. Models were trained with a minimum sample of 1,000 randomly selected points from each Sentinel-2 tile, with raster data and derived indices used in model development including: Sentinel-2 surface reflectance data (2018 annual composite, 10 m and 20 m bands resampled to 10 m spatial resolution), 23 derived vegetation and water indices, elevation data (1 second SRTM Level 2 Derived Digital Elevation Model) and derived products (slope, relief 150 m radius and relief 300 m radius). Results of this classification were checked manually and the model re-run with additional training data where appropriate to account for misclassification in certain locations. Classified image objects were exported in shapefile format (.shp) for further processing.

Vegetation structural formation information was obtained from woody foliage projective cover derived from Landsat 8 imagery (Queensland Department of Environment and Science (QDES) DC4 product code; Armston *et al.* 2009; Kitchen *et al.* 2010) and height model information derived from Staben et al. (2018). Proportion cover of vegetation structural formations within each classified image object was calculated, and a rule set which assessed the relative dominance of each vegetation structural formation was used to define a final class to each object (refer to the digital metadata for further details).

#### *1.1.1.2. Preliminary waterbody (wetlands and aquatic habitats) mapping*

This spatial dataset was developed for the BESA using pixel-based (raster) information delineating surface water features from a variety of sources at a compilation scale of approximately 1:100 000. Three separate raster data sources were used to develop these data with the base information in all cases being time-series or single date Landsat (5TM, 7 ETM+ or 8) digital satellite imagery (Table 1.1).

Relevant data were supplied or sourced from the Commonwealth of Australia (Geoscience Australia) to support product development and this information was used under Creative Commons Attribution 4.0 Public Licencing.

Table 1.1. Surface water feature class descriptions.

| Feature Class | Alias | Data Source | Date Range | Description |
|---|---|---|---|---|
| **dd7_water_count** | DD7 Water Body Count | Landsat 5 and 7 | 1987 – 2014 | Canonical variates analysis of visually identified water and non-water signatures in radiometrically calibrated Landsat imagery (Danaher and Collett 2006). Values present the number of times a pixel was identified as water over the compiled date range. |
| **wofs_filtered_summary** | Water Observations from Space | Landsat 5 and 7 | 1987 – 2012 | Calculated from valid Landsat scenes in the Geoscience Australia archive for the date range specified. Water detections based on spectral analysis with the detection algorithm based on a statistical regression tree analysis of a set of normalised difference indices and corrected band values using a set of visually identified water and non-water samples (after Mueller *et al.* 2016). Values present the proportion of observations in which water was detected over the compiled date range. https://data.gov.au/data/dataset/719a5433-2af0-4601-8036-a03f77199442 |
| **maxExtentRaster** | Maximum Extent Water Bodies | Landsat 5 and 8 | November to February, 1987 – 2018, considered but not all images used to create final product. | Water and non-water pixels were identified using multiple threshold classification of the Automated Water Extraction Index (AWEI; Feyisa *et al.* 2014) for Landsat images over the compiled date range that captured unique and significant areas of surface water. Cloud and cloud shadow features were manually selected and removed. Values present the maximum AWEI threshold class value assigned to a pixel. |

## 1.1.2. Results

### *1.1.2.1. Land zones and Vegetation Structural Formations*

Figure 1.2 shows the mapped vegetation structural formation classes derived from the image analysis. These data were supplied to DAWE in April 2020 and further details regarding class descriptions can be found in the metadata accompanying that report.

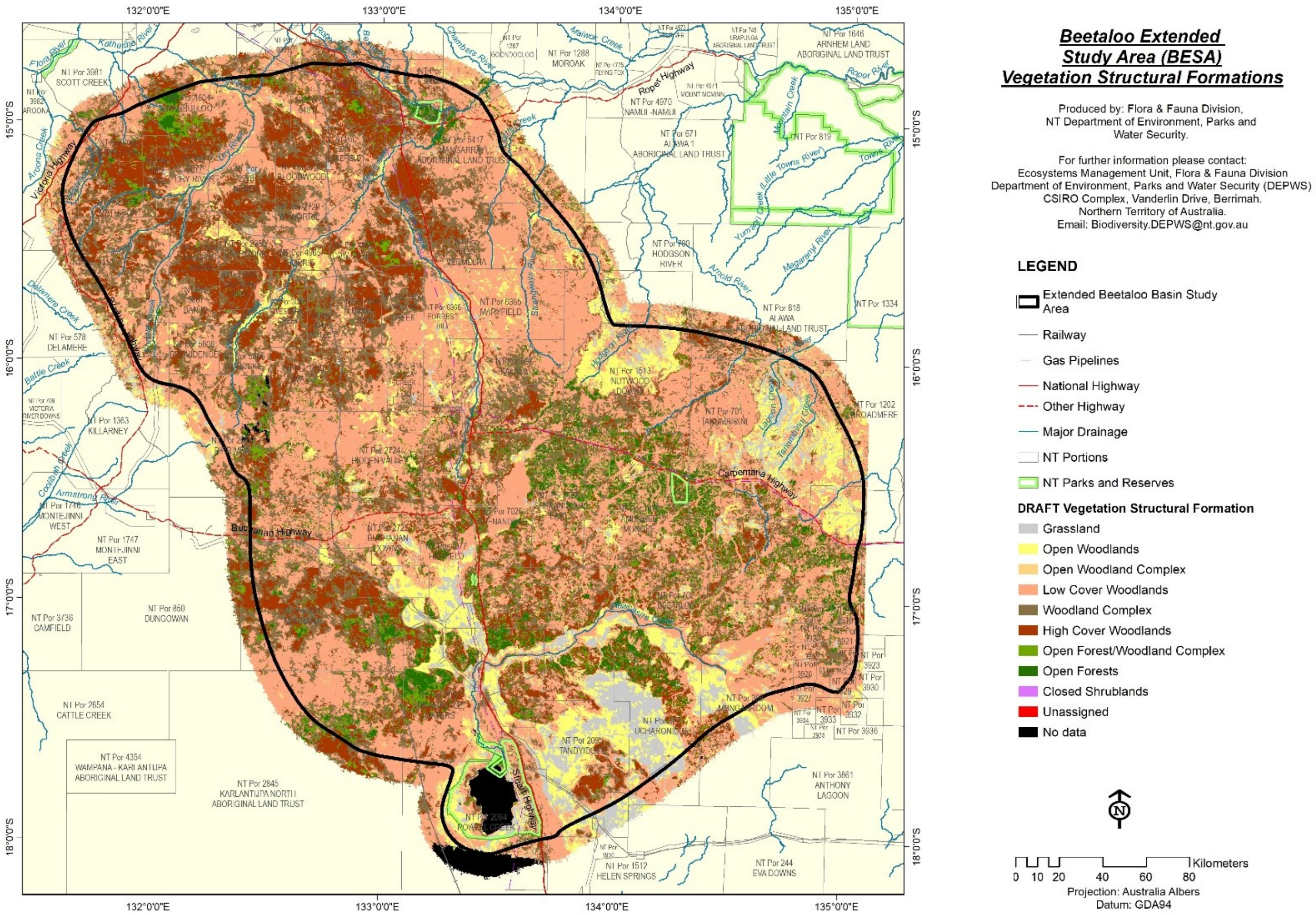



Figure 1.2. Vegetation structural formations of the BESA. Class nomenclature is adapted from the National Vegetation Attribute Manual (NVIS, 2017).

Table 1.2 details the mapped area of the vegetation structural formation classes within the BESA.

Table 1.2. Total area of mapped vegetation structural formation classes within the BESA. Note that the total mapped area exceeds that of the study area due to buffering of the study area for satellite image analysis purposes.

| Structural Formation Class | Frequency | Area (km 2) |
|---|---|---|
| ***Grasslands*** | | |
| | Grasslands (GL_OWvl) | 847.6314 |
| | Grasslands (OW_GL) | 3,355.369 |
| ***Open Woodlands*** | | |
| | Open Woodland (OWlmt) | 6,759.555 |
| | Open Woodland Complex (Mix_GL_OW_WLC) | 5,060.012 |
| ***Woodlands*** | | |
| | Woodland Complex (WMC) | 20,530.63 |
| | Woodland – Low Cover (WLC) | 38,006.6 |
| | Woodland – High Cover (WHC) | 10,798.35 |
| ***Open Forest*** | | |
| | Open Forest/Woodland Complex (OFW_MC) | 3,601.868 |
| | Open Forest (OF) | 244.6216 |
| | Open Forest (OFmt) | 2,214.438 |
| ***Shrublands*** | | |
| | Closed Shrublands (OFvll) | 3.518761 |
| ***Other Categories*** | | |
| | No data | 921.6494 |
| | Unassigned | 0.268216 |
| **Sum** | | **92,344.51** |

Figure 1.3 shows the mapped land zones of the BESA derived from classification of Sentinel 2 satellite imagery.

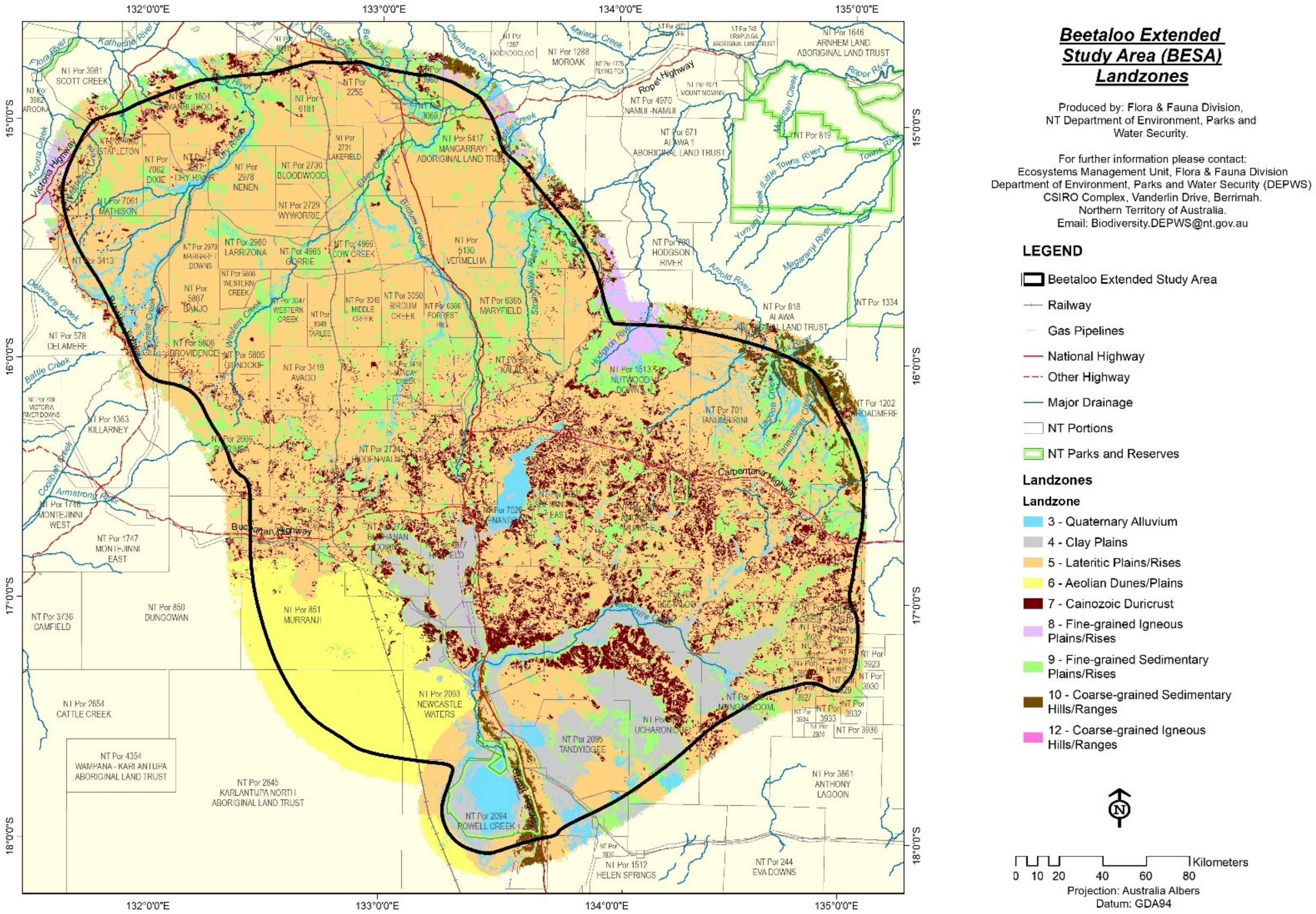



Figure 1.3. Geomorphic land zones (following Wilson and Taylor, 2012) of the BESA.

#### *1.1.2.2. Waterbody mapping*

The waterbody mapping identifies both the maximum extent and frequency-occurrence of surface water features in a more comprehensive manner than previously available, by combining multi-temporal analyses of water indices from a number of sources with a targeted exercise to identify the 'maximum possible extent' of surface water in the landscape associated with large rainfall or flooding events (Figure 1.4). These data were supplied to DAWE in April 2020. Details of the classification system associated with each raster product are provided with the metadata that accompanied that report.

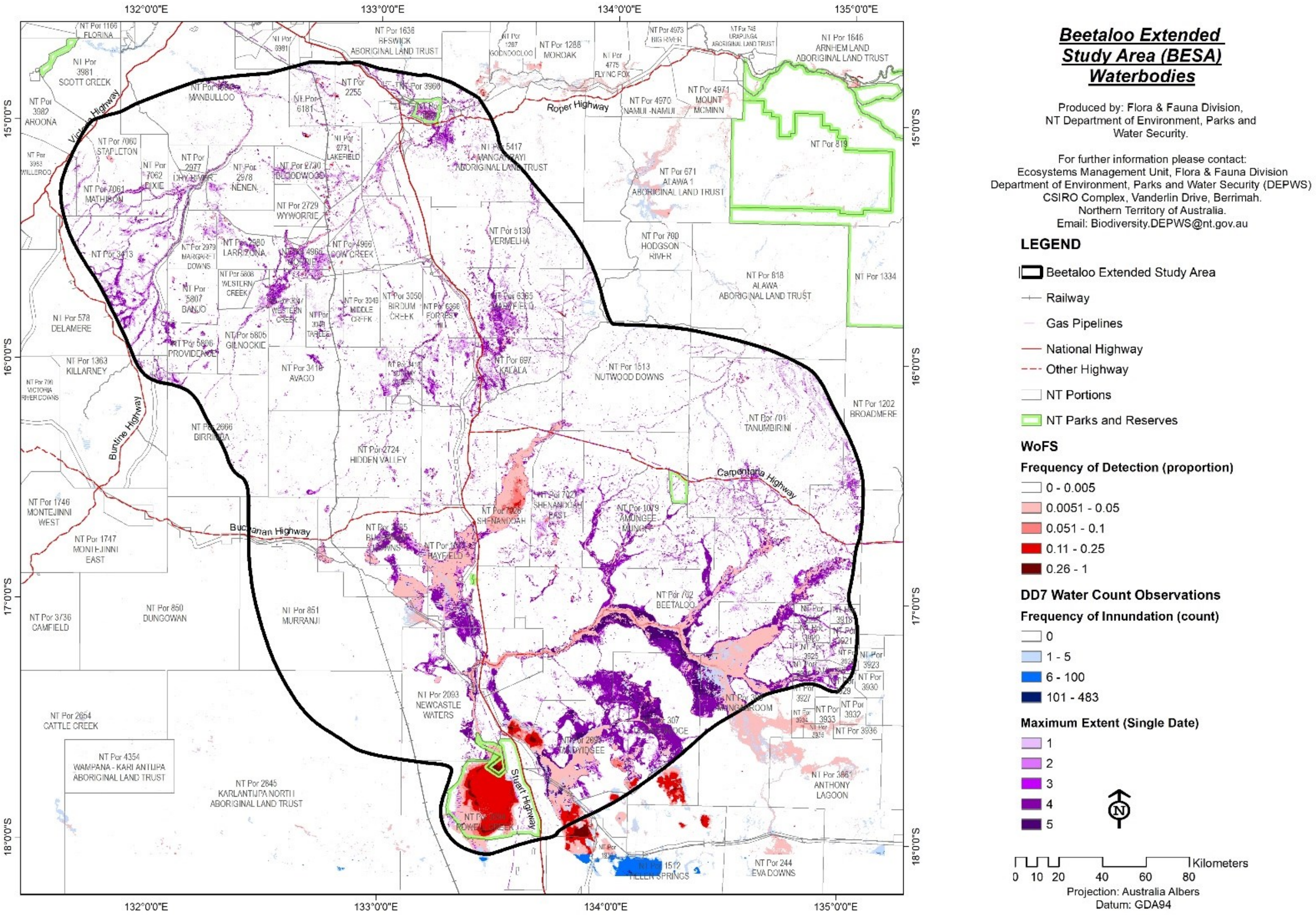



Figure 1.4. Multi-temporal and single date maximum extent surface water detections for the BESA derived from Landsat (5 TM, 7 ETM+ and 8) satellite imagery. Relevant data were supplied or sourced from the Commonwealth of Australia (Geoscience Australia) under Creative Commons Attribution 4.0 Public.

## 1.2. Terrestrial Vegetation and Wetlands

### 1.2.1. Methods

#### *1.2.1.1. Field surveys*

Field surveys for the flora and vegetation components of the terrestrial work program occurred between 16th March and 24th July 2020. Prior to COVID-19 delays, a small number of sites were sampled in Elsey National Park and surrounds in mid-March 2020 (Figure 1.5). The bulk of this work occurred after 1st June 2020 across Shenandoah, Shenandoah East, Sturt Downs, Murranji, Newcastle Waters, Beetaloo, Mungabroom, Tanumbirini, Powell Creek, Tandyidgee, Manbulloo, Dixie, Lakefield, Kalala, and Forrest Hill pastoral leases (Figure 1.5). The timing of the majority of this sampling was not optimal for the collection of data to support baseline floristic inventory, which is typically during the late wet season between March and early May. However, there was value in collecting the fullest possible floristic data in certain vegetation types that were not represented in the current vegetation typology for the BESA or where seasonal conditions allowed for a more complete representation of species diversity on a site.

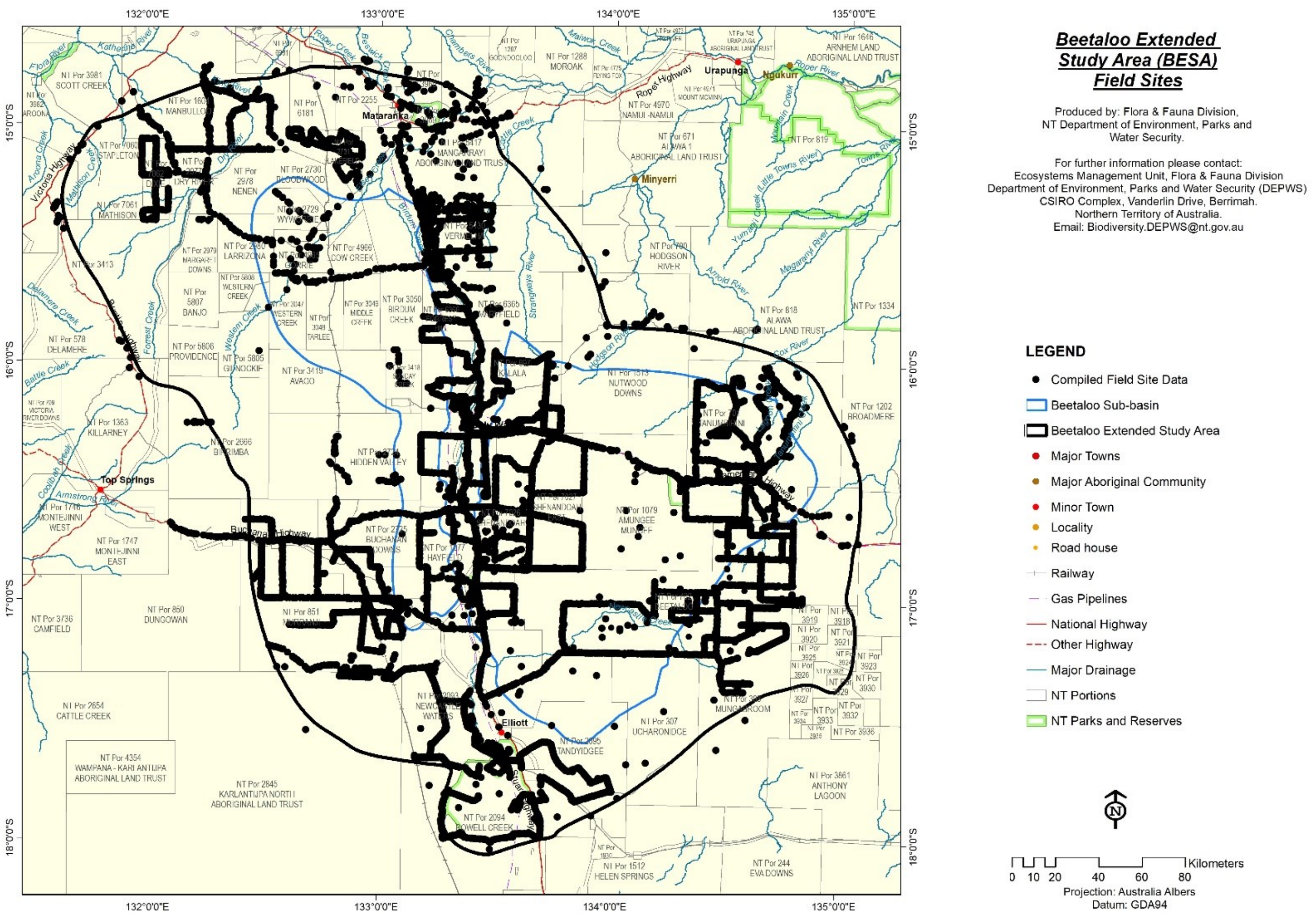



Figure 1.5. Distribution of compiled field sampling sites used for classification of mapping products in the BESA.

The surveys focused on the collection of information that would inform the regional ecosystem typology, and the calibration and validation of the draft land zone and vegetation structure mapping to enable development of a more complete regional ecosystem map coverage. This included structural and full/dominant floristic sites and rapid observational sites (Figure 1.5; Table 1.3).

Table 1.3. Sites surveyed during the 2020 vegetation field survey program in the BESA.

| Site Type | Number | Theme |
|---|---|---|
| Structural and full floristic assessments | 46 | 2 |
| Structural and dominant floristic assessments | 187 | 2 |
| Rapid observational | 6,915 | 2 |
| Compiled legacy sites | 2,032 | 1.3 |

The structural and full/dominant floristic sites assisted in the development of the regional ecosystem typology for the BESA. Vegetation assessment at these sites followed the methodology outlined in Brocklehurst et al. (2007) and is compliant with the National Vegetation Information System (NVIS) approach to the collection of floristic and structural attributes to support vegetation survey and mapping (NVIS Technical Working Group 2017).

Rapid observational sites allowed the classification of point locations to vegetation type based on dominant floristics and structure, which was then used for the classification of preliminary image objects developed as part of this project to vegetation communities and in turn regional ecosystems. Rapid observations were taken in line with the method described in Brocklehurst et al. (2007).

All plant species occurrence records from these sites were entered into DEPWS corporate database systems (Vegetation Site Database (VSD) and HOLTZE Specimen Database).

#### 1.2.1.2. Legacy information

Existing site information housed in the DEPWS corporate database system (VSD) were extracted and appraised for their compliance with national vegetation information standards (NVIS Technical Working Group 2017) and suitability for use in the development of a vegetation typology for the BESA. Where information requirements were compliant with an NVIS level 5 ('Association') or higher standard, site data were compiled for use in the development of the regional ecosystem mapping and typology. Each site was assigned a Definitive Vegetation Type (DVT) following the typology of Brocklehurst and Gibbons (2015).

In addition, existing mapping descriptions were reviewed and compiled across the various studies previously conducted in the BESA. These data were related using the DVT framework established by Brocklehurst and Gibbons (2015) to provide the preliminary vegetation and regional ecosystem typology for the study area.

#### 1.2.1.3. Regional Ecosystem Map

The preliminary image objects with associated land zone and vegetation structural attributes provided the basis for the further development of a regional ecosystem map product for the BESA.

Compiled field site data (described above) provided training information to classify image objects with vegetation communities within the study area. The random forest classifier in eCognition was used to assign image objects with a DVT based on the mean statistics derived from Sentinel-2 surface reflectance data (2018 annual composite, 10 m and 20 m bands resampled to 10 m spatial resolution) and 23 derived vegetation and water indices. To reduce commission errors, resulting from particular vegetation communities only occurring in particular land zones, preliminary image objects were grouped according to their land zone classification and random forest models were then developed for each land zone to assign vegetation communities to image objects.

Classified image objects were exported as polygons in shapefile format (.SHP), with land zone and vegetation community classification attributes, for further processing and assessment. A regional ecosystem attribution was assigned to each polygon based on its combination of land zone and vegetation community. These regional ecosystems were described in the data package accompanying the map product provided to the Commonwealth in March 2021.

Each regional ecosystem describes the geomorphic surfaces of the study area in accordance with Wilson and Taylor (2012) at a finer resolution than previously available. Within these geomorphic surfaces, dominant vegetation communities, approximately equivalent to NVIS Level 5 Associations (Thackway *et al.* 2008) were described following a modified version of the regional ecosystem nomenclature of Neldner *et al.* (2019a; 2019b) for the extended BESA study area, Northern Territory.

#### *1.2.1.4. Wetland Mapping*

Mapping of surface water features was further developed to produce a baseline map of wetlands within the study area.

The Australian National Aquatic Ecosystem (ANAE) classification scheme was initially applied to delineate four aquatic systems (riverine, lacustrine, palustrine, and floodplain). We further modified this scheme to allow attribution of palustrine and lacustrine wetlands as either occurring within or outside of floodplain areas, to identify areas of land subject to inundation that are not spatially connected to mapped streams, and to include point locations of springs. The ANAE classification scheme was developed to provide consistency at a national scale and a 'common language' across jurisdictions for the comparison of aquatic ecosystem information. The hierarchical nature of our modified classification scheme allows ANAE Level 3 Systems to be derived from our baseline map of wetlands, if required.

Spatial data were primarily derived from remote sensing, which enabled a consistent mapping approach to be applied across the entire study area (Figure 1.6). Primary spatial data sources used for mapping were:

- Water Observations from Space Filtered Water Summary 25 m v2.1.5
- Australian Hydrological Geospatial Fabric (Geofabric) v3.2
- Maximum Extent Water Bodies
- Woody foliage projective cover model (Queensland Department of Environment and Science (QDES) DC4 product code; (Armston *et al.* 2009; Kitchen *et al.* 2010))
- Northern Territory Government springs database

*Water Observations from Space (WOfS)* filtered summary data report the proportion of observations in which water was detected between 1986 and 2017 by Landsat-5, Landsat-7 and Landsat-8 satellites. Values between 0.01 and 0.04 include areas of flooding and misclassified as shadow; values between 0.05 and 0.79 include intermittent waterbodies and waterbodies that dry out; and values between 0.8 and 1 indicate permanent waterbodies. For this analysis, values between 0.01 and 0.04 were considered to represent floodplain systems and values between 0.05 and 1 were considered to represent waterbodies. The dd7 water body count data product which is a product similar to WOfS, was not included in this analysis because it did not appear to detect waterbodies as consistently as WOfS.

The *Australian Hydrological Geospatial Fabric (Geofabric)* contains spatial data for a range of hydrological features including mapped streams, waterbodies, monitoring points, aquifers and catchments. Of these, we utilised the mapped streams (polyline) data product, which was derived from the drainage enforced Digital Elevation Model based on Australia National University and Geoscience Australia's SRTM 1 second Digital Elevation Model. Other data products in the Geofabric that were based on 1:250,000 mapping, such as dam and waterbodies, were not used in this analysis because their mapping of surface water features across the study area is not as consistent, accurate or precise as WOfS.

*Maximum Extent Water Bodies* data , derived from Landsat images selected on an ad hoc basis to capture maximum surface water extent, were used to define floodplains and land subject to inundation. The *woody foliage projective cover model* was used to differentiate between palustrine and lacustrine waterbodies. The *Northern Territory Government springs database* was used to identify locations of springs.

Decision rules were applied to the spatial data as presented in (Figure 1.6). These rules are consistent with those applied for wetland mapping in Queensland (Environmental Protection Agency 2005) and northern Australia (Kennard 2010)

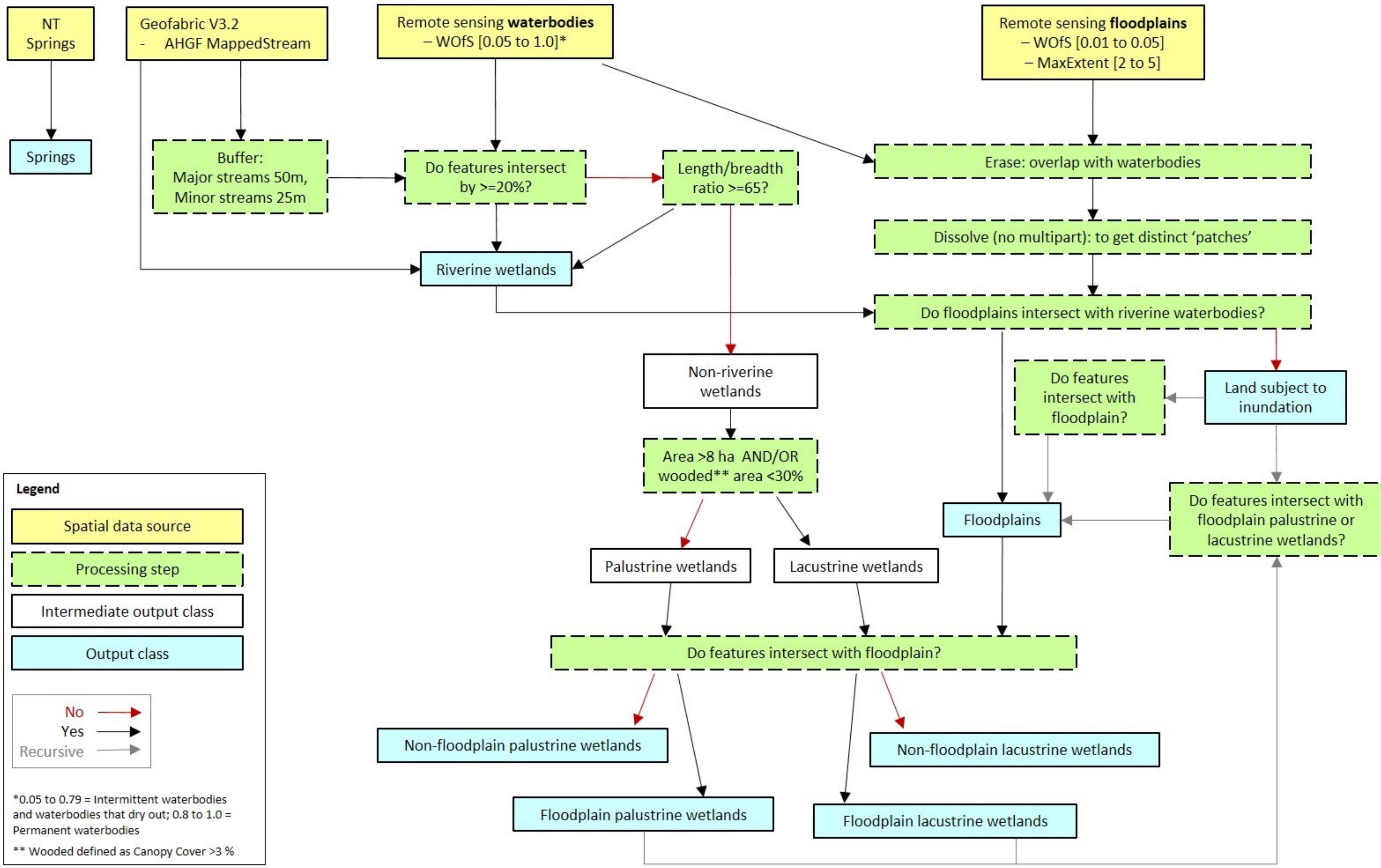



Figure 1.6. Decision rules and processing steps used to map wetlands in the BESA.

### 1.2.2. Results

A total of 9,180 vegetation sites were compiled for the BESA from existing data and the 2020 field program (Figure 1.5; Table 1.3).

#### *1.2.2.1. Vascular plant list*

A total of 1,664 plant taxa (at all ranks) have been recoded from within the BESA. 536 of these taxa were recorded during the 2020 field survey, comprising approximately 3,100 records. Some records represent significant range extensions of taxa within the BESA or the NT as a whole. A complete list of taxa recorded during field surveys has been provided to DAWE and a complete preliminary list of vascular plant species for the BESA is provided in Appendix 1.

No plant species listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or the *Territory Parks and Wildlife Conservation Act* (TPWC Act) have been recorded within the study area to date. A total of 89 taxa currently regarded as Near Threatened or Data Deficient under the TPWC Act have been recorded in the BESA (Table 1.4). A breakdown of number of taxa by legislative status is provided in Table 1.4. In addition, a total of 55 taxa endemic to the NT have been recorded from the BESA to date, none of which currently have any conservation significance.

Table 1.4. Summary of legislative status of taxa recorded from the BESA under the TPWC Act.

| Legislative Status | Near Threatened | Data Deficient | Least Concern | Not Evaluated | Not Applicable (e.g. Genus only) |
|---|---|---|---|---|---|
| **Count** | 16 | 73 | 1,316 | 124 | 135 |

One Restricted Range species, *Cladium mariscus*, has been recorded in the BESA to date. Restricted Range species in the Northern Territory are defined as those with their entire distribution restricted to a very small area; either in its available habitat (area of occupancy) or total geographic range (extent of occurrence). This sedge species is recorded from permanently wet spring-fed habitats associated with the Elsey Springs complex discharge sites of the Cambrian Limestone Aquifer that underlies the BESA. Although this species has a large extent of occurrence, it is considered restricted in range in the NT due to the small total number of records (c. 40) from a habitat type that is likely to be restricted in extent to less than 5,000 $km^2$. Of the known records in the NT, this occurrence is somewhat atypical of the landform situation in which it is generally recorded (permanently wet swamps in coastal situations), although it is not considered atypical in the broader sense of its global distribution, occurring in similar habitats outside of Australia (Timor Leste).

#### *1.2.2.2. Floristic assemblages, vegetation communities and regional ecosystems*

One hundred and one definitive vegetation types (DVTs) have been recognised as occurring within the BESA to date. This includes both previously described DVTs and 18 new DVTs defined using the 2020 survey data. These DVTs translate to 151 preliminary Regional Ecosystems (REs) based on the best available current estimates of their distribution across Land zones and Bioregions within the study area. A complete list of these Regional Ecosystems was in the March 2021 update of spatial data provided to DAWE.

Of the currently known DVTs/REs from the BESA, 17 are considered to be wetlands and likely to support aquatic Groundwater Dependent Ecosystems (GDEs). An additional 16 DVTs/REs are likely Groundwater Dependent Vegetation (GDV) types requiring some access to groundwater to meet their ecological requirements. Further mapping of these ecosystems is being undertaken as part of the ongoing refinement of the environmental baseline mapping.

#### *1.2.2.3. Regional ecosystem and wetland maps*

Regional Ecosystem mapping has been developed for the BESA at a scale of approximately 1:100,000 (Figure 1.7). Embedded within this mapping are areas mapped to a minimum polygon size of approximately one hectare (equivalent to 1:25,000 scale) for spatially restricted regional ecosystems such as wetlands, closed forests, GDV and GDEs. All spatial information and supporting field data were provided in the required DAWE format and relevant ESRI spatial formats to DAWE in March 2021. Details of the regional ecosystems displayed in Figure 1.7 can be found in the supporting information accompanying those datasets.

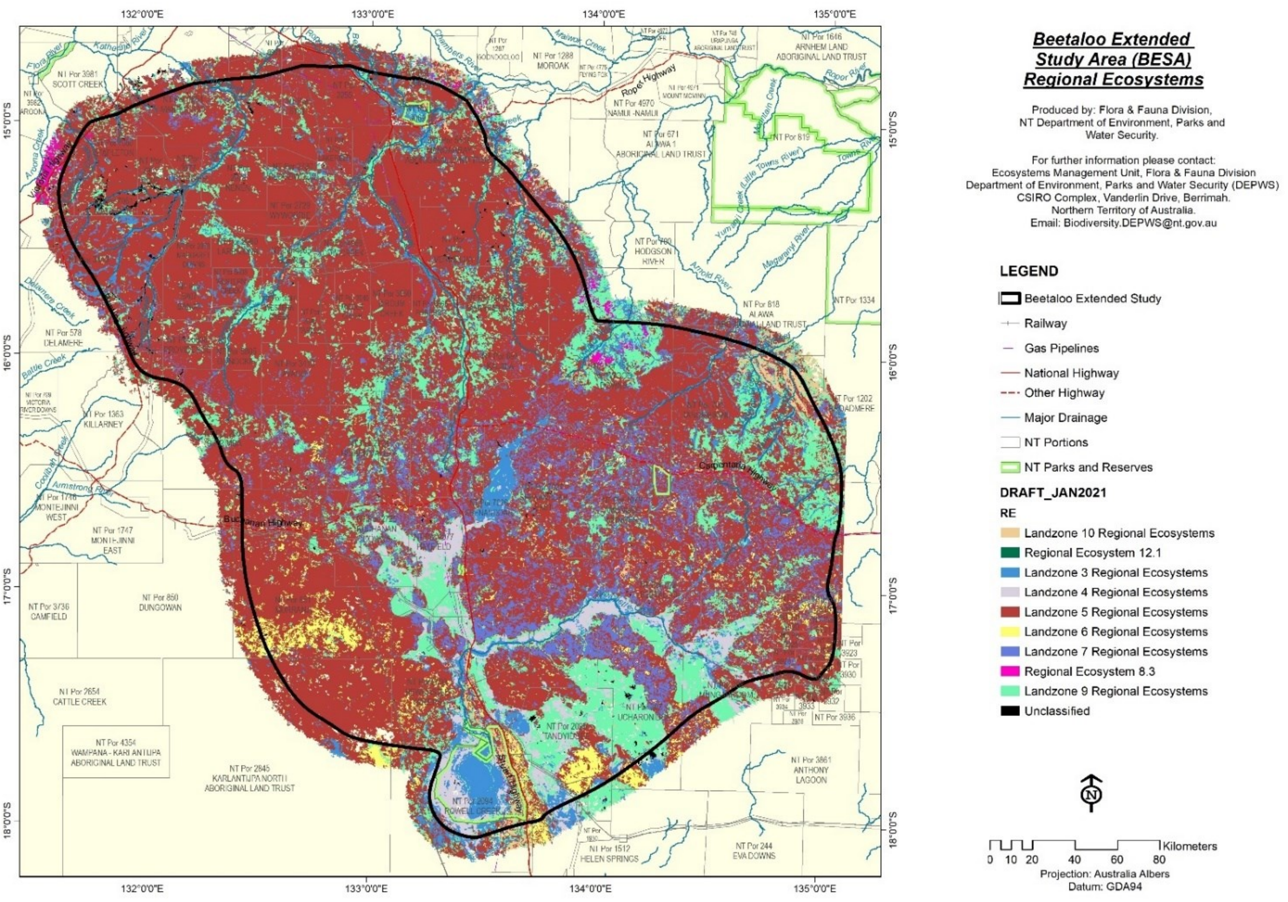



Figure 1.7. Draft regional ecosystem mapping for the BESA. Regional ecosystems have been amalgamated to the land zone level for display purposes only. Individual regional ecosystems codes are contained in the polygon attributes associated with the spatial data and descriptions of these codes can be found in the regional ecosystem description documentation accompanying the digital data.

Wetlands or surface water features intermittently cover 969,472 ha or approximately 12% of the study area (Figure 1.8) across the series of analysed imagery. The majority (75%) were classified as floodplain (726,952 ha), followed by land subject to inundation (129,935 ha), floodplain palustrine (99,445 ha), riverine (8,090 ha) and non-floodplain palustrine (5,050 ha). No lacustrine systems were mapped within the study area. Mapped streams within the study area have a total length of 11,728 km of which 15% (1,798 km) are considered major streams. Twenty-two spring locations have been identified within the study area.

Classification of waterbodies as ‘natural’, ‘modified’ or ‘artificial’ (e.g., dams) was not possible given the available imagery resources and it was considered that all waterbody type were likely to provide a degree of ecological value in this setting. This is in line with the definitions of wetlands currently applied in local (NT Land Clearing Guidelines), national (DIWA) and international (RAMSAR) contexts. These distinctions may be incorporated into future product releases as their importance or value may differ from natural waterbodies.

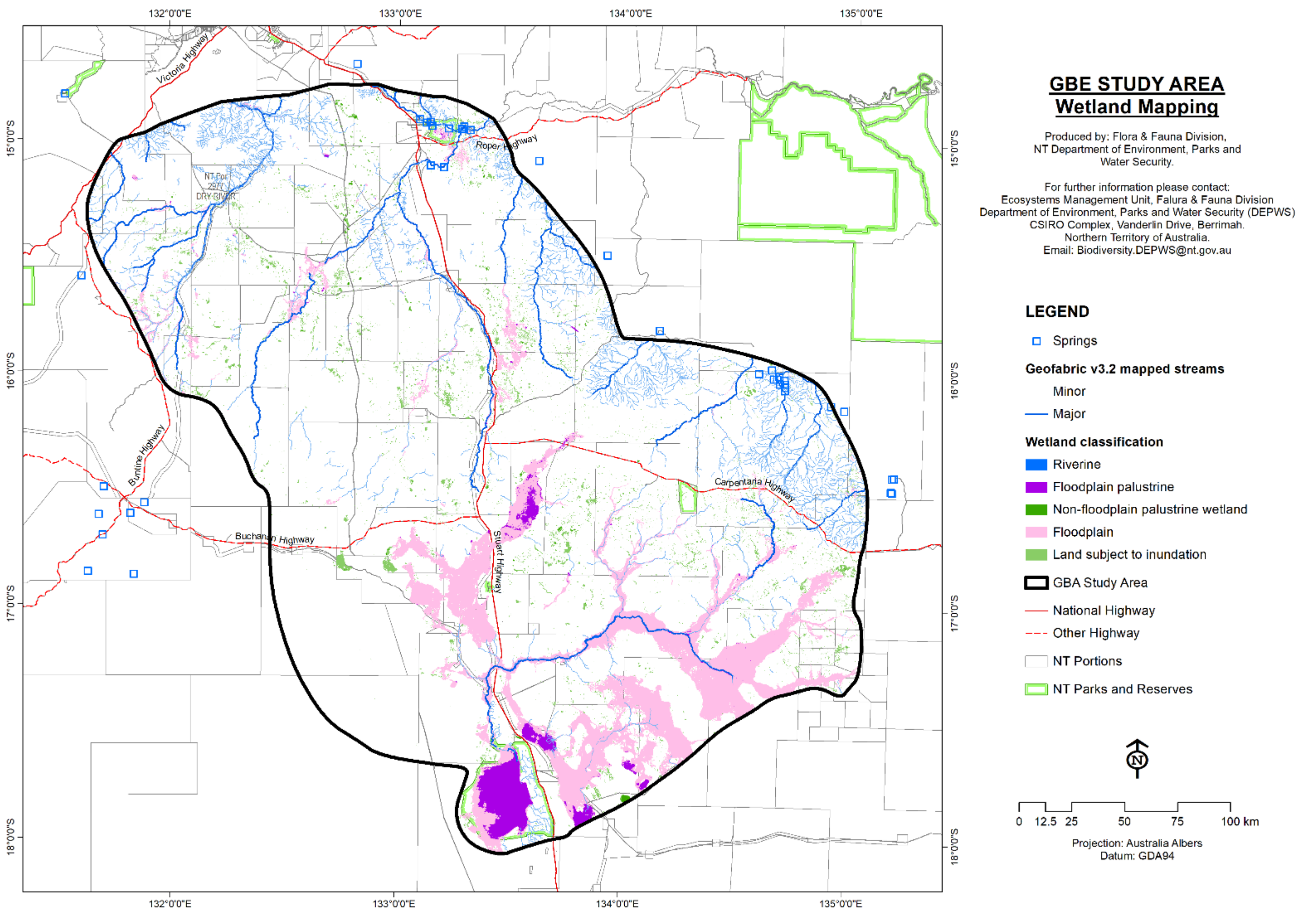



Figure 1.8. Draft wetland map of the BESA.

#### *1.2.2.4. Recommendations for additional sampling sites*

The preliminary regional ecosystem mapping is being used as the basis to select an additional c. 550 full floristic vegetation sampling plots for survey in 2021/22 for the Beetaloo Strategic Regional Environmental and Baseline Assessment (SREBA). This additonal plot will be used to further refine the mapping, and improve the description and delineation of the Regional Ecosystems.

## 1.3. Terrestrial Environmental Protected Matters

The GBA Stage 2 report identified four species as Priority 1 matters of national environmental significance and one species as a matter of Territory environmental significance that are potentially at risk from unconventional gas development in the Beetaloo GBA region (Pavey *et al.* 2020)

(Table 1.5). In addition to the Priority 1 matters of environmental significance, the GBA Stage 2 report also identified seven species of national environmental significance and four species of Territory environmental significance as being Priority 2 matters at some risk from unconventional gas development in the Beetaloo GBA region (Pavey *et al.* 2020) (Table 1.5). Of these species, the NT DEPWS considered that priority should be given to undertaking field surveys for the crested shrike-tit (northern; *Falcunculus frontatus whitei*), Gouldian finch (*Erythrura gouldiae*), greater bilby (*Macrotis lagotis*) and ghost bat (*Macroderma gigas*). It was determined that there was high feasibility for improving the current knowledge base on the distribution and habitat associations of these species in the Beetaloo GBA region within the scope of this project. It was considered that targeted surveys for the grey falcon (*Falco hypoleucos*), bare-rumped sheath-tailed bat (*Saccolaimus saccolaimus nudicluniatus*), masked owl (northern; *Tyto novaehollandiae kimberli*), night parrot (*Pezoporus occidentalis*) and Australian painted snipe (*Rostratula australis*) would not be practical during the timeframe of the project. Waterbirds were also considered to be important EPMs within the BESA. Targeted field surveys for waterbirds were not feasible during the timeframe of the project. However, existing published and unpublished data were collated, including data currently held in the NT Fauna Atlas and data sourced from an additional seven sources.

Table 1.5. Species identified as Priority 1 and Priority 2 matters of national or Territory environmental significance in the GBA Stage 2 report (Pavey *et al*. 2020) and their status under the EPBC Act and TPWC Act.

| Priority | Common name | Scientific name | Significance | EPBC Act | TPWC Act |
|---|---|---|---|---|---|
| 1 | Gouldian finch | *Erythrura gouldiae* | National | Endangered | Vulnerable |
| 1 | Australian painted snipe | *Rostratula australis* | National | Endangered | Vulnerable |
| 1 | Crested shrike-tit (northern) | *Falcunculus frontatus whitei* | National | Vulnerable | Near threatened |
| 1 | Greater bilby | *Macrotis lagotis* | National | Vulnerable | Vulnerable |
| 1 | Grey falcon | *Falco hypoleucos* | Territory | Not listed | Vulnerable |
| 2 | Curlew sandpiper | *Calidris ferruginea* | National | Critically endangered | Vulnerable |
| 2 | Night parrot | *Pezoporus occidentalis* | National | Endangered | Critically endangered |
| 2 | Plains death adder | *Acanthophis hawkei* | National | Vulnerable | Vulnerable |
| 2 | Painted honeyeater | *Grantiella picta* | National | Vulnerable | Vulnerable |
| 2 | Ghost bat | *Macroderma gigas* | National | Vulnerable | Not listed |
| 2 | Bare-rumped sheath-tailed bat | *Saccolaimus saccolaimus nudicluniatus* | National | Vulnerable | Not listed |
| 2 | Masked owl (northern) | *Tyto novaehollandiae kimberli* | National | Vulnerable | Vulnerable |
| 2 | Pale field-rat | *Rattus tunneyi* | Territory | Not listed | Vulnerable |
| 2 | Merten’s water monitor | *Varanus mertensi* | Territory | Not listed | Vulnerable |
| 2 | Mitchell’s water monitor | *Varanus mitchelli* | Territory | Not listed | Vulnerable |
| 2 | Yellow-spotted monitor | *Varanus panoptes* | Territory | Not listed | Vulnerable |

### 1.3.1. Revised distribution data for targeted EPMs

Following delays due to COVID-19, targeted surveys for the Gouldian finch, crested shrike-tit and greater bilby were undertaken in the BESA from 3rd June – 24th July 2020. Due to COVID-19 delays, targeted surveys for ghost bats were not undertaken in the BESA during 2020. However, surveys for ghost bats were undertaken by the Flora and Fauna Division around Pine Creek and Katherine for an unrelated project, and this data were provided for refinement of the species distribution model for the GBA project.

### 1.3.2. Methods

#### *1.3.2.1. Gouldian finch*

Targeted surveys for Gouldian finches were undertaken at nine sites across Tanumbirini, Manbulloo and Kalala Stations from 3rd June – 24th July 2020 (Figure 1.9; Table 1.6). The waterhole count method for the Gouldian finch is described in the *Standard Operating Procedure for the Survey of Gouldian Finches at Waterholes in the BESA* developed by the Flora and Fauna Division (Young 2020c). Gouldian finches drink from standing water sources daily. These water sources are generally small in size with some overhanging vegetation and a shallow bank. Waterhole surveys were undertaken at sites identified as fitting this description in the early morning and late afternoon for up to two consecutive days. Morning surveys began at approximately 7 am and lasted 1 ½ hours. Late afternoon surveys began between 4 pm and 5 pm and lasted until sunset. Sunrise occurred between 6:50 am and 7:10 am and sunset occurred between 6:05 pm and 6:30 pm during June and July 2020. During surveys, one person sat 10–15 m from the edge of the waterhole and counted all birds coming into the water and within the surrounding 20–50 m, depending on the vegetation cover and topography of the site. The number of each bird species was recorded for each 15 min time period from the start of the survey. If Gouldian finches were detected at a site during surveys, no subsequent surveys were undertaken at that site.

As Gouldian finches were regularly observed during site reconnaissance or incidentally, there was often no need for formal survey to record this species.

Table 1.6. Number of sites where targeted surveys were undertaken for northern shrike-tits, Gouldian finches and greater bilbies at Tanumbirini, Manbulloo, Kalala, Forrest Hill and Murranji stations.

| Property | Northern shrike-tit | Gouldian finch | Greater bilby (plots) |
|---|---|---|---|
| Tanumbirini | 18 | 6 | 0 |
| Manbulloo | 11 | 1 | 0 |
| Kalala | 17 | 2 | 0 |
| Forrest Hill | 12 | 0 | 0 |
| Murranji | 0 | 0 | 26 |
| **Total** | **58** | **9** | **26** |

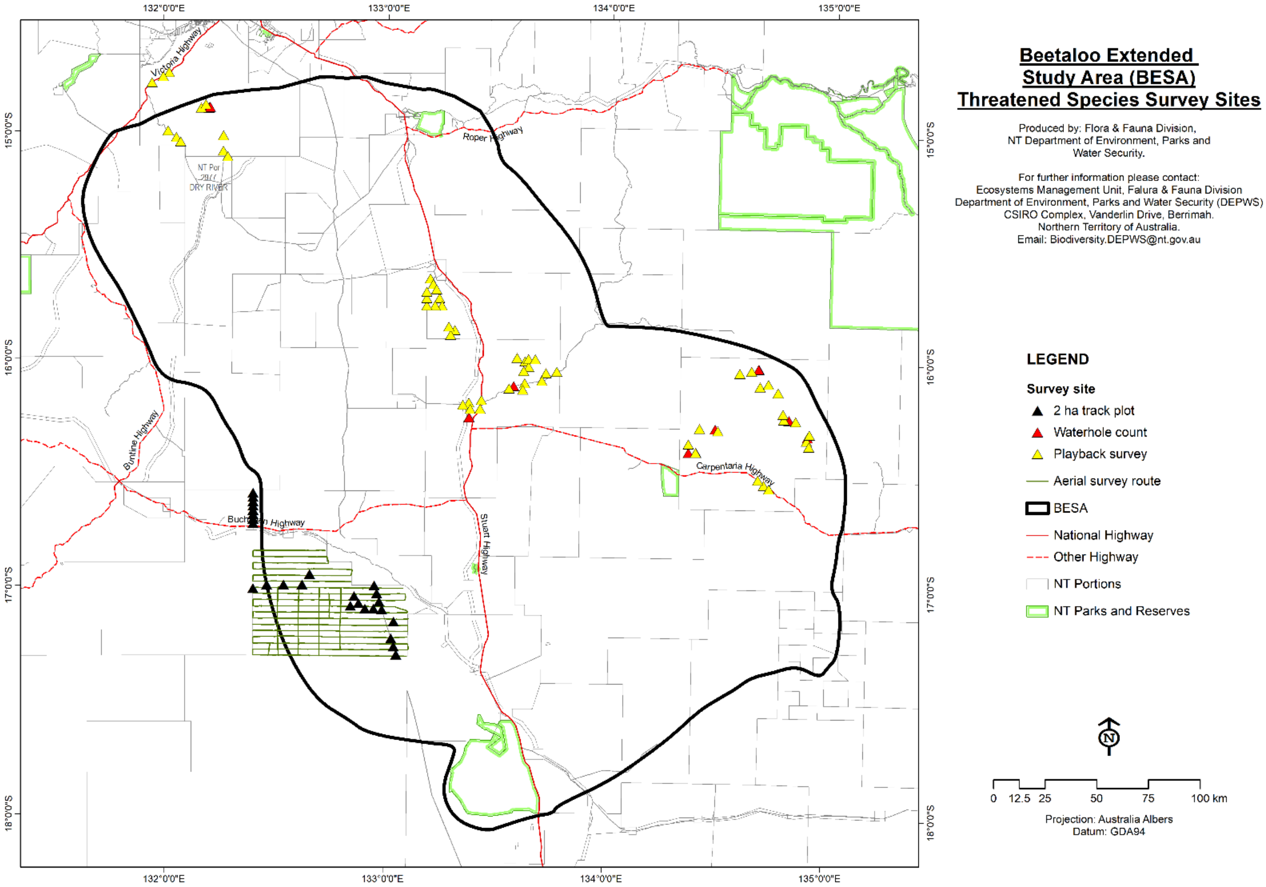



Figure 1.9. Location of sites and aerial transects where surveys were undertaken for Gouldian finches (waterhole count), crested shrike-tits (northern; playback survey) and greater bilbies (track plots and aerial surveys) in the BESA.

#### *1.3.2.2. Crested shrike-tit (northern)*

Targeted surveys for crested shrike-tits were undertaken at 58 sites across Tanumbirini, Manbulloo, Kalala and Forrest Hill stations from 3$^{rd}$ June – 24$^{th}$ July 2020 (Figure 1.9; Table 1.6). Sites in the north-east of Beetaloo Station were also investigated but found to not contain suitable habitat for crested shrike-tits. The playback method for the crested shrike-tit is described in the *Standard Operating Procedure for Playback Survey of the Crested Shrike-tit (Northern) in the BESA* developed by the Flora and Fauna Division (Young 2020a). Call-playback sites comprised a 150 x 150 m plot with four playback points at each corner and meander transects between them. A meander transect was undertaken prior to the first playback point to give observers a chance to record birds on the site prior to potential disturbance from the recorded call sequence. Each 150 m meander transect lasted 5 min. Observers were then static at each playback corner point for 5 min following a meander transect. During the first survey trip (Tanumbirini), a 1 min call sequence was played at each corner followed by a 4 minute period of static observation during which the call was not played. During the second (Manbulloo) and third (Kalala and Forrest Hill) survey trips a 2 min call sequence was played, which had longer greater silence periods between calls in case birds responded to the recorded sequence immediately. This 2 min sequence was followed by 3 min of static observation.

#### 1.3.2.3. Greater bilby

Aerial and ground-based survey methods for greater bilbies are described in the *Standard Operating Procedure for the Aerial and Ground Survey of Bilbies* in the BESA (Young 2020b). Aerial surveys for greater bilbies were undertaken by two observers in a R44 helicopter from 23rd – 26th June 2020. Approximately 1,300 km of aerial transects were flown over ~3,000 km$^2$ of the southern two-thirds of Murranji station. The helicopter was flown 30–50 m above the ground at speeds from 50–70 km/hr. Observers surveyed a strip width of 50–100 m either side of the helicopter. Helicopter altitudes and speeds, and survey strip width were dependent on vegetation height and density. For example, in lancewood (Acacia shirleyi) open forests the helicopter was flown higher and slower, and the strip width was narrower due to the taller and denser structure of the vegetation. Transects were flown at 3 km intervals in an east-west direction across the entire width of Murranji station (Figure 1.9). An additional four north-south transects were flown across the area where bilby sign was recorded during the east-west transects to provide further data (Figure 1.9).

Ground-based surveys for the greater bilby involved undertaking 2 ha (200 m x 100 m) plot-based tracking surveys similar to those described by Moseby *et al*. (2009) and Southgate *et al*. (2018) at 26 locations on Murranji station between 25th – 30th June 2020 (Figure 1.9; Table 1.6). Plots were between 2 and 8.14 km apart, depending on vehicle access and the level of cattle activity, and were 200 m x 100 m (2 ha). Two observers each spent 25 min surveying a 100 x 100 m section of the plot for any sign of the greater bilby (e.g., tracks, scats, burrows, diggings). Plots were situated adjacent to unsealed vehicle tracks so that each observer could walk a 100 m section searching for tracks of the greater bilby following the plot-based search. Any sign recorded was attributed with an estimate of the age of the sign and the confidence of the observer in the identification of the taxon. However, for some sign it was not possible to identify taxon beyond family due to similarity of sign between species or sign age (e.g. toe placement of macropod tracks becomes obscured with increasing time since the track was made).

#### 1.3.2.4. Ghost bat

Ghost bats were not surveyed for in the BESA for the GBA project. However, ghost bat surveys were undertaken north of the BESA in the Katherine region of the Northern Territory for an unrelated project (Flora and Fauna Division, unpublished data). Data collected and collated for this project were provided to Griffith University for use in species distribution model refinement. The survey area of 124,800 ha (52 km x 24 km) was divided into a grid and surveys were conducted at locations that were 5 km apart. Surveys involved the use of call playback, in a similar way to that of 'calling in' birds using their own vocalisations. For ghost bats, a track of repeating calls – to which both males and females are known to be responsive – was used as a lure. The vocalisation was broadcast from a speaker that was attached to a post. A night vision-enabled video camera with an infrared lamp below it (to illuminate the survey location) was used to record for a 2 hour survey period each night (Flora and Fauna Division, in prep.). Footage from the video camera was reviewed to determine whether ghost bats were present at the survey location. Adult ghost bats can be distinguished by their size, anatomical features and behaviour around the speaker.

#### 1.3.2.5. Incidental observations

Observations of relevant species that were made incidentally (e.g. while driving between formal survey sites) were recorded during all survey periods.

### 1.3.2.6. Habitat

Regional ecosystems described in the draft regional ecosytems mapping were aggregated based on expert opinion to form a habitat typology for the BESA (Table 1.7). Species records from the GBA project were intersected with this habitat mapping to identify which habitat the species was recorded in. Species associations should be interpreted with caution, as the draft Regional Ecosystem mapping requires further ground-truthing.

Table 1.7. Habitat typology for the BESA. Habitats are based on aggregated regional ecosystems.

| Habitat number | Description |
|---:|---|
| 1 | *Acacia shirleyi* +/- *Macropteranthes kekwickii* woodlands and open forests |
| 2 | *Acacia shirleyi* +/- *Macropteranthes kekwickii* woodlands and open forests – rocky substrate types (Land zones 7, 9 and 10) |
| 3 | *Macropteranthes kekwickii* woodland and shrubland |
| 4 | Eucalyptus and Corymbia woodlands and open-woodlands with mixed tussock and hummock (*Triodia bitextura*) grasses – sandy/loam soils |
| 5 | Eucalyptus and Corymbia open-forests and woodlands with mixed with mixed tussock and hummock (*Triodia bitextura*) grasses – sandy/loam soils (typically *Eucalyptus tetrodonta* and/or *E. miniata* associations) |
| 6 | Eucalyptus and Corymbia woodlands with tussock grass – clay/loam soils |
| 7 | Eucalyptus and Corymbia woodlands with hummock grass – sandy/loam soils |
| 8 | Eucalyptus and Corymbia woodlands with hummock grass on sandstone or similar geologies |
| 9 | Melaleuca woodland and open forest associated with streams, springs and swamps |
| 10 | Melaleuca woodland and open woodland with variable ground layers on plains |
| 11 | Coolibah low open woodland (alluvial, relict alluvium or basement geologies) |
| 12 | Riparian woodlands (*Eucalyptus camaldulensis* with *T. platyphylla* on mostly sandy streams; *E. microtheca*/*E. parvifolia* or *L. grandiflorus* with *T. platyphylla* on clay/loam streams) |
| 13 | *Corymbia bella* and/or *Corymbia polycarpa* drainage open-woodland |
| 14 | *Lophostemon grandiflorus* +/- *Eucalyptus microtheca* (sens. lat) low woodland (swamps) |
| 15 | *Bauhinia cunninghamii* and/or *Terminalia* spp. +/- scattered Eucalyptus/Corymbia spp. with tussock grasses on clay |
| 16 | *Corymbia aspera* and *Corymbia dichromophloia* low open woodland/sandstone shrubland complex on coarse grained sedimentary substrates |
| 17 | Mixed shrublands and low woodlands |
| 18 | Mixed tussock grasslands (predominantly on heavy clay soils) |
| 19 | Swamp grassland/sedgeland |
| 20 | Limestone shrubland/open-forest complex (*Acacia ampliceps* and *Melaleuca* spp. around Mataranka) |
| 21 | Acacia shrublands (predominantly desert sandplains) |

### 1.3.2.1. Provision of data

The spatial data for all terrestrial fauna records, including threatened and non-threatened species, collected during the GBA project were provided to DAWE on 16/10/2020 and to Griffith University on 11/12/2020 in a format compatible with databases currently used by DAWE.

### 1.3.3. Results

#### *1.3.3.1. Gouldian finch*

Gouldian finches were recorded at nine sites on Tanumbirini Station, seven sites on Kalala Station and two sites on Forrest Hill Station (Figure 1.10) at a range of formal survey sites (*n* = 4), call-playback survey sites (*n* = 4) crested shrike-tit (northern) and during incidental or reconnaissance site visits (*n* = 10). Gouldian finches were not recorded at Manbulloo Station. They were recorded in six habitat types in the BESA (Table 1.8) and at one location where the habitat has not as yet been classified.

Table 1.8. Habitat type that each threatened species was recorded in during the June–July 2020 surveys for the GBA project.

| Habitat ID | Habitat description | Gouldian finch | Crested shrike-tit | Greater bilby | Yellow-spotted monitor |
|---|---|---|---|---|---|
| 3 | *Macropteranthes kekwickii* woodland and shrubland | 0 | 0 | 2 | 0 |
| 4 | Eucalyptus and Corymbia woodlands and open-woodlands with mixed tussock and hummock (*Triodia bitextura*) grasses – sandy/loam soils | 5 | 3 | 10 | 0 |
| 6 | Eucalyptus and Corymbia woodlands with tussock grass – clay/loam soils | 4 | 0 | 1 | 2 |
| 8 | Eucalyptus and Corymbia woodlands with hummock grass on Sandstone or similar geologies | 0 | 1 | 0 | 0 |
| 10 | Melaleuca woodland and open woodland with variable ground layers on plains | 1 | 0 | 0 | 0 |
| 11 | Coolibah low open woodland (alluvial, relict alluvium or basement geologies) | 4 | 0 | 0 | 0 |
| 12 | Riparian woodlands (*Eucalyptus camaldulensis* with *T. platyphylla* on mostly sandy streams; *E. microtheca/E. parvifolia* or *L. grandiflorus* with *T. platyphylla* on clay/loam streams) | 1 | 0 | 0 | 0 |
| 18 | Mixed Tussock Grasslands (predominantly on heavy clay soils) | 3 | 0 | 0 | 0 |
| 21 | Acacia shrublands (predominantly desert sandplains) | 0 | 0 | 6 | 0 |
| | Unclassified | 1 | 0 | 0 | 0 |
| | Outside mapped extent | 0 | 1 | 0 | 0 |

#### *1.3.3.2. Crested shrike-tit (northern)*

Crested shrike-tits were recorded at one known site (the species had been recorded at the site during previous surveys) and two new sites on Manbulloo Station, and at two new sites on Forrest Hill Station (Figure 1.10). Surveys were undertaken at known sites north of the BESA on Manbulloo Station to confirm the efficacy of the survey method. Crested shrike-tits were not recorded at Tanumbirini or Kalala Stations. Crested shrike-tits were recorded in two habitat types in the BESA (Table 1.8). The species was also recorded at one site outside the mapped habitat extent.

### 1.3.3.3. Greater bilby

Bilby sign classified as active (evidence that the site was occupied at the time of survey) was recorded at ten locations during the aerial survey and sign that was classified as inactive (evidence that the site was not occupied at the time of the survey, but had been previously) was recorded at nine locations (Figure 1.10). No bilby sign was detected during plot-based surveys. Greater bilby sign was recorded in four habitat types in the BESA (Table 1.8).

### 1.3.3.4. Ghost bat

Ghost bats were detected at 13 new localities in the Katherine region. These data were provided to Griffith University for incorporation into refined species distribution modelling for the species.

### 1.3.3.5. Yellow-spotted monitor

Yellow-spotted monitors were recorded incidentally twice on Tanumbirini Station in one habitat type (Figure 1.10; Table 1.8).

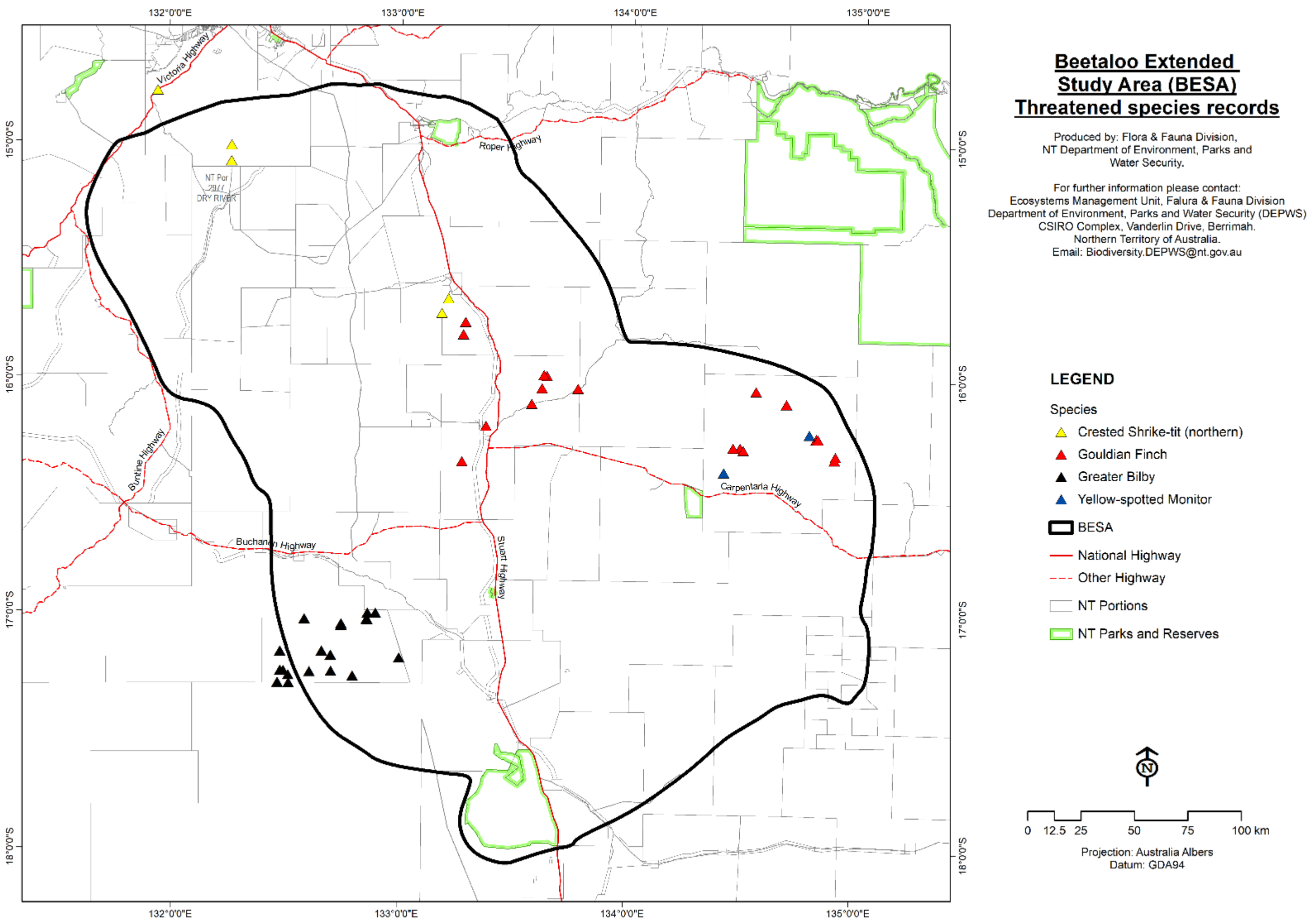



Figure 1.10. Location of Gouldian finch, crested shrike-tit (northern), greater bilby and yellow-spotted monitor records collected between June and July 2020 for the GBA project.

## 1.4. Waterbird data synthesis

*Synthesis of published and unpublished data for waterbirds and migratory species for Lake Woods and Sturt Plateau wetlands*

The BESA contains one of the most important wetlands for waterbirds in inland NT. Lake Woods is recognised as an Important Bird Area (IBA) by Birdlife International because of the large number of birds and diversity of species observed at this location. There are several other important sites for waterbirds in the area, some with permanent water, such as Longreach Waterhole and the Roper River near Elsey National Park.

Conditions in the BESA for waterbirds can change significantly between years, due to the ephemeral nature of many of the wetlands and variation in rainfall between years in the area. During wet conditions the area can be home to large numbers of waterbirds, both resident as well as migratory, and provide nesting grounds for numerous species. Furthermore, several species listed under the EPBC Act and/or TPWC Act have been observed in the BESA. Migratory shorebirds are listed under the EPBC Act and a number of bilateral international agreements, such as with Japan (JAMBA), China (CAMBA) and Korea (ROKAMBA).

Besides occasional surveys of large wetlands in the BESA as part of a larger project, no regular monitoring of waterbirds has been conducted in the area. As such, the data are spatially and temporally patchy. All records of waterbirds from the NT Fauna Atlas were collated. An extensive literature search was also conducted to identify any datasets that might have been missing from the NT Fauna Atlas that could be relevant to the area. Several datasets not included in the NT Fauna Atlas were identified and a brief description is provided below. Unpublished data from the Barkly Tablelands were also collated as the Barkly Lakes systems are partially incorporated into the BESA, represent a highly connected system, and are recognised as IBAs by Birdlife International.

### 1.4.1. Datasets

#### *1.4.1.1. NT Fauna Atlas*

The NT Fauna Atlas holds the majority of records of waterbirds in the NT, as it collates data from a variety of sources (e.g. surveys, Atlas of Living Australia, eBird). Records of waterbirds in the BESA were extracted from the NT Fauna Atlas in May 2020 to use for this synthesis. In total, the NT Fauna Atlas holds over 6,916 records on waterbirds in the BESA collected between 1891 and June 2019. Just over 25% of these 6,916 records in the NT Fauna Atlas do not include information on date. Data were vetted for duplicates before being included in this synthesis.

#### *1.4.1.2. An Inventory of wetlands of the sub-humid tropics of the Northern Territory*

Jaensch (1994) conducted a series of surveys of wetlands in the sub-humid tropics, including Lake Woods, Newcastle Creek waterholes and the Barkly Tablelands Lakes (e.g., Lake Sylvester, Tarrabool Lake – Eva Downs Swamp system) during 1992 and 1993 (Jaensch 1994). Lake Woods was visited in April, May and September during 1993 for ground surveys and aerial surveys were carried out in April and September. Above average rainfall resulted in good conditions for waterbirds in 1993. During this time a large number of species (and individuals) and breeding events were recorded at Lake Woods. This dataset contributed an additional 467 records relevant to the BESA that are not currently in the NT Fauna Atlas.

##### *1.4.1.3. Inventory of the Wetlands of the Sturt Plateau Bioregion, Northern Territory*

Jaensch (2001) conducted surveys of waterbirds at several sites on the Sturt Plateau in June 2001. These sites were only visited once, but provide data for sites in the BESA for which there are little other data. In total, this dataset contributed an additional 247 records relevant to the BESA that are not currently in the NT Fauna Atlas.

##### *1.4.1.4. Records of northern waterbirds in the Barkly wetlands, Northern Territory, 1993–2002*

Records were collated from journal articles published on waterbirds in the Barkly Tablelands (Jaensch 2003a; Jaensch 2003b). This dataset contributed an additional 37 records that are not currently in the NT Fauna Atlas.

##### *1.4.1.5. National Waterbird Survey 2008*

Several sites in the BESA were included in the aerial surveys of the National Waterbird Survey in October 2008. In total, 72 observations were made of waterbirds around Elsey Creek and Newcastle Waters.

##### *1.4.1.6. Tropical Rivers Inventory and Assessment Project*

The Tropical Rivers Inventory and Assessment Project (TRIAP) dataset contains 61 presence/absence records of waterbirds at several sites in the north of the BESA (Franklin 2008). This data was sourced from the Northern Australia Water Futures Assessment Dataset (Kennard 2010).

##### *1.4.1.7. Interim summary report for 2017 waterbird counts*

An aerial survey was conducted at Lake Woods on the 25th of May 2017, contributing an additional 88 records of waterbirds at Lake Woods that are not currently in the NT Fauna Atlas (Carter 2017).

#### 1.4.2. Waterbird species

Eighty-one waterbird species were recorded within the BESA, from 7,325 species level records listed in all of the abovementioned datasets (Figure 1.11; Appendix 2). The Great Egret (*Ardea alba*; 373 records) and White-necked Heron (*Ardea pacifica*; 349 records) were the most frequently recorded species in the BESA.

More than 50% of records in the datasets included abundance information (55%; 4,046 observations). The species with most individuals recorded across all datasets was the Plumed Whistling-duck (*Dendrocygna eytoni*: 41,413 individuals), followed by the Australian Pelican (*Pelecanus conspicillatus*; 18,229 individuals) and Oriental Pratincole (*Glareola maldivarum*; 15,144 observations).

An additional 7,670 records were collated from the Barkly Lakes outside the BESA, but no additional species were observed.

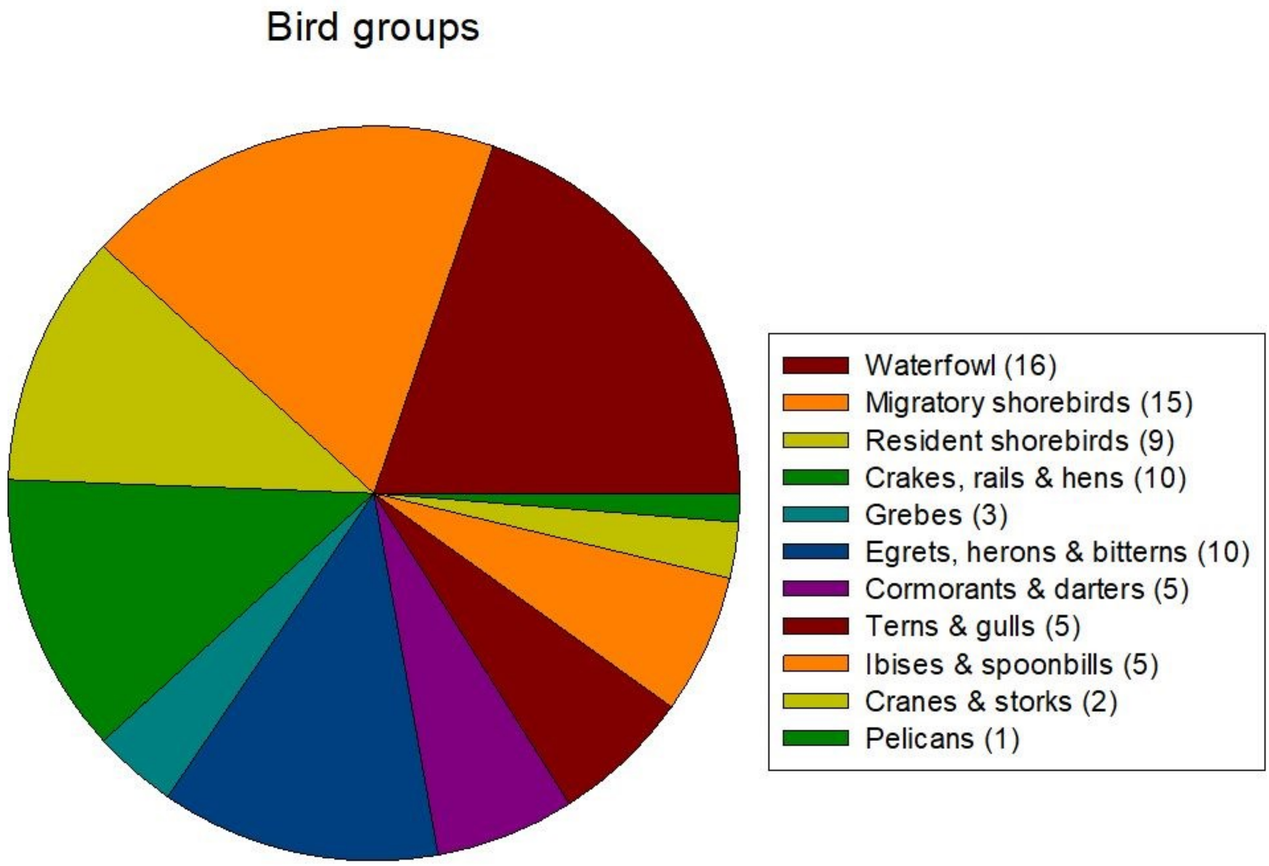



Figure 1.11. The number of species per bird group observed in the BESA (total number of waterbird species is 81).

### 1.4.3. Geographic distribution of waterbirds

The majority of waterbird observations were recorded at seven locations in the BESA (5,381 observations, 73%; Figure 1.12; Table 1.9). Most records were from Lake Woods and Longreach Waterhole in the south of the BESA. These two locations are also where the highest waterbird diversity was recorded (70 and 61 species, respectively). There is a clear bias in the available data based on accessibility of the locations, with the vast majority of records being made close to major roads (Stuart Highway, Carpentaria Highway, Victoria Highway and Buntine Highway). Relatively few observations have been made away from major infrastructure, although the newly identified datasets provide some additional data, for example from several locations on the Sturt Plateau (Jaensch 2001).

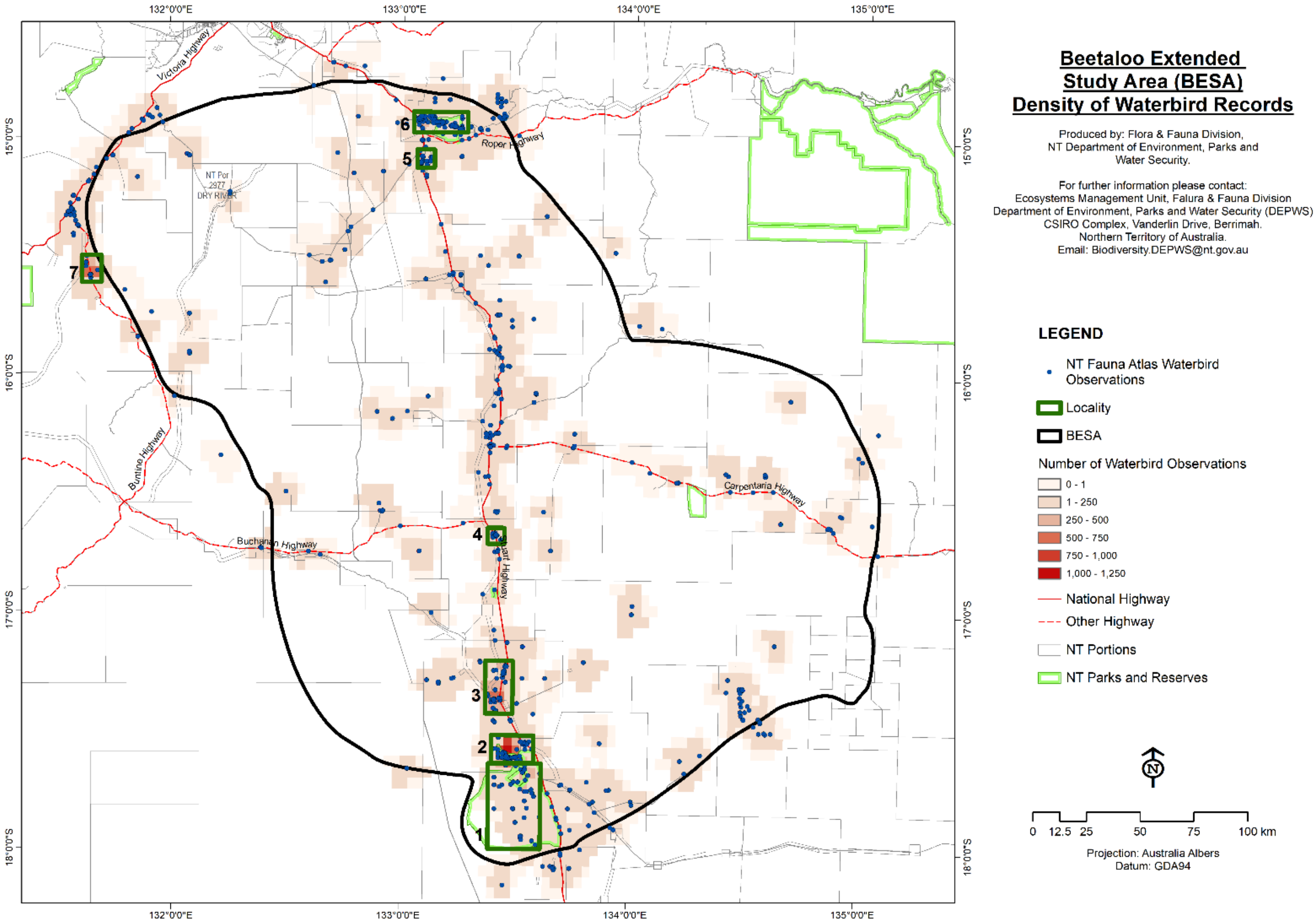



Figure 1.12. Density of NT Fauna Atlas waterbird records across the BESA. Seven locations were identified with the highest number of observations. More information on these seven locations can be found in Table 1.9.

Table 1.9. Seven locations where most of the observations of waterbirds in the BESA occurred.

| **Locations** | **Latitude (min, max)** | **Longitude (min, max)** | **Observations (*N*)** | **Species (*N*)** |
|---|---|---|---|---|
| 1. Lake Woods | -18.00, -17.64 | 133.39, 133.62 | 804 | 70 |
| 2. Longreach Waterhole/Elliot | -17.64. -17.52 | 133.40. 133.59 | 1,549 | 61 |
| 3. Newcastle Waters (Stuart Hwy) | -17.43, -17.20 | 133.37, 133.49 | 987 | 59 |
| 4. Dunmarra (Stuart Hwy) | -16.71, -16.64 | 133.37, 133.45 | 343 | 49 |
| 5. Elsey Creek (Stuart Hwy) | -15.13, -15.05 | 133.00, 133.14 | 359 | 47 |
| 6. Mataranka and Elsey national park | -14.98, -14.89 | 133.00, 133.28 | 568 | 42 |
| 7. Delamere (Buntine Hwy) | -15.62, 15.50 | 131,61, 131.70 | 771 | 567 |

### 1.4.4. Timing of waterbird records

Most observations were recorded during the dry season (April-September), when there are likely more visitors to the area (Figure 1.13a). However, the number of waterbirds recorded varied between months (Figure 1.13b); Greater numbers of waterbirds were recorded in March, May and September than the other months. This is partially explained by observations of large groups of single species as discussed further below.

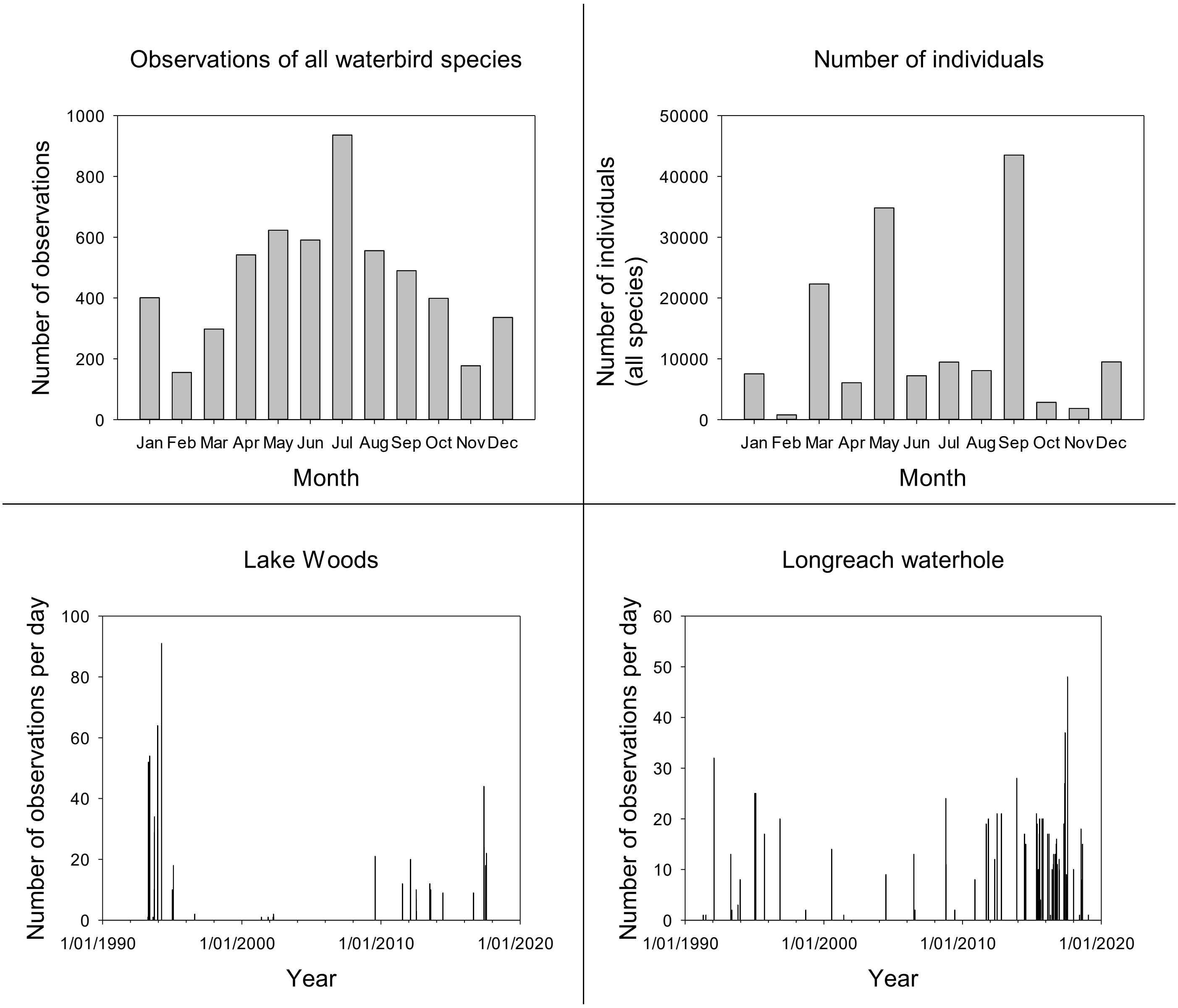



Figure 1.13. Timing of observations for all waterbirds. a) Number of observations per month for all waterbirds recorded in the BESA. b) Number of individuals observed per month for all waterbirds. c) Number of observations per day from 1990 till 2020 at Lake Woods. d) Number of observations per day from 1990 till 2020 at Longreach waterhole.

The number of observations per day also varied between 1990–2020 at Lake Woods and Longreach Waterhole (Figure 1.13c and Figure 1.13d). There are few days with 20 or more records from Lake Woods after the Jaensch (1994) surveys. There have been a greater number of records per day at Longreach Waterhole over the past decade, possibly due to the increase in people recording their observations in online databases such as eBird, which subsequently get incorporated into the NT Fauna Atlas.

### 1.4.5. Large congregations of waterbirds

Almost all of the observations of large groups of a single species (≥500 individuals) occur at Lake Woods. Groups of ≥500 individuals have been observed in the BESA on 61 occasions where abundance information was recorded. Only five of these observations are outside of Lake Woods; three large groups of Plumed Whistling Duck at Delamere, and a large group of straw-necked ibis (*Threskiornis spinicollis*) recorded twice on a wetland near the Barkly Stock Route Road. The largest congregation of a single species observed on Lake Woods in one day was 27,000 Plumed Whistling Duck in 1993 and two observations of a large group of straw-necked ibis on a wetland near the Barkly Stock Route Road in 1993. They are the species most commonly observed in large, and occasionally internationally significant, numbers, along with Straw-necked Ibis (*Threskiornis spinicollis*), Eurasian Coot (*Fulica atra*), Little Black Cormorant (*Phalocrocorax sulcirostris*), Grey Teal (*Anas gracilis*), Australian Pelican and Oriental Pratincole, (Jaensch 1994b).

Lake Woods is recognised as an important breeding area for waterbirds in the inland of the NT and can support large colonies of cormorants, egrets and other waterbirds. For example, Jaensch (1994) reports nesting by Little Black Cormorants, Great Egrets, Australian White Ibis (*Threskiornis molucca*) and Royal Spoonbill (*Platalea regia*). Lake Woods is possibly the only recorded breeding site for Great Egrets in the NT (Jaensch 1994).

### 1.4.6. Threatened species

Two species listed under the EPBC act were recorded in the BESA. The critically endangered Curlew Sandpiper (*Calidris ferruginea*) was recorded once on Lake Woods in 1993 (four individuals) and once just outside of the BESA (also in 1993, one individual). The endangered Australian Painted-snipe (*Rostratula australis*) was recorded near Elliott three times in 1941 and three times since 1990. There have also been observations of breeding by the Australian Painted-snipe on the Sturt Plateau (Jaensch 2003a).

The Australian Painted-snipe and the Curlew Sandpiper are also listed as vulnerable in the TPWC act. Three species listed as near-threatened under the TPWC Act have been recorded in the BESA: the Freckled Duck (*Stictonetta naevosa*; 31 observations), Black-tailed Godwit (*Limosa limosa*; 2 observations) and Pale-vented Bush-hen (*Amaurornis moluccana*; 1 observation). There are also four species listed as data deficient under the TPWC Act: Ballion's Crake (*Porzana pusilla*; 2 observations), Australian Spotted Crake (*Porzana fluminea*; 5 observations), Pectoral Sandpiper (*Calidris melanotos*; 2 observations) and Swinhoe's Snipe (*Gallinago megala*; 2 observations). Most of these species have only been observed in the BESA on Lake Woods (Figure 1.14). The Barkly Tableland Lakes also contain several observations of listed species (mostly Freckled Duck) (Jaensch 1994).

### 1.4.7. Migratory shorebirds

Several migratory shorebird species use inland wetlands, including Lake Woods, whilst they are in Australia. Fifteen species of migratory shorebird have been recorded in the BESA. The most commonly observed species are Oriental Pratincole (observed 31 times), Common Sandpiper (*Actitis hypoleucos*) and Sharp-tailed Sandpiper (*Calidris acuminate*; both observed 27 times). Only the Oriental Pratincole has been seen in large numbers in the BESA, with <1,000 individuals observed for all other species. The number of observations of migratory shorebirds recorded in the BESA is highest between September and April (Figure 1.15). The majority of these observations are at Lake Woods (Figure 1.16).

The Barkly Tableland Lakes have also been identified as potentially important sites for shorebirds (Jaensch 1994). Jaensch (1994a and 1994b) recorded large congregations of migratory shorebirds on these lakes during surveys (Figure 1.16). For example, in December 1993 more than 1,000 oriental plover (*Charadrius veredus*) were recorded at Lake Sylvester, and 1,900 and 13,310 oriental pratincoles were recorded at Lake Sylvester and Lake De Burgh, respectively (Jaensch 1994). No species additional to those recorded in the BESA were recorded at the Barkly Tablelands Lakes.

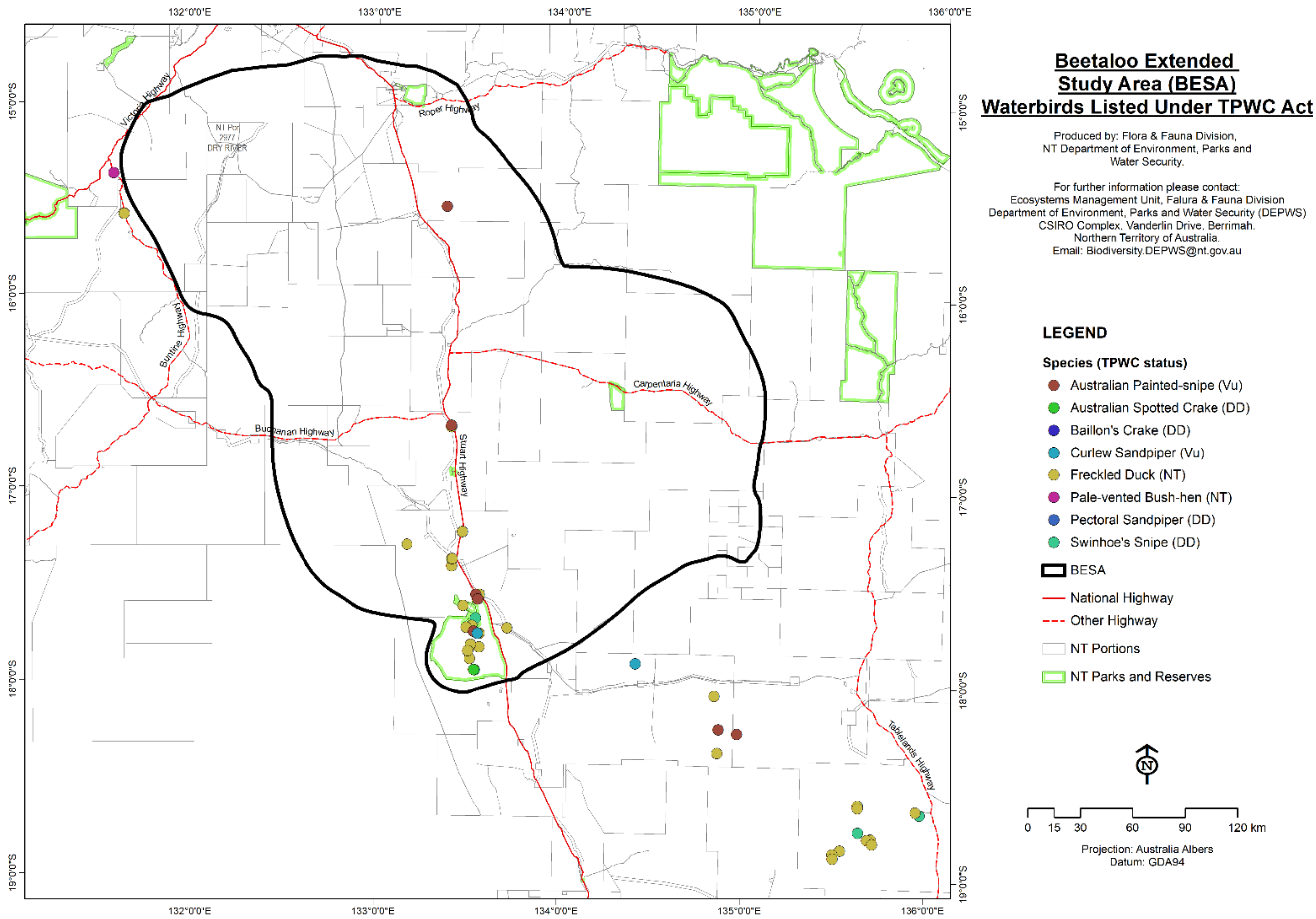



Figure 1.14. Locations of waterbird species listed under the TPWC act (DD: data deficient, NT: near threatened and Vu: vulnerable) recorded within the BESA and in the Barkly Tableland Lakes.

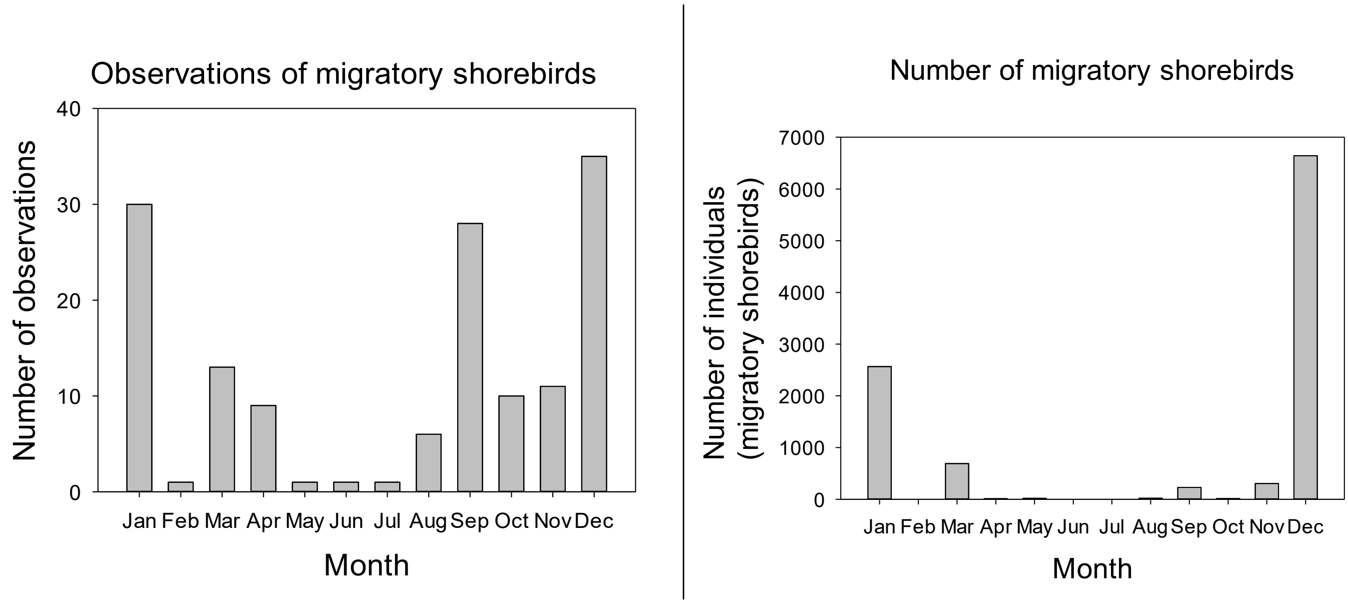



Figure 1.15. Timing of observations for migratory shorebirds. a) Number of observations per month for all migratory shorebirds recorded in the BESA. b) Number of individuals observed per month for all migratory shorebirds.

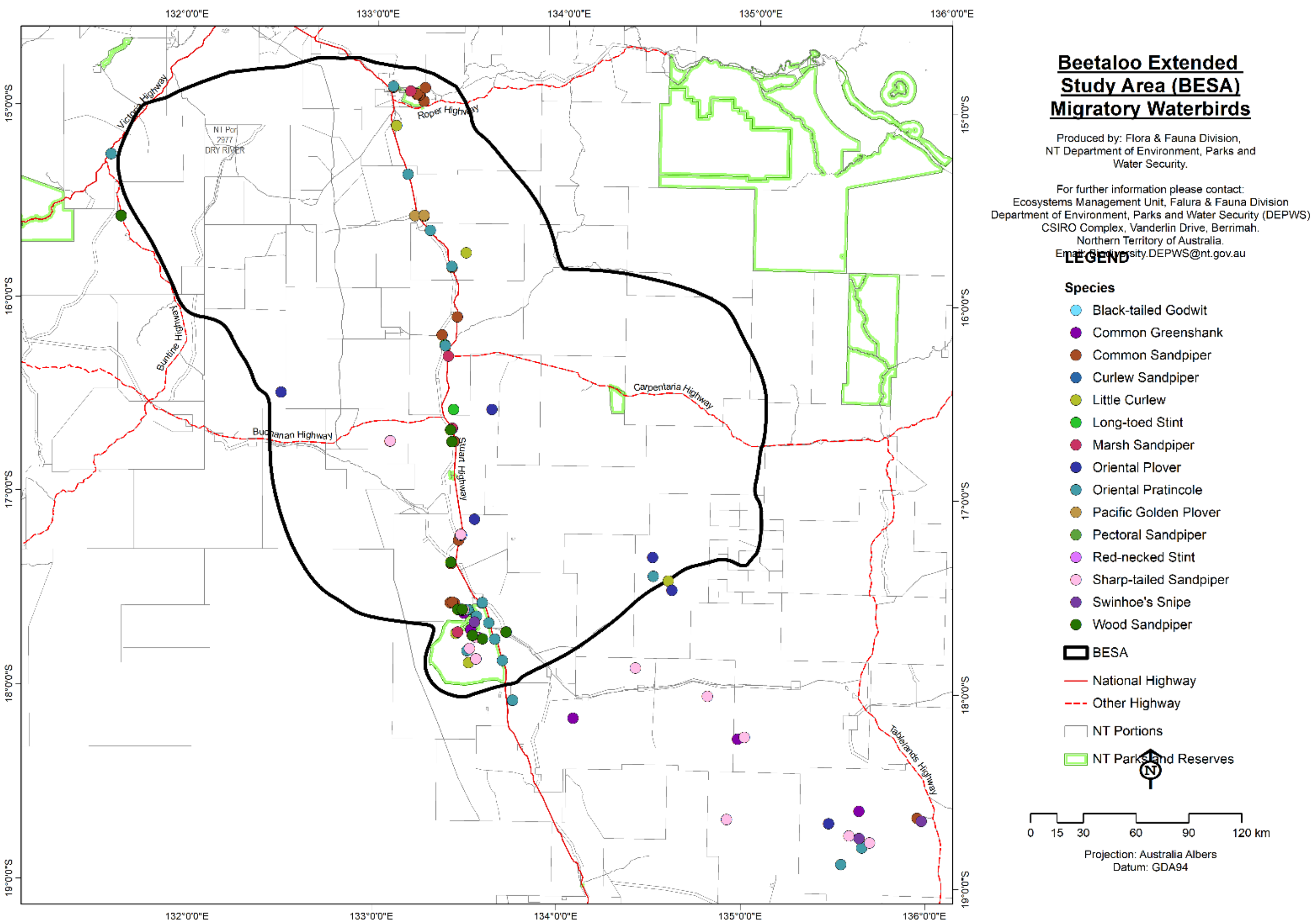



Figure 1.16. Locations of migratory shorebird species recorded within the BESA and in the Barkly Tableland Lakes.

### 1.4.8. Discussion

This synthesis provides a brief overview of the currently available waterbird data for the BESA. As part of this synthesis, several datasets were identified, from which records of waterbirds from the BESA and Barkly Tablelands Lakes not currently included in the NT Fauna Atlas were collated.

The collated data confirm that the BESA has the potential to be an important area for waterbirds, especially around Lake Woods and Longreach Waterhole in the south (Jaensch 1994a). Large numbers of waterbird species have been recorded in these areas (e.g., Lake Woods has been estimated to have held over 100,000 individuals during surveys in 1993; Jaensch 1994). Lake Woods and nearby permanent waterholes also provide habitat for large numbers of nesting waterbirds (Jaensch 1994) and several species listed under the EPBC Act and TPWC Act.

However, there are clear limitations and biases in the available waterbird data from the BESA. As there has been no regular survey effort of waterbirds in this area, the data contains large spatial and temporal gaps. As expected, the vast majority of the records are from wetlands close to major highways in the area, especially the Stuart Highway (Figure 1.12). Furthermore, the number of records varies between months, with a higher number of records from the Dry Season when the region is more accessible. There is also variation in the number of records between years, and this may be related to climatic conditions or survey effort. The birds most commonly observed in the area are also some of the most easily spotted bird species (e.g. Great Egret and White-necked Heron).

Some of the less accessible and less surveyed wetlands in the BESA should be visited during future surveys. It will be beneficial to visit the area during good conditions (flooding/Wet Season) and less than optimal conditions (late Dry Season), to assess how waterbird species use the region when there is an abundance of water compared to when water is significantly more restricted in distribution and amount. Furthermore, ground surveys in the area should be used to target smaller species, such as migratory waders and smaller threatened species, which are typically not seen or identifiable from the air.

## 1.5. Terrestrial Fauna

### 1.5.1. Vertebrate and invertebrate species list

There are records in the NT Fauna Atlas from the BESA for 494 terrestrial vertebrate species (Appendix 3). This includes 279 bird species, 25 frog species, 61 mammal species and 129 reptile species. As discussed for the waterbird records above, the spatial distribution of terrestrial fauna records in the BESA from the NT Fauna Atlas is biased towards major public roads. Seventeen vertebrate species recorded in the BESA are listed as threatened under the TPWC Act and 15 are listed as threatened under the EPBC Act (Table 1.10). Forty vertebrate species recorded in the BESA are listed as data deficient or near threatened under the TPWC Act (Table 1.10). Twenty-one migratory species listed as migratory under the EPBC Act have been recorded in the BESA (Table 1.10). Just one additional species, purple-crowned fairy-wren (eastern; *Malurus coronatus macgillivrayi*) was recorded during the June–July 2020 surveys. The purple-crowned fairy-wren (eastern) is listed as near threatened under the TPWC Act.

Table 1.10. Number of species recorded in the NT Fauna Atlas in the BESA listed in each category under the TPWC Act and EPBC Act. For more information see Appendix 3.

| Act | Status | Birds | Frogs | Mammals | Reptiles | Invertebrates |
|---|---|---|---|---|---|---|
| ***TPWC*** | Extinct regionally | 0 | 0 | 1 | 0 | 0 |
| | Critically endangered | 0 | 0 | 1 | 0 | 0 |
| | Endangered | 0 | 0 | 2 | 0 | 0 |
| | Vulnerable | 7 | 0 | 2 | 4 | 1 |
| | Near threatened | 18 | 0 | 8 | 3 | 0 |
| | Data deficient | 5 | 0 | 0 | 6 | 2 |
| | Introduced | 1 | 1 | 8 | 1 | 0 |
| ***EPBC*** | Critically endangered | 1 | 0 | 0 | 0 | 0 |
| | Endangered | 2 | 0 | 1 | 0 | 0 |
| | Vulnerable | 6 | 0 | 4 | 1 | 0 |
| | Migratory | 21 | 0 | 0 | 0 | 0 |

### 1.5.2. Faunal assemblages

#### *1.5.2.1. Methods*

Due to COVID-19 delays only the camera-trapping component of the proposed general fauna survey was undertaken. Cameras were deployed at 15 sites across Manbulloo, Kalala and Forrest Hill stations for 34–61 days. Five cameras were deployed at each site following the methodology outlined in Gillespie *et al*. (2015). The centre camera had a short focal length and was positioned so that the lens was 65 cm above the ground surface and angled ~45° downwards so that the focal point was focused on the centre of a corkboard. The corkboard was situated 65 cm from the base of the tree that the camera was fixed to, and had a 4 m drift fence running either side. Four cameras were positioned on the corners of the plots up to 70 m distant from the centre camera and so that the top of the camera housing was 40 cm from the ground surface. The focal point of two corner cameras was aimed at the base of a picket holding the bait station that was 2.5 m from the base of the tree that the camera was fixed two. The focal point of the remaining two cameras was focused at the base of the bait station picket 1.5 m from the base of the tree that the camera was fixed to.

Regional Ecosystems and habitats were defined and mapped after cameras had been deployed, and as such were not available to inform the stratification of camera sites for the GBA project. Habitat types (Table 1.7) were assigned to camera site locations based on on-ground descriptions and draft mapping when it became available. Eight sites were assigned to Habitat 4, two sites were assigned to Habitat 5, two sites were assigned to Habitat 6, two sites were assigned to Habitat 11 and one site was assigned to Habitat 15.

#### *1.5.2.2. Provision of data*

The spatial data for all terrestrial fauna records collected during the GBA project were provided to DAWE on 16/10/2020 and to Griffith University on 11/12/2020 in a format compatible with databases currently used by DAWE.

### *1.5.2.3. Results*

Thirty-seven species were recorded on camera-traps across Manbulloo, Kalala and Forrest Hill stations between June and August 2020 (Appendix 4). A further eight taxa could not be identified to species level (Appendix 4). This includes one vulnerable species, four near threatened species, one data deficient species and three introduced species listed under the TPWC Act (Table 1.11). No species listed under the EPBC Act were recorded on camera-traps.

The most commonly recorded species on camera-traps was the agile wallaby (*Notomacropus agilis*; 12 sites), followed by cattle (*Bos Taurus*; 11 sites), common bronzewing (*Phaps chalcoptera*; six sites) and peaceful dove (*Geopelia placida*; six sites). FOH_CAM05, KAL_CAM07 and MAN_CAM04 had the highest richness of taxa that could be identified to at least genus (Figure 1.17).

Table 1.11. Species listed under the TPWC Act recorded on camera-traps at Forrest Hill, Kalala and Manbulloo stations between June and August 2020.

| **Scientific name** | **Common name** | **TPWC Act** | **Station** |
|---|---|---|---|
| *Varanus panoptes* | Yellow-spotted monitor | Vu | Forrest Hill, Kalala |
| *Burhinus grallarius* | Bush stone-curlew | NT | Forrest Hill |
| *Lagorchestes conspicillatus* | Spectacled hare-wallaby | NT | Forrest Hill, Kalala, Manbulloo |
| *Onychogalea unguifera* | Northern nailtail wallaby | NT | Forrest Hill, Kalala |
| *Pseudomys nanus* | Western chestnut mouse | NT | Manbulloo |
| *Tiliqua scincoides* | Common blue-tongue | DD | Kalala, Manbulloo |
| *Bos taurus* | Cattle | Int | Forrest Hill, Kalala, Manbulloo |
| *Equus caballus* | Horse | Int | Manbulloo |
| *Felis catus* | Cat | Int | Forrest Hill, Manbulloo |

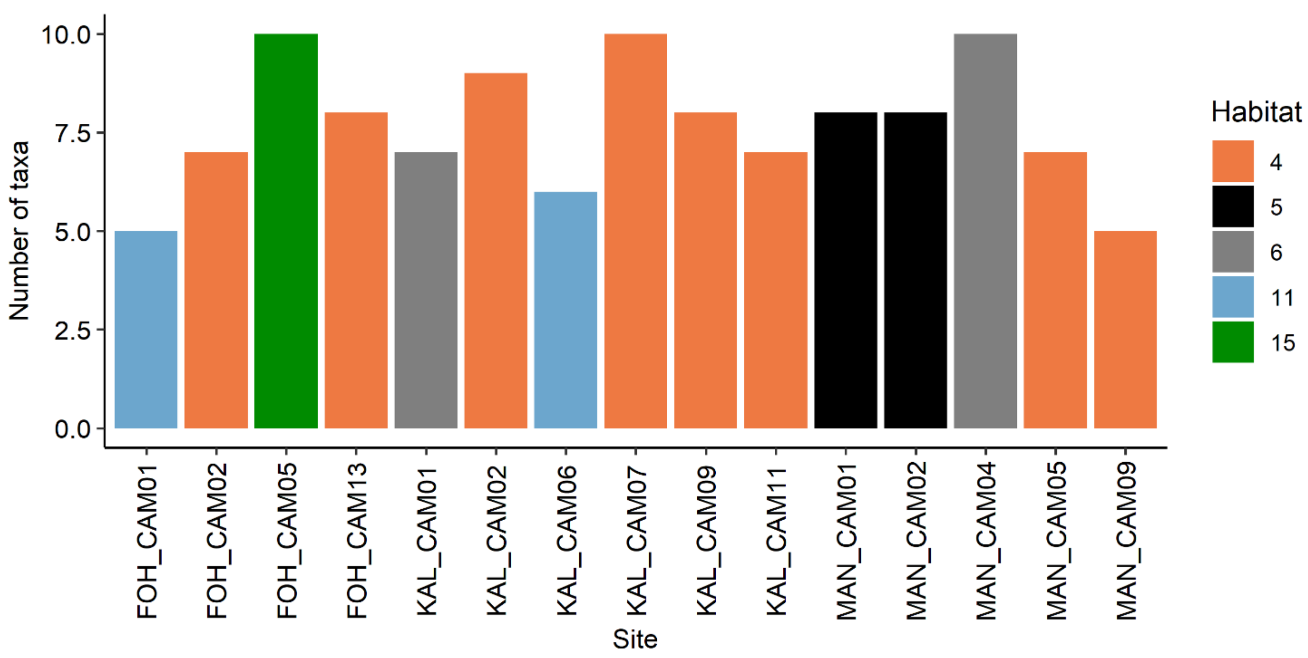



Figure 1.17. Number of taxa identified to genus or species level recorded at each camera-trap site on Forest Hill (FOH), Kalala (KAL) and Manbulloo (MAN) stations between June and August 2020, coloured by habitat type (Table 1.7).

Differences in species composition across the sites and habitats were summarised using nonmetric multidimensional scaling (NMDS) based on a Bray-Curtis dissimilarity matrix (Figure 1.18). There was no clear separation of Habitat 4 from Habitat 15 or Habitat 6. Sites within Habitat 5 and Habitat 11 clustered together and away from sites in other habitat types. Due to low sample sizes in most habitats, no further analysis was undertaken.

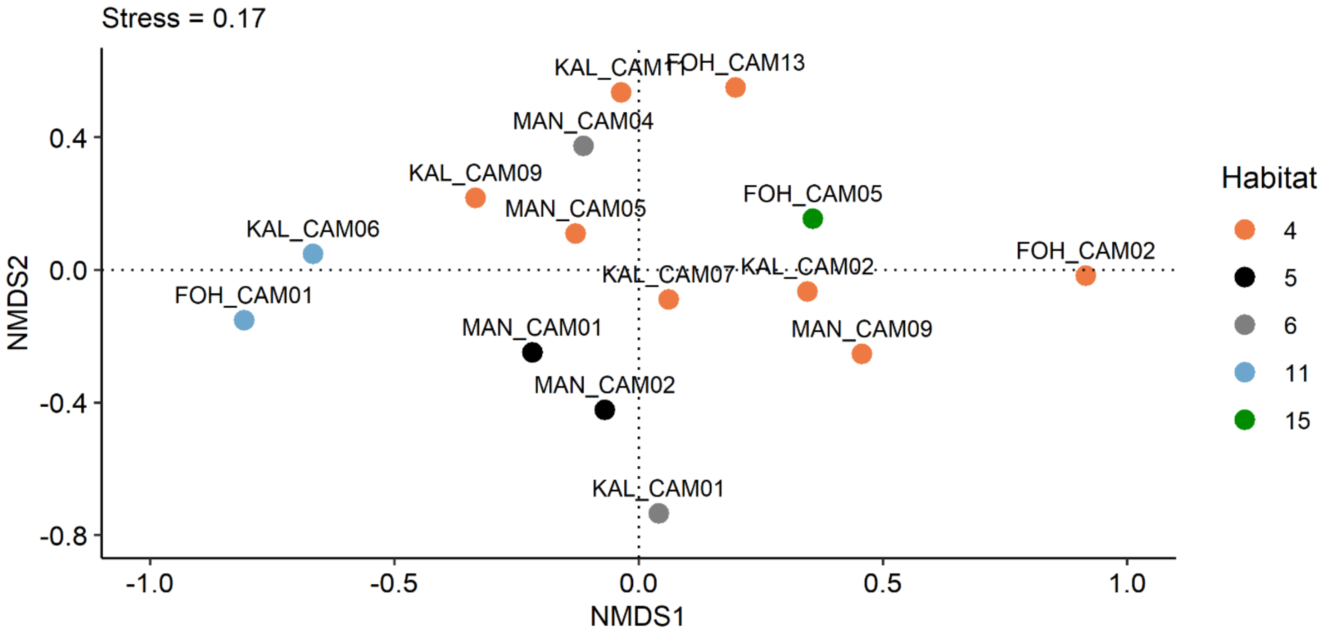



Figure 1.18. Non-metric multi-dimensional scaling plot of sites based on fauna species composition recorded on camera-traps coloured by habitat type (Table 1.7).

#### *1.5.2.3.1. Recommendations for additional sampling sites*

Survey work undertaken for the GBA project will inform further survey effort in the BESA, particularly for the Beetaloo SREBA that is to be undertaken during 2021 and 2022. Draft Regional Ecosystem mapping is aiding in the stratification of ~120 additional survey sites where full general fauna surveys, including live-trapping, bird surveys, nocturnal searches, invertebrate trapping and camera-trapping, will be undertaken. Survey sites are being stratified across 21 habitats (Table 1.7) and across the climatic gradient covered by the BESA (Figure 1.19). Data from this additional survey effort for the SREBA will be used to further analyse the distribution, assemblages and environmental determinants for the terrestrial vertebrate fauna and key terrestrial invertebrate groups in the region and identify habitats or locations of high conservation value.

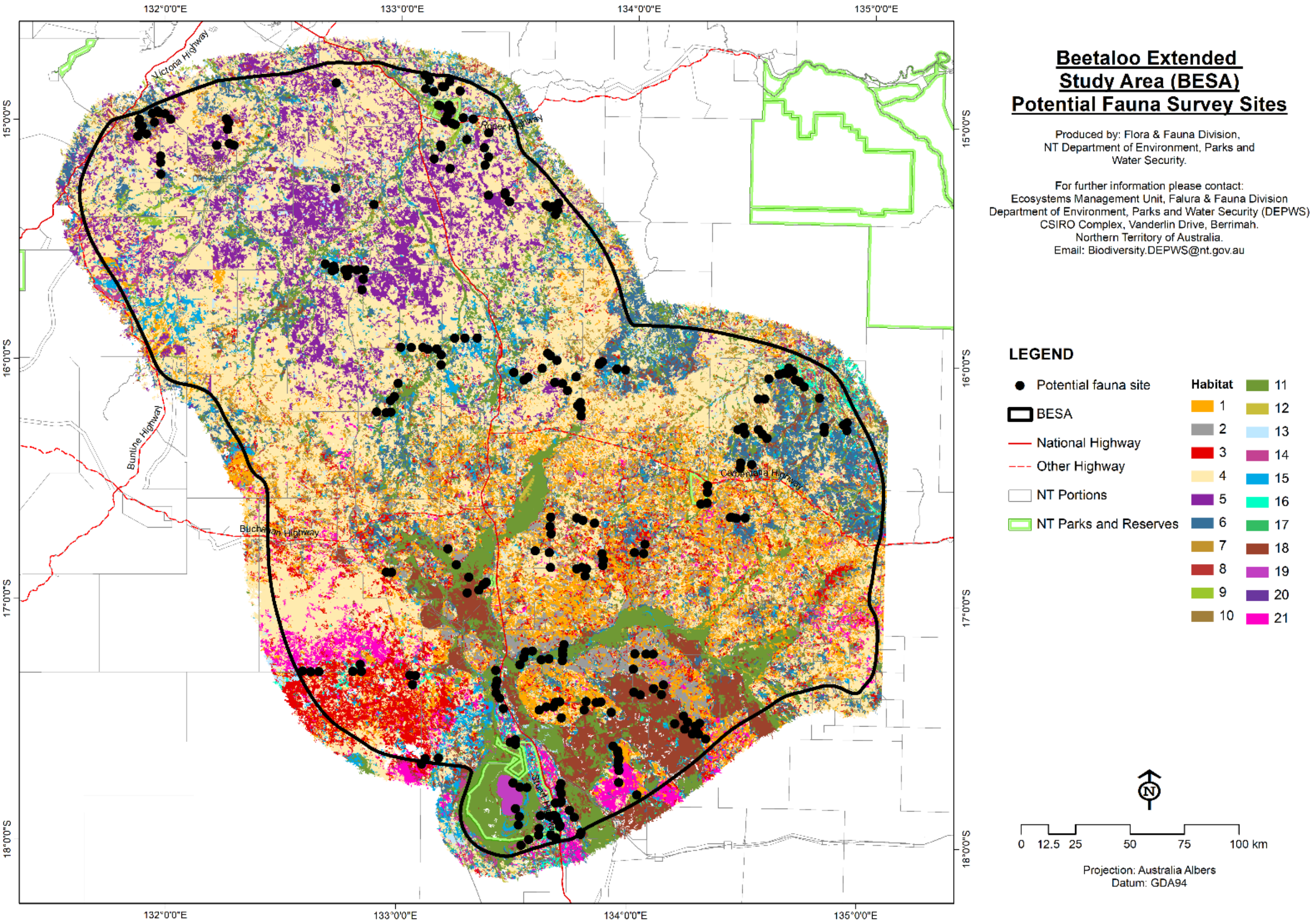



Figure 1.19. Potential additional general fauna survey sites stratified by habitat type and the climatic gradient in the BESA. See Table 1.7 for habitat descriptions.

## 1.6. Terrestrial Biodiversity – Invertebrates (Ants)

### Summary

This chapter describes results from ant surveys at 20 sites in the Beetaloo region in the semi-arid tropics of Australia's Northern Territory, along with an analysis of the broader distributions of the species based on records in the ant collection held at the CSIRO Tropical Ecosystems Research Centre in Darwin. Sites were located on three properties along the north-south rainfall gradient traversed by the Stuart Highway: Elsey National Park (approximately 950 mm mean annual rainfall), Forrest Hill Station (800 mm) and Hayfield-Shenandoah Station (650 mm). Ants were sampled using pitfall traps during October 2020. A total of 232 species from 27 genera were collected across the 20 survey sites. The richest genera were *Monomorium* (60 species), *Melophorus* (34), *Tetramorium* (30), *Iridomyrmex* (19), *Meranoplus* (17), *Pheidole* (14), *Camponotus* (14) and *Rhytidoponera* (14), as occurs throughout Australia's monsoonal tropics. Site species richness was lowest (10–16) on seasonally waterlogged clay soils and highest (35–41) at savanna woodland sites on well-drained sands and loams. Species composition varied systematically with geographic location and soil and vegetation type. Hayfield-Shanandoah sites on clayey loam showed a gradient in species composition from eucalypt-dominated sites through open lancewood and closed lancewood to closed bullwaddy. Most of the 230 native species belong to taxonomically unresolved complexes that require DNA barcoding (using the cytochrome c oxidase I (CO1) genebefore their broader distributions can be assessed; however, 24 of the 76 assessable species are known only from the Beetaloo region, with

23 of these recorded for the first time during this survey. The Beetaloo region has a highly diverse ant fauna with an apparently significant level of endemism, as is typical of monsoonal Australia. However, a much more comprehensive range of sites needs to be surveyed to determine the total size and level of endemism of the fauna, along with the occurrence of any particular centres of diversity or endemism within it.

### 1.6.1. Introduction

Ants are Australia's dominant faunal group in terms of biomass and energy flow. The ant fauna of Australia's monsoonal tropics is exceptionally diverse (Andersen 2000; Andersen *et al.* 2018), rivalling that of the Amazon Basin, which is widely regarded as the world's centre of ant diversity. Remarkably, such diversity is maintained along the strong aridity gradient from the coast inland (Andersen *et al.* 2015), and site-level diversity appears to be particularly high (up to 150 species/ha) in the semi-arid region that includes the Beetaloo Sub-basin (Del Toro *et al.* 2019). However, the Beetaloo fauna is poorly known taxonomically; not only are most species undescribed but such diversity is unrecognised by recent taxonomic revisions (Andersen *et al.* 2013a, 2013b; 2020a, 2020b; Oberprieler *et al.* 2018). Many of the genera have hundreds of species, containing highly diverse complexes that require DNA barcoding (using the cytochrome c oxidase I (CO1) gene found on mitochondrial DNA) to resolve species boundaries (Andersen *et al.* 2016, 2020a, 2020b). For example, an integrated morphological, CO1 and distributional analysis revealed that the recently described *Melophorus* '*rufoniger*' comprises dozens of species just in the Top End of the Northern Territory, with very high levels of local endemism.

Ant surveys in the Beetaloo Sub-basin have been restricted to sites near the Stuart Hwy. A study by Del Toro *et al* (2019) included six sites in the sub-basin, spaced by 50 km along the highway from Larrimah to Elliot. The richest genera were *Monomorium*, *Melophorus*, *Camponotus*, *Tetramorium*, *Rhytidoponera*, *Meranoplus*, *Pheidole* and *Iridomyrmex*; this is the case throughout monsoonal Australia (Andersen 2000) and indeed arid and semi-arid regions of Australia more generally (Andersen 2016). Estimated site species richness ranged from about 90 to 120. In addition, ants have been sampled along the highway in three plots each on Maryfield and Newcastle Waters Stations, as part of the Terrestrial Ecosystem Research Network (TERN) (A. Andersen, unpublished data). Ants have also been sampled in three TERN plots on Mataranka Station in the northern buffer of the sub-basin. Ants were also sampled on Hayfield Station as part of a PhD thesis on faunal impacts of cattle grazing (Alaric Fisher, unpublished data). Finally, in another study of grazing impacts, ants were surveyed at 38 sites on Lakefield Station in the Mataranka region, also in the northern buffer. A total of 130 species from 24 genera were recorded, with the richest genera being *Monomorium*, *Camponotus*, *Tetramorium*, *Iridomyrmex* and *Melophorus*, and species of *Iridomyrmex* and *Monomorium* contributing nearly 90% of all ants (Arcoverde *et al*. 2017).

The great majority of the Beetaloo Sub-basin has not been surveyed for ants. Moreover, almost all the above studies were of eucalypt-dominated savanna, and so other vegetation types have been inadequately or never surveyed. Further, all the above studies used different species identification codes and so it is not possible to compile a combined species list, or to analyse the broader distributions of species, based on their data. Fortunately, voucher specimens of all species from the above studies have been deposited in the ant collection held at the CSIRO Darwin Laboratory, which provides an opportunity to match them with each other. The Darwin collection also holds many specimens from opportunistic collections in the Beetaloo region. Other ant collections are likely to hold few, if any, ant records from the region that are not represented in the Darwin collection; it has by far the most comprehensive collection of ants from monsoonal Australia more generally, and so can be used to analyse the broader distributional patterns of the Beetaloo fauna.

The aims of this report are to: (1) describe results from new ant surveys at 20 sites in the Beetaloo region; and (2) use the Darwin collection to assess broader distributional patterns of the species collected. Assessments of the biogeographical significance of regional faunas require a robust understanding of species delimitation; given the many unresolved species complexes, this study also includes extensive CO1 barcoding to help resolve species boundaries. However, CO1 results are not yet available and so are not included in this report.

### 1.6.2. New ant surveys

#### *1.6.2.1. Methods*

##### *1.6.2.1.1. Survey sites*

New ant surveys were conducted at 20 sites selected to cover a broad range of vegetation types along the regional rainfall gradient traversed by the Stuart Highway. Six sites were located in Elsey National Park near Mataranka (sites ENP-A – ENP-F; approximately 950 mm mean annual rainfall), seven on Forrest Hill Station (800 mm) 20–50 km south of Larrimah (sites FH-A – FH-G), and seven on Hayfield-Shenandoah Station (650 mm) 70–100 km south of Daly Waters (sites HAY-A – HAY-G) (Figure 1.20; Table 1.12). Most sites supported the regionally dominant eucalypt woodlands on loamy or sandy soils, but seasonally waterlogged sites on clay (Elsey NP) and sites dominated by lancewood (*Acacia shirleyi*) and bullwaddy (*Macropteranthes kekwickii*) were also included.

#### *1.6.2.2. Sampling*

Ants were sampled using 4.5 cm-diameter pitfall traps, partly filled with ethylene glycol as a preservative, during 12–19 October 2020. Twenty traps arranged with 10 m spacing along the edges of a 70 m x 70 m square were operated for a 3-day period at each site. The weather was hot (daily maxima >35 $^{o}$C) and mostly dry throughout, with little or no rain.

#### *1.6.2.3. Sample processing*

All specimens were sorted to species, and where possible named. Unnamed species were identified to species group following Andersen (2000) and were provided species codes that apply to this study only. Pinned voucher specimens of all species will be incorporated into the Darwin collection.

#### *1.6.2.4. Data analysis*

Sampling completeness was assessed through rarefaction, with site as the unit of analysis and considering each of the three locations separately as well as combined. Variation among sites in species composition was investigated through non-metric multi-dimensional scaling (NMDS) using Bray-Curtis dissimilarity and based on the frequency of occurrence of species (the number of traps out of 20 in which a species was recorded). Species associations with the three locations were assessed using IndVal analysis, which considers both fidelity and specificity (Dufrêne & Legendre 1997).

Table 1.12. Summary descriptions of new survey sites. Photographs of survey sites are in Appendix 5.

| Site code | Latitude | Longitude | Description |
|---|---|---|---|
| ***Elsey National Park*** | | | |
| ENP-A | -14.93785 | 133.15439 | *Corymbia bella* and/or *C. polycarpa* drainage open woodland |
| ENP-B | -14.99888 | 133.17969 | Open grass/sedgeland plain on black soil |
| ENP-C | -14.94395 | 133.15039 | Limestone shrubland/open-forest complex, dominated by *Acacia ampliceps* and *Melaleuca* spp. |
| ENP-D | -14.938 | 133.183 | Melaleuca woodland on black soil |
| ENP-E | -14.98443 | 133.1243 | *Corymbia*/*Lysiphyllum*/*Erythrophleum* woodland on sand |
| ENP-F | -15.00111 | 133.18124 | Melaleuca open thicket on black soil |
| ***Forrest Hill Station*** | | | |
| FH-A | -15.85888 | 133.27906 | Eucalypt woodlands with mixed tussock and hummock grasses on sandy loam |
| FH-B | -15.91125 | 133.30013 | Eucalypt woodland with tussock grass on clayey loam |
| FH-C | -15.70411 | 133.30862 | Eucalypt/*Erythrophleum* woodland on clayey loam |
| FH-D | -15.71642 | 133.30066 | Eucalypt woodland on sand |
| FH-E | -15.76549 | 133.37665 | Eucalypt woodland with tussock grass on clayey loam |
| FH-F | -15.80386 | 133.38025 | Eucalypt woodland with tussock grass on red loam |
| FH-G | -15.86511 | 133.40662 | Eucalypt woodland with tussock grass on clayey loam |
| ***Hayfield-Shenandoah Station*** | | | |
| HAY-A | -16.82888 | 133.64914 | Eucalypt woodland with mixed tussock and hummock grasses on sandy loam |
| HAY-B | -16.7152 | 133.87665 | *Eucalyptus pruinosa* woodland with tussock grass on loamy clay |
| HAY-C | -16.7815 | 133.87877 | *Corymbia* drainage open woodland |
| HAY-D | -16.80441 | 133.65021 | Open acacia shrubland on sandy loam |
| HAY-E | -16.86509 | 133.7789 | Closed bullwaddy thicket on clayey loam |
| HAY-F | -16.8404 | 133.88034 | Closed lancewood thicket on clayey loam |
| HAY-G | -16.74312 | 133.62045 | Open lancewood thicket with tussock grass on clayey loam |

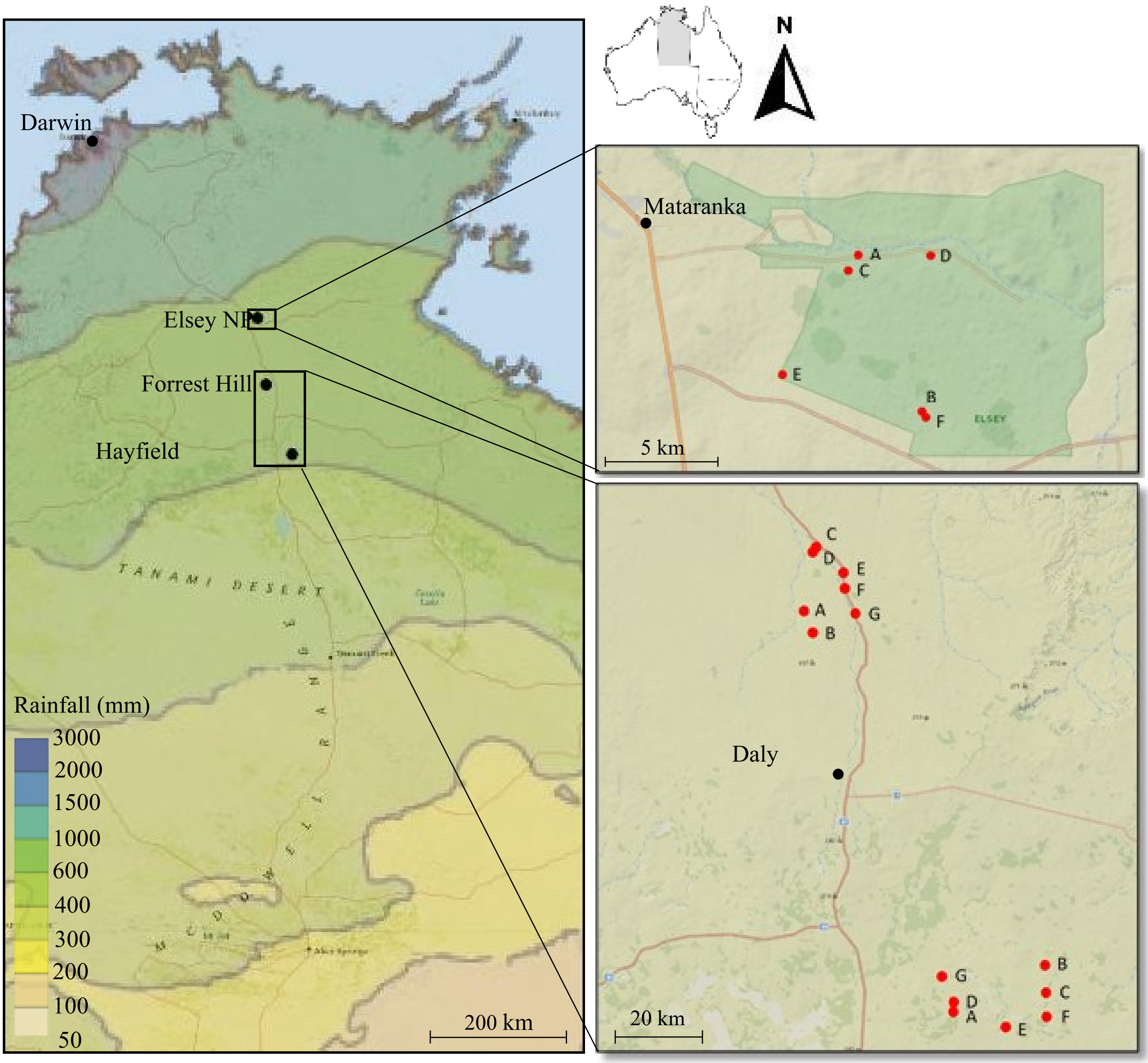



Figure 1.20. Map showing location of survey sites in Elsey National Park (ENP-A – ENP-F), Forrest Hill Station (FH-A – FH-G) and Hayfield-Shenandoah Station (HAY-A – HAY-G).

### 1.6.3. Results

A total of 232 species from 27 genera were provisionally (subject to CO1 results) recognised across the 20 survey sites, with site species richness averaging 25 (Appendix 6). Site species richness was lowest (10–16) on seasonally waterlogged clay soils (HAY-B; ENP-D, ENP-F) and highest (35–41) at savanna woodland sites on well-drained sands and loams (FH-A, FH-D, FH-F, HAY-A, HAY-D). Species accumulation curves show that sampling was highly incomplete at each of the three locations as well as overall (Figure 1.21).

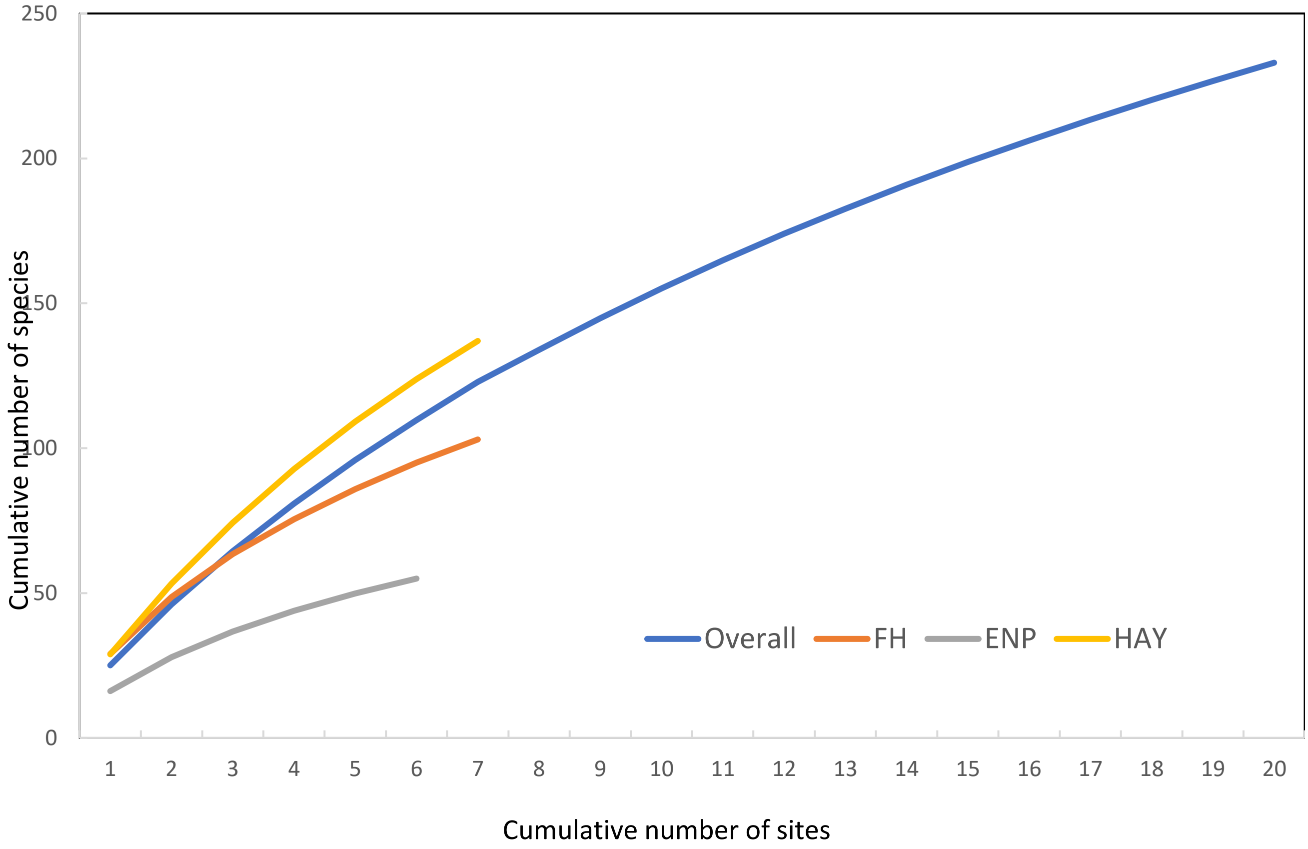



Figure 1.21. Species rarefaction curves for each of the three survey locations (ENP = Elsey NP, FH = Forrest Hill Stn, HAY = Hayfield-Shenandoah Stn) and for all sites combined ('Overall').

The richest genera were *Monomorium* (60 species), *Melophorus* (34), *Tetramorium* (30), *Iridomyrmex* (19), *Meranoplus* (18), *Pheidole* (14), *Camponotus* (14) and *Rhytidoponera* (14); these eight genera collectively contributed 86% of all species. The most frequently recorded genera were *Monomorium* (24.0% total species records at the trap level), *Iridomyrmex* (23.3%), *Melophorus* (22.5%) and *Rhytidoponera* (11.3%); these four genera collectively contributed 81% of all species records. By far the most frequently recorded species were two species of *Iridomyrmex*: the northern meat ant *Iridomyrmex sanguineus*, with 193 records (8.6% total species records) and occurring at 14 of the 20 sites, and *Iridomyrmex* sp. anc1 (*anceps* complex), with 166 (7.4%) records and also occurring at 14 sites. Both species occurred at all three locations, as was the case for only five other species: *Rhytidoponera* sp. aur1 (*aurata* gp.), *Monomorium* sp. nig4 (*nigrius* gp.), *Monomorium* sp. nig9 (*nigrius* gp.), *Melophorus* sp. bir1 (*biroi* gp.) and *Melophorius* sp. lud1 (*ludius* gp.). The fauna includes two introduced species, *Paratrechina longicornis* (occurring at 3 Elsey sites) and *Tetramorium bicarinatum* (a single Elsey site). Both occur throughout the tropics, including throughout northern Australia, mostly associated with anthropogenic habitats.

Of the 55 species in total recorded at the Elsey sites, only 19 (35%) were recorded in another location, and this percentage was similar at Hayfield-Shenandoah: 49 (36%) from 137 species (Figure 1.22). The proportion of shared species was higher at Forrest Hill – 47 (46%) from 102 species, which reflects its geographically central location. Species overlap between Forrest Hill and Hayfield-Shenandoah (42 (21%) from 197 combined species) was far higher than overlaps involving Elsey: 10% with Forrest Hill, and 8% with Hayfield-Shenandoah (Figure 1.22). These patterns of species overlap were reflected in patterns in overall species composition (Figure 1.23). Species composition at Elsey sites was generally distinct from that at Forrest Hill and Hayfield-Shenandoah sites (Figure 1.22). Site ENP-E (eucalypt-dominated woodland on sandy soil) was most similar to sites from other locations, as reflects similarity of vegetation type. The most distinct sites were ENP-B and ENP-F, a grassland/sedgeland and fringing melaleuca thicket respectively on a seasonally waterlogged, black soil plain (Figure 1.22). All Forrest Hill sites occurred in a single cluster in the centre of ordination space, whereas Hayfield-Shenandoah included two outlier sites, HAY-A and HAY-D, the only sites on this station occurring on sandy rather than clayey loam. For the Hayfield-Shanandoah sites on clayey loam there was a gradient from the two eucalypt-dominated sites (HAY-B and HAY-C) through open lancewood (HAY-G) and closed lancewood (HAY-F) to closed bullwaddy (HAY-E).

Eight species (including the introduced *Paratrechina longicornis*) were identified by IndVal analysis as significant indicators of Elsey NP and six of Forrest Hill Station; no species were indicators of Hayfield-Shenandoah Station, but two were indicators of Forrest Hill plus Hayfield-Shenandoah Stations (Table 1.13).

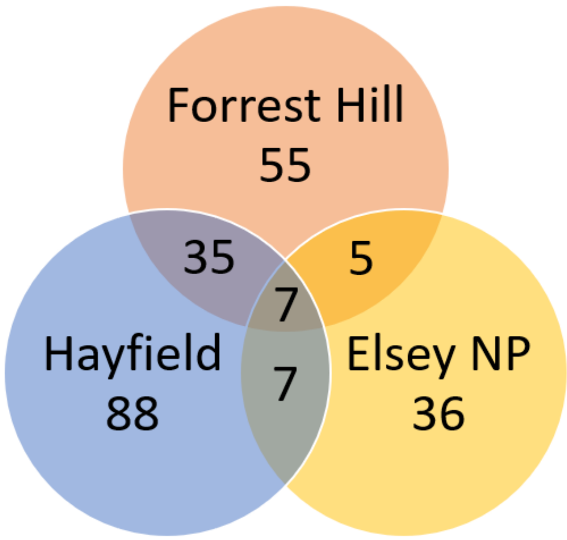



Figure 1.22. Numbers of shared species among the three survey locations.

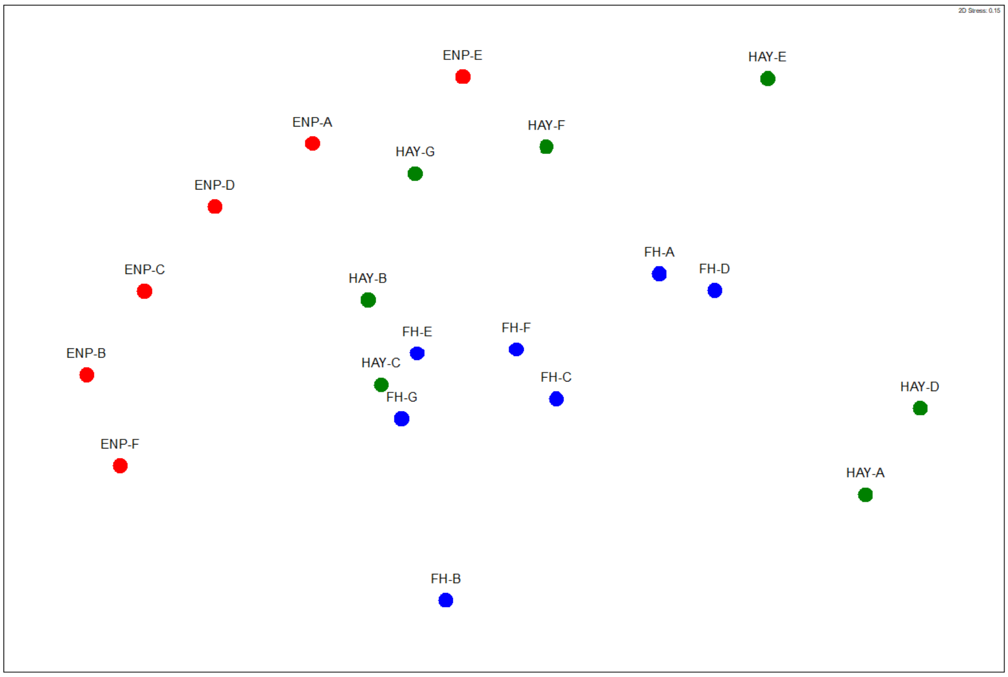



Figure 1.23. NMDS ordination of survey sites based on species frequency of occurrence in traps. Colours indicate the three locations: Elsey NP (red), Forrest Hill Stn (blue) and Hayfield-Shenandoah Stn (green). Stress = 0.15.

Table 1.13. Indicator species for the different locations, based on IndVal analysis. There were no indicator species for Hayfield-Shenandoah Station.

| Location/species | IndVal | P-value |
|---|---|---|
| ***Elsey National Park*** | | |
| *Monomorium* sp. sor3 (*sordidum* gp.) | 0.816 | 0.005 |
| *Rhytidoponera* sp. aur2 (*aurata* gp.) | 0.816 | 0.005 |
| *Monomorium* sp. lae7 (*laeve* gp.) | 0.789 | 0.009 |
| *Odontomachus* nr. *turneri* | 0.783 | 0.009 |
| *Camponotus* sp. nov2 (*novaehollandiae* gp.) | 0.707 | 0.023 |
| *Monomorium* sp. dis2 (*disetigerum* gp.) | 0.707 | 0.023 |
| *Paratrechina longicornis* | 0.707 | 0.020 |
| *Polyrhachis* sp. obt1 (*obtusa* gp.) | 0.707 | 0.019 |
| ***Forrest Hill Station*** | | |
| *Monomorium* sp. mic2 (*micula* gp.) | 0.845 | 0.003 |
| *Melophorus* tur2 (*turneri* gp.) | 0.832 | 0.013 |
| *Melophorus postlei* | 0.782 | 0.009 |
| *Monomorium* sp. lae1 (*laeve* gp.) | 0.756 | 0.017 |
| *Monomorium* sp. nig7 (*nigrius* gp.) | 0.756 | 0.022 |
| *Tetramorium* sp. str1 (*striolatum* gp.) | 0.756 | 0.016 |
| ***Forrest Hill + Hayfield-Shenandoah Stations*** | | |
| *Monomorium* sp. mic1 (*micula* gp.) | 0.845 | 0.012 |
| *Rhytidoponera* sp. ret1 (*reticulata* gp.) | 0.802 | 0.031 |

#### *1.6.3.1. Analysis of broader distributions*

Of the 230 native species recorded, 154 (67%) belong to taxonomically unresolved complexes that require CO1 results before their broader distributions can be assessed (Appendix 7). Of the 76 assessable native species, 24 (32%) are known only from the Beetaloo region, with 23 of these recorded for the first time during this survey (Appendix 7). These newly recorded species are from seven genera: *Tetramorium* (7 species), *Rhytidoponera* (5), *Monomorium* (5), *Melophorus* (3), *Discothyrea* (1), *Meranoplus* (1) and *Camponotus* (1)

Nearly half (35) of the assessable species are also known from the Top End of the NT, most of which were recorded from Elsey NP. Twenty-six (34%) of the assessable species have very broad distributions across monsoonal Australia, occurring also in Western Australia and Queensland. Only seven (9%) of the species are known from the NT south of the Beetaloo region, but this is likely to be at least partly an artefact of the northerly location of most sites along with lower survey effort in central Australia.

#### *1.6.3.2. Conclusion*

The Beetaloo region has a highly diverse ant fauna, as is typical of monsoonal Australia. A particularly notable finding from the survey is that nearly one-third of all recorded species whose broader distributions could be confidently assessed are known only from the Beetaloo region, including 23 species recorded here for the first time. There is high species turnover along the marked north-south rainfall gradient, as has previously been documented (Andersen *et al.* 2015; Del Toro *et al.* 2019). There are also clear ant-habitat associations relating to soils and vegetation. Species richness is lowest on seasonally waterlogged clay soils and highest on well-drained sands and loams, as also has previously been noted (Andersen *et al.* 2015).

This is the first time that lancewood and bullwaddy habitats have been surveyed for ants. Ant species composition varies markedly within these habitats according to tree cover, with open lancewood woodlands supporting similar ant communities to those in eucalypt woodlands, whereas the fauna of the closed bullwaddy thicket was markedly different. Fifteen (41%) of the 37 assessable species from the Bullwaddy site were not recorded elsewhere during the survey. These include *Leptogenys exigua*, which is widespread in monsoonal Australia but typically occurs in areas of higher rainfall. This suggests that closed formations of lancewood and bullwaddy may facilitate the penetration of mesic species into more-arid regions.

The results presented here are clearly very preliminary given the small number of sites, their very limited geographic coverage, and the fact that most species belong to taxonomically unresolved complexes that await CO1 data. There is very high species turnover along the north-south rainfall gradient, but east-west patterns of turnover are entirely unknown. It is therefore not possible to estimate the total size of the Beetaloo ant fauna with any precision, but it is likely to be at least 500 species. It is also not possible to estimate the level of endemism of the fauna. Of the species that could be confidently assessed in this study, about a third are known only from the region; however, given that common and widespread species tend to be the best-known taxonomically, this figure is likely to be substantially higher when the entire fauna is considered. It is also not possible at this stage to undertake any analysis of patterns of endemism within the study region. All such analyses require a far more comprehensive range of sites to be surveyed.

## 1.7. References

Andersen, A. N. (2000) *The Ants of Northern Australia: A Guide to the Monsoonal Fauna*. CSIRO Publishing, Collingwood.

Andersen, A. N. (2016) Ant megadiversity and its origins in arid Australia. *Austral Entomology* 55, 132–147.

Andersen, A. N., Arnan, X. & Sparks, K. (2013a) Limited niche differentiation within remarkable co-occurrences of congeneric species: *Monomorium* ants in the Australian seasonal tropics. *Austral Ecology* 38, 557–567.

Andersen, A. N., Del Toro, I. & Parr, C. L. (2015) Savanna ant species richness is maintained along a bioclimatic gradient of decreasing rainfall and increasing latitude in northern Australia. *Journal of Biogeography* 42, 2313–2322.

Andersen, A. N., Hoffmann, B. D. & Berman, M. (2013b). Diversity in the Australian ant genus *Iridomyrmex* Mayr, 1862 (Hymenoptera: Formicidae): A critique of Heterick & Shattuck (2011), with particular reference to *I. coeruleus* Heterick & Shattuck, 2011. *Myrmecological News* 18, 103–111

Andersen, A. N., Hoffmann, B. D. & Oberprieler, S. (2018) Diversity and biogeography of a species-rich ant fauna of the Australian seasonal tropics. *Insect Science* 25, 519–526.

Andersen, A. N., Hoffmann, B. D. & Oberprieler, S. K. (2020a) Megadiversity in the ant genus *Melophorus*: the *M. rufoniger* Heterick, Castalanelli & Shattuck species group in the Top End of Australia's Northern Territory. *Diversity* 12, 386.

Andersen, A. N., Hoffmann, B. D. & Oberprieler, S. K. (2020b) Integrated morphological, CO1 and distributional analysis confirms many species in the *Iridomyrmex anceps* (Roger) complex of ants. *Zoological Systematics* 45, 219–230.

Andersen, A. N., Hoffmann, B. D. & Sparks, K. (2016) The megadiverse Australian ant genus Melophorus: using CO1 barcoding to inform species richness. *Diversity* 8, 30.

Arcoverde, G. B., Andersen, A. N. & Setterfield, S. A, (2017) Is livestock grazing compatible with biodiversity conservation? Impacts on savanna ant communities in the Australian seasonal tropics. *Biodiversity and Conservation* 26, 883–897.

Armston, J., Denham, R., Danaher, T., Scarth, P., and Moffiet, T. (2009). Prediction and validation of foliage projective cover from Landsat-5 TM and Landsat-7 ETM+ imagery. *Journal of Applied Remote Sensing* **3**, 033540–28. doi:10.1117/1.3216031

Brocklehurst, P., and Gibbons, A. (2015). Developing a Systematic Taxonomy for Northern Territory Vegetation Communities: Part 1. NT Vegetation Compendium Project. Technical Report 06/2015D. Land Assessment Branch, Department of Land Resource Management, Darwin, Australia.

Brocklehurst, P., Lewis, D., Napier, D., and Lynch, D. (2007). Northern Territory guidelines and field methodology for vegetation survey and mapping. Technical Report 02/2007D. Department of Natural Resources, Environment and the Arts, Palmerston, Australia.

Carter, M. (2017). Interim summary report for 2017 waterbird counts. Report for Lake Woods Bird Count Project Coordinator. Birding and Wildlife, Alice Springs, Australia.

Danaher, T., and Collett, L. (2006). Development Optimisation and Multi-Temporal Application of a Simple Landsat Based Water Index. In 3th Australasian Remote Sensing and Photogrammetry Conference. (Spatial Sciences Institute: Canberra, Australia.)

Del Toro, I., Ribbons, R. R., Hayward, J. & Andersen, A. N. (2019) Are stacked species distribution models accurate at predicting multiple levels of diversity along a rainfall gradient? *Austral Ecology* 44, 105–113.

Dufrêne, M. and P. Legendre (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67, 345–366.

Environment Australia (2000). Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the Development of Version 5.1. – Summary Report. Department of Environment and Heritage, Canberra, Australia.

Environmental Protection Agency (2005). Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping and Classification for Wetlands in Queensland, Version 1.2. Queensland Government, Brisbane, Australia. Available at: https://wetlandinfo.des.qld.gov.au/resources/static/pdf/facts-maps/mapping-method/p01769aa.pdf

Feyisa, G. L., Meilby, H., Fensholt, R., and Proud, S. R. (2014). Automated Water Extraction Index: A new technique for surface water mapping using Landsat imagery. *Remote Sensing of Environment* 140, 23–35. doi:10.1016/j.rse.2013.08.029

Franklin, D. C. (2008). Report 9: The waterbirds of Australian tropical rivers and wetlands (BA_ATLAS1 – Field atlas record). A report to Land & Water Australia. National Centre for Tropical Wetland Research, Townsville, Australia.

Gillespie, G. R., Brennan, K., Gentles, T., Hill, B., Low Choy, J., Mahney, T., Stevens, A., and Stokeld, D. (2015). A guide for the use of remote cameras for wildlife survey in northern Australia. National Environmental Research Program, Northern Australia Hub, Charles Darwin University, Casuarina, Australia.

Jaensch, R. P. (1994). An inventory of wetlands of the sub-humid tropics of the Northern Territory. Conservation Commission of the Northern Territory, Palmerston, Australia.

Jaensch, R. P. (2001). Inventory of the Wetlands of the Sturt Plateau Bioregion, Northern Territory. Wetlands International – Oceania for the Parks and Wildlife Commission of the Northern Territory, Northern Territory, Australia.

Jaensch, R. P. (2003a). Recent records and breeding of Painted Snipe *Rostratula benghalensis* in the Mitchell Grass Downs and Sturt Plateau, Northern Territory. *Northern Territory Naturalist* 17, 31–37.

Jaensch, R. P. (2003b). Records of northern waterbirds in the Barkly wetlands, Northern Territory, 1993–2002. *Northern Territory Naturalist* 17, 20–30.

Kennard, M. J. (2010). Identifying high conservation value aquatic ecosystems in northern Australia. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin, Australia.

Kitchen, J., Armston, J., Clark, A., Danaher, T., and Scarth, P. (2010). Operational use of annual Landsat-5 TM and Landsat-7 ETM+ image time-series for mapping wooded extent and foliage projective cover in north-eastern Australia. In (Eds B. Sparrow and G. Bhalia.) 15th Australian Remote Sensing and Photogrammetry Conference. (Alice Springs, Australia.)

Moseby, K. E., Nano, T., and Southgate, R. (2009). *Tales in the Sand. A Guide to Identifying Australian Arid Zone Fauna Using Spoor and Other Signs*. Ecological Horizons, South Australia.

Mueller, N., Lewis, A., Roberts, D., Ring, S., Melrose, R., Sixsmith, J., Lymburner, L., McIntyre, A., Tan, P., Curnow, S., and Ip, A. (2016). Water observations from space: Mapping surface water from 25 years of Landsat imagery across Australia. *Remote Sensing of Environment* 174, 341–352. doi:10.1016/j.rse.2015.11.003

Neldner, V. J., Niehus, R. E., Wilson, B. A., McDonald, W. J. F., Ford, A. J., and Accad, A. (2019a). The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 4.0. Queensland Herbarium, Department of Environment and Science, Brisbane, Australia.

Neldner, V. J., Wilson, B. A., Dillewaard, H. A., Ryan, T. S., Butler, D. W., McDonald, W. J. F., Addicott, E. P., and Appelman, C. N. (2019b). Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 5.0. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane, Australia. Available at: https://www.publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4

NVIS Technical Working Group (2017). Australian Vegetation Attribute Manual: National Vegetation Information System, Version 7.0. Department of the Environment and Energy, Canberra, Australia.

Oberprieler, S. K., Andersen, A. N. & Moritz, C. C. (2018) Ants in Australia's Monsoonal Tropics: CO1 barcoding reveals extensive unrecognised diversity. *Diversity* 10, 36

Pavey, C. R., Herr, A., McFarlane, C. M., Merrin, L. E., and O'Grady, A. P. (2020). Protected matters for the Beetaloo GBA region. Technical appendix for Geological and Bioregional Assessment: Stage 2. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Sattler, P., and Williams, R. (Eds.) (1999). *The conservation status of Queensland's bioregional ecosystems*. Environmental Protection Agency, Brisbane, Australia.

Southgate, R., Dziminski, M., Paltridge, R., Schubert, A., and Gaikhorst, G. (2018). Verifying bilby presence and the systematic sampling of wild populations using sign-based protocols – with notes on aerial and ground survey techniques and asserting absence. *Australian Mammalogy* 41, 27–38. doi:10.1071/AM17028

Staben, G., Lucieer, A., and Scarth, P. (2018). Modelling LiDAR derived tree canopy height from Landsat TM, ETM+ and OLI satellite imagery—A machine learning approach. *International Journal of Applied Earth Observation and Geoinformation* 73, 666–681. doi:10.1016/j.jag.2018.08.013

Thackway, R., Neldner, V. J., and Bolton, M. (2008). Vegetation. In *Australian soil and land survey field handbook: guidelines for conducting surveys*. (Eds N. J. McKenzie, M. J. Grundy, R. Webster, and A. J. Ringrose-Vogse.) Australian Department of Agriculture, Fisheries and Forests, Canberra, Australia.

Wilson, P. R., and Taylor, P. M. (2012). *Land Zones of Queensland*. Queensland Herbarium, Queensland Department of Science, Information Technology, Innovation and the Arts, Brisbane, Australia.

Young, L. I. (2020a). *Standard Operating Procedure for Playback Survey of the Crested Shrike-tit (Northern) in the BESA*. Department of Environment and Natural Resouces, Northern Territory, Australia.

Young, L. I. (2020b). *Standard Operating Procedure for the Aerial and Ground Survey of Bilbies in the BESA*. Department of Environment and Natural Resources, Northern Territory, Australia.

Young, L. I. (2020c). *Standard Operating Procedure for the Survey of Gouldian Finches at Waterholes in the BESA*. Department of Environment and Natural Resouces, Northern Territory, Australia.

# Chapter 2. Modelled distributions of Ecological Protected Matters (EPM) species

## 2.1. Introduction

This chapter describes the development and validation of predictive species distribution models for taxa listed as matters of national environmental significance (Ecological Protected Matters; EPM) that were known or likely to occur within the BESA. The outputs from the models are intended to represent the predicted potential present-day distribution for each taxon based on habitat suitability and expert input. The predicted species distribution maps generated from the models can be useful tools when used in combination with known locations of occurrence for managers and researchers to better understand where a taxon might occur and/or where further field surveys may be needed. An important caveat is that modelled habitat suitability indicates where it is statistically likely for a taxon to occur, not where it is guaranteed to occur or has been observed. The models developed through this project should be considered as preliminary and that they can be improved and updated in the future (e.g. through the SREBA) through more intensive model vetting (e.g. further checking of veracity of species distribution records used in model calibration) and by including additional species distribution records if they become available.

## 2.2. Methods

Taxa used for distribution modelling included EPM species listed as matters of national environmental significance that were known or likely to occur within the Beetaloo region. The conservation status of each taxon at the time of data collation are shown in Table 2.1. Many of these taxa had very few records within the Beetaloo (0–75 records), which reflects the poor knowledge of their distribution within the region and the need to fill this knowledge gap with species distribution models (see Table 2.1). Distributions for 26 species or subspecies in the Beetaloo region were modelled. Individual species distribution models in this collection represent the predicted potential present-day distribution for each species based on habitat suitability and expert input. These models are useful tools when used in combination with known locations of occurrence for managers and researchers to better understand where a species might occur and/or where further field surveys may be needed. Naturally, modelled habitat suitability indicates where it is statistically likely for a species to occur, not where it is guaranteed to occur or has been observed.

There are various approaches to species distribution modelling ranging from simple bioclimatic envelopes to machine learning. For the purposes of this project, we used a machine learning approach (Maxent Version 3.3.3; Elith *et al.* 2011; Phillips, 2005; Phillips *et al.* 2006; Phillips and Dudík, 2008). Maxent software uses a set of environmental predictor variables and a set of known occurrence locations to establish habitat suitability per grid cell (Phillips, 2006). Maxent performs well compared to other methods, especially when only presence data (as opposed to presence/absence data) are available (Elith, 2006).

### 2.2.1. Occurrence records

Distribution models were based on occurrence records extracted from several databases, including the Atlas of Living Australia (ALA), state and territory government data bases managed by the Western Australia Parks and Wildlife Service, the Queensland Department of Environment and Heritage Protection, the Northern Territory Department of Environment and Natural Resources, the

Victoria Department of Environment, Land, Water and Planning, and several databases managed by universities, museums or individuals (Arthur Georges from the University of Canberra, Mark Kennard from Griffith University, and additional records provided by the NT government specifically for this project).

Occurrence records were cleaned (i.e. dubious records excluded) and filtered to the appropriate precision and date range, in consultation with NT Government staff. Generally, only records from 1975 or more recent and with precision of 250 m or better were used. However, if either of these two filters (precision and date) reduced the number of unique records substantially or led to spatially biased datasets, criteria were relaxed (to 1,000 m or any precision; to all historic records). Records were further reduced to the single most recent and highest precision record per grid cell. Only records from distinct populations relevant to the Beetaloo region were used (e.g. *Trichosurus vulpecula arnhemensis* rather than all *Trichosurus vulpecula* populations) because some species with highly disjunct populations or subspecies may be under-sampled and under-represented in parts of their entire range, meaning that models using complete species data can be biased towards more common populations that are of concern for conservation actions in the Beetaloo region. Any non-Australian-mainland records were excluded. Cleaning was done according to feedback elicited from experts, information from the literature, and any information on trustworthiness available in the source databases. Records were reduced to the single most recent and highest precision record per 250 m grid cell. All species had a final number of occurrence records between 27 and 3,334.

### 2.2.2. Environmental predictor variables

Environmental predictor variables used in any of the distribution models were chosen from a larger set of candidate environmental variables depending on each taxon's ecological traits (such as freshwater dependence, or broad taxonomic affiliation), which was further reduced in a variable selection process. The base set of variables included environmental layers adapted to our required extent, resolution and coordinate system from various sources and included layers based on:

- the National Catchment and Stream Environment Database version 1.1.5 (J.L. Stein, M.F. Hutchinson and J.A. Stein, Fenner School of Environment and Society, Australian National University; https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/75066),
- the National Vegetation Information System (NVIS; http://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system),
- climate layers created using ANUCLIM (http://fennerschool.anu.edu.au/research/products/anuclim-vrsn-61),
- the 9-sec digital elevation model available from Geoscience Australia (https://ecat.ga.gov.au/geonetwork/srv/eng/search#!a05f7892-d78f-7506-e044-00144fdd4fa6),
- AusCover foliage projective/forest cover (http://auscover.org.au/purl/landsat-persistent-green-2000-2010),
- vegetation height and structure (http://auscover.org.au/purl/icesat-vegetation-structure),
- land cover type (http://www.ga.gov.au/scientific-topics/earth-obs/accessing-satellite-imagery/landcover),
- dominant lithology (as described in the Bureau of Meteorology Geofabric product groundwater cartography at ftp://ftp.bom.gov.au/anon/home/geofabric/),

- distance to water based on a combination of features described by Bureau of Meteorology Geofabric products at ftp://ftp.bom.gov.au/anon/home/geofabric/ and by Geoscience Australia 'surface hydrology' products (https://data.gov.au/),
- distance to coast based on Australia's coast line as described by IBRA7 products (http://www.environment.gov.au/land/nrs/science/ibra),
- soil properties (depth to regolith, pH, etc.) and soil type (calculated based on combination of sand, silt and clay in top 30 cm of soil) as described by the CSIRO 'Soil and Landscape Grid National Soil Attribute Maps' at 3-sec resolution (accessed through CSIRO data portal at https://data.csiro.au/dap/home?execution=e1s1),
- CSIRO soil classification (http://www.asris.csiro.au/themes/NationalGrids.html),
- fraction photosynthetic active vegetation ('Australia, MODIS-fPAR time series (2000–2014), 9 arcsec (~250 m)' accessed through the BCCVL at http://www.bccvl.org.au/), and
- a weathering index (Wilford, 2012).

Detailed information on the creation of each layer can be viewed in the supplementary information 'AUS_250m_Environmental_Variables.xlsx'.

### 2.2.3. Species distribution modelling & vetting

Species distributions were modelled using Maxent Version 3.3.3 (Elith *et al.* 2011; Phillips, 2005; Phillips *et al.* 2006; Phillips and Dudík, 2008). We used target backgrounds for species' taxa to adjust for potential sampling bias, e.g. bird species were modelled against a background of other bird observations across Australia. Starting variables were selected based on variables that have previously been shown to perform well for each species (Pintor *et al.* 2018) and additional variables recommended by NT government staff. Variables from each starting set were excluded if both their mean permutation importance and percent contribution were under 1% in a 10-fold cross-validated model run using subsampling of 70% training records and 30% test records. Model outputs were thresholded (value under threshold = unsuitable habitat) using the Maxent threshold for 'Maximum test sensitivity plus specificity' for each individual species (or subspecies), which is a commonly used threshold that maximizes the probability that the model correctly predicts an observation (sensitivity) while also maximizing the probability that the model correctly predicts an absence (specificity; (de Barros Ferraz *et al.* 2012; Jorge *et al.* 2013; Vale *et al.* 2014). Presence/ absence maps were created by reclassifying values under the threshold as unsuitable (0) and values above the threshold as suitable (1). Species hotspot maps were created by summing individual species' presence/absence maps. Maxent result files for each species can be accessed by stakeholder to select other potentially suitable thresholds suggested by Maxent for different purposes.

## 2.3. Results and Discussion

We modelled the distribution of 26 EPM species of conservation concern in the Beetaloo region. Species had between 27 and 3,334 records, with 0–75 records of each species falling within the Beetaloo region (Table 2.1). Final models included between 5 and 14 variables. The contribution of each final variable to each species' model is shown in Table 2.2. Most models had a very high test AUC of over 0.9, with only four species showing lower AUCs (Figure 2.1). These still had a very satisfactory test AUC of over 0.75 and were mostly wide-ranging species for which lower AUCs are generally expected because of the increased difficulty in distinguishing suitable from non-suitable habitats when most of the study area is occupied.

After applying a threshold that maximizes sensitivity plus specificity, models predicted an overall distribution area between ~90,000 km$^2$ (*Antechinus bellus*) and ~6,000,000 km$^2$ (*Falco hypoleucos*) for the included taxa, with 1,200–80,000 km$^2$ falling within the Beetaloo region, except for *Antechinus bellus*, which was only modelled species that was predicted not to be present in the Beetaloo.

Maps of the thresholded predicted habitat suitability and occurrence records for each species across Australia and within the Beetaloo region are presented in Appendix 8. An example of the modelled habitat suitability map for the Painted honeyeater (*Grantiella picta*) is shown in Figure 2.2. When adding binary distribution maps together to create a 'hotspot' or species richness map, the number of modelled species that were predicted to be present in each grid cell reached a maximum of 23 in some areas (Appendix 8). Areas of high threatened species richness tended to occur in the northern and eastern parts of the Beetaloo region.

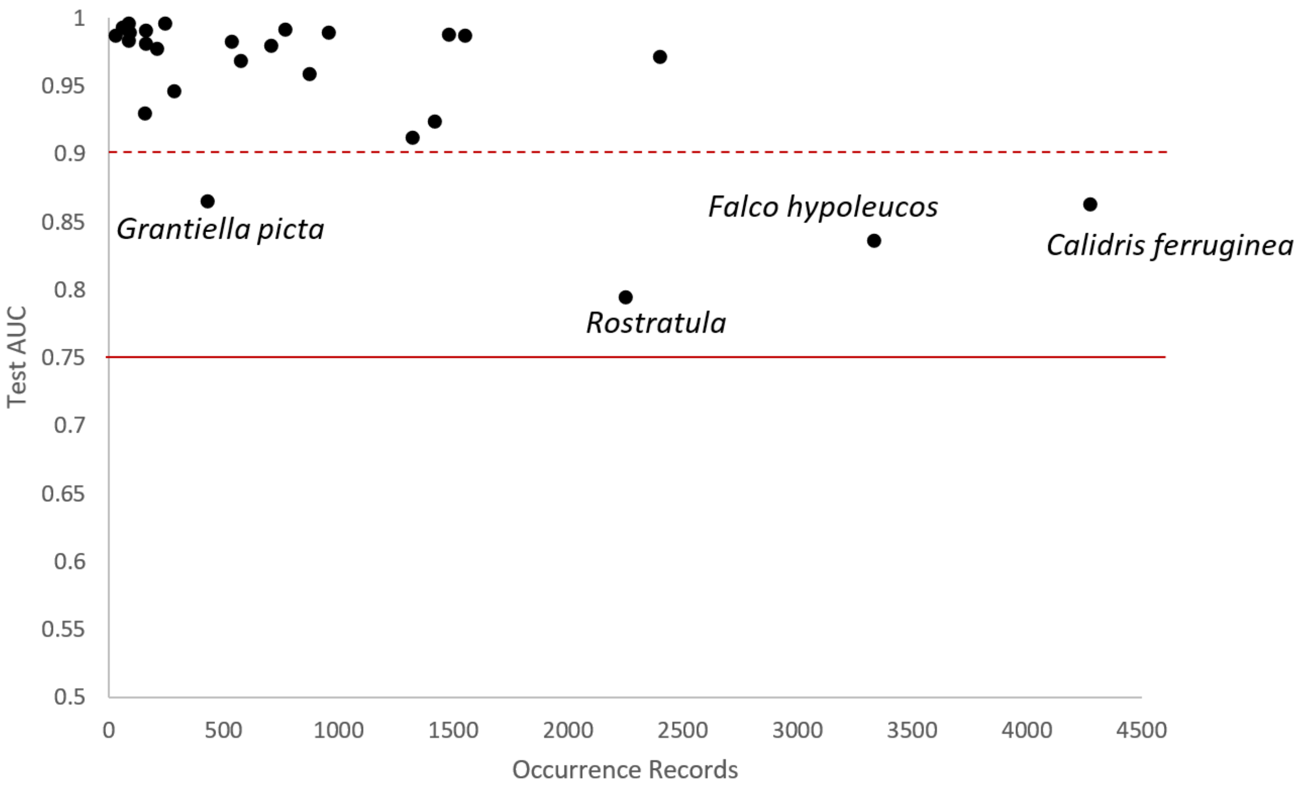



Figure 2.1. Test AUC for cross-validated Maxent models. All species have 'significant' AUCs of above 0.75 and most species have superior AUCs of above 0.9. AUC decreases with number of occurrence records, which is a common pattern because model fit decreases in wide ranging species that have less 'distinct' habitat preferences compared to overall available habitat.

Table 2.1. Details of EPM species, threat status, number of occurrence records and predicted distribution extent and Test AUC values (a measure of model predictive performance).

| Scientific Name | Common Name | Conservation Status | | Occurrence Records | | Predicted Suitable Area (km²)* | | Test AUC |
|---|---|---|---|---|---|---|---|---|
| | | TPWCA | EPBCA | Overall | Beetaloo | Overall | Beetaloo | |
| *Acanthophis hawkei* | Plains Death Adder | VU | VU | 84 | 2 | 890,882 | 62,188.02 | 0.983 |
| *Antechinus bellus* | Fawn antechinus | EN | VU | 242 | 0 | 89,362 | 0 | 0.997 |
| *Calidris ferruginea* | Curlew Sandpiper | VU | CR | 4274 | 1 | 658,511 | 1,273.68 | 0.864 |
| *Dasyurus hallucatus* | Northern Quoll | CR | EN | 951 | 2 | 682,135 | 43,870.81 | 0.990 |
| *Elseya lavarackorum* | Gulf Snapping Turtle | LC | EN | 81 | 1 | 189,507 | 5,209.656 | 0.997 |
| *Erythrotriorchis radiatus* | Red Goshawk | VU | VU | 1319 | 34 | 1,769,868 | 68,781.57 | 0.912 |
| *Erythrura gouldiae* | Gouldian Finch | VU | EN | 2402 | 75 | 1,341,243 | 80,215.02 | 0.971 |
| *Falco hypoleucos* | Grey Falcon | VU | Not listed | 3334 | 48 | 6,208,162 | 83,983.55 | 0.836 |
| *Falcunculus frontatus* | Crested Shrike-tit | NT | VU | 158 | 38 | 827,615 | 73,515.83 | 0.991 |
| *Geophaps smithii* | Partridge Pigeon | VU | VU | 1547 | 3 | 494,071 | 46,143.14 | 0.987 |
| *Grantiella picta* | Painted Honeyeater | VU | VU | 430 | 8 | 3,245,033 | 55,205.67 | 0.866 |
| *Macroderma gigas* | Ghost Bat | NT | VU | 707 | 5 | 2,116,808 | 72,584.25 | 0.980 |
| *Macrotis lagotis* | Greater Bilby | VU | VU | 1483 | 30 | 2,444,057 | 29,932.21 | 0.988 |
| *Pezoporus occidentalis* | Night parrot | CR | EN | 153 | 0 | 5,134,607 | 47,198.1 | 0.930 |
| *Phascogale pirata* | Northern brush-tailed phascogale | EN | VU | 56 | 0 | 499,970 | 37,217.78 | 0.993 |
| *Polytelis alexandrae* | Princess Parrot | VU | VU | 530 | 13 | 3,135,333 | 16,453.28 | 0.982 |
| *Pristis pristis* | Largetooth Sawfish | VU | VU | 280 | 1 | 900,671 | 44,613.88 | 0.946 |
| *Rattus tunneyi* | Pale Field-rat | VU | Not listed | 872 | 0 | 2,096,892 | 83,919.35 | 0.959 |
| *Rostratula australis* | Australian Painted-snipe | VU | EN | 2244 | 7 | 1,628,730 | 9,942.447 | 0.795 |
| *Saccolaimus saccolaimus nudicluniatus* | Bare-rumped sheath-tailed bat | DD | VU | 90 | 0 | 761,394 | 23,534.69 | 0.990 |

| Scientific Name | Common Name | Conservation Status | | Occurrence Records | | Predicted Suitable Area (km²)* | | Test AUC |
|---|---|---|---|---|---|---|---|---|
| | | TPWCA | EPBCA | Overall | Beetaloo | Overall | Beetaloo | |
| *Trachiopsis victoriana* | Snail | VU | Not listed | 27 | 7 | 499,148 | 46,320.04 | 0.987 |
| *Trichosurus vulpecula arnhemensis* | Common Brushtail Possum (north-western) | NT | Not listed | 766 | 4 | 863,050 | 80,397.96 | 0.992 |
| *Tytonovae hollandiae kimberli* | Masked owl (northern) | VU | VU | 158 | 0 | 1422,558 | 76,464.54 | 0.981 |
| *Varanus mertensi* | Mertens Water Monitor | VU | Not listed | 572 | 9 | 1,468,521 | 48,750.99 | 0.968 |
| *Varanus mitchelli* | Mitchells Water Monitor | VU | Not listed | 204 | 5 | 1,037,914 | 70,308.83 | 0.978 |
| *Varanus panoptes* | Yellow-spotted Monitor | VU | Not listed | 1417 | 7 | 4,659,984 | 82,052.31 | 0.924 |

*based on Maximum test sensitivity plus specificity threshold

Table 2.2. Average percent contribution of each variable to each species' 10x cross-validated models using subsampling (70% training, 30% testing points). Please see the accompanying spreadsheet 'AUS_250m_Environmental_Variables.xlsx' for definitions and sources of the abbreviated predictor variables below.

| Variable \ Species | *Acanthophis hawkei* | *Antechinus bellus* | *Calidris ferruginea* | *Dasyurus hallucatus* | *Elseya lavarackorum* | *Erythrotriorchis radiatus* | *Erythrura gouldiae* | *Falco hypoleucos* | *Falcunculus frontatus* | *Geophaps smithii* | *Grantiella picta* | *Macroderma gigas* | *Macrotis lagotis* | *Pezoporus occidentalis* | *Phascogale pirata* | *Polytelis alexandrae* | *Pristis pristis* | *Rattus tunneyi* | *Rostratula australis* | *Saccolaimus saccolaimus nudicluniatus* | *Trachiopsis victoriana* | *Trichosurus vulpecula* | *Tyto novaehollandia* | *Varanus mertensi* | *Varanus mitchelli* | *Varanus panoptes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| auscov_maxh_250m | | | | | | | | | | | 3.6 | | | | 0.5 | | | | | | 0.9 | | | | | |
| auscov_peakh_250m | | | | | | | | | | | | | | | | | | | | 1.0 | 0.7 | | | | | |
| bccvl_fparmax_250m | 2.0 | 1.0 | | | | | 1.9 | | | | | | | 18.6 | | 25.5 | | 0.8 | | | | | | 0.5 | | |
| bccvl_fparmin_250m | | | 7.2 | | | 1.9 | | 3.0 | 1.2 | | | | | | | | | | 14.2 | | | | | | | 1.0 |
| bdw_00-30_250m | | | | | | | | | | | | | | | | | | | | | | | | | | |
| cat_domlith_250m | | 0.9 | 4.5 | | | 6.3 | 0.9 | 1.7 | 7.9 | | 11.3 | 11.6 | | 21.0 | 6.8 | 12.8 | 3.3 | 4.6 | 28.3 | 13.2 | 3.5 | 1.8 | 8.7 | 6.1 | 4.1 | 5.9 |
| cat_nvis_mvs_250 | | | 6.3 | 1.6 | | 4.6 | 2.7 | 2.3 | 10.9 | | 14.0 | | 8.2 | 7.8 | 2.6 | 10.7 | 2.8 | | 26.0 | 2.1 | 4.7 | | 7.4 | 1.6 | 3.5 | 7.3 |
| cat_soiltype_250m | 12.4 | | | | | | | | | | | | 10.4 | | | | | | | | 2.2 | | | | | |
| clay_250m | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Clim_21-95_minRH | 3.9 | | | | | | 2.2 | 50.3 | 2.3 | 0.6 | | | | 37.5 | | 37.9 | | 6.8 | 1.3 | | | | | | 2.0 | |
| Clim_76-05_p01 | 0.3 | | | | | | | | 2.5 | | | 42.9 | | 0.6 | | | | | 5.6 | 5.4 | 1.9 | | 3.1 | 2.6 | 3.9 | 1.9 |
| Clim_76-05_p04 | | | 1.0 | 3.4 | 24.1 | 1.9 | | 4.1 | | | 12.9 | 4.0 | | 2.1 | 13.7 | 3.8 | 0.5 | | 3.6 | | | 1.4 | 2.4 | 0.2 | 1.0 | 3.9 |
| Clim_76-05_p05 | | 3.9 | | | | | | | | | 25.5 | | 16.5 | | | | | | 2.1 | | | | | 0.3 | | 4.9 |
| Clim_76-05_p06 | | 4.8 | | | | 1.7 | | 0.2 | | | | | | | | 2.5 | | | | 1.0 | | | 6.0 | | | 0.9 |
| Clim_76-05_p12 | | 10.4 | | 6.6 | | | 0.3 | | 7.3 | | 2.6 | | 5.1 | | | | | | | 9.9 | | 0.4 | 0.9 | | | 4.7 |
| Clim_76-05_p15 | 15.7 | 5.6 | 1.4 | 21.6 | 48.4 | 22.0 | 19.0 | 0.9 | | | 1.7 | | 37.5 | 0.9 | | 4.2 | 31.7 | 22.4 | | 59.1 | | | 20.5 | 16.9 | 9.9 | 14.8 |
| Clim_76-05_p16 | | | | | | | 8.9 | | | 23.5 | | | | | | | | | 3.6 | | | 14.5 | | | | |
| Clim_76-05_p17 | | | 1.4 | | | | | 1.6 | | | 2.8 | | | | 15.8 | 0.7 | 43.9 | | | 8.3 | | | | | | 27.6 |
| Clim_76-05_p18 | 1.2 | | | | | 41.8 | | | | 0.3 | 6.7 | | 1.1 | 1.2 | | 1.7 | | 1.8 | 3.0 | | | | 0.9 | | | |
| Clim_76-05_p19 | 29.3 | 68.2 | | | | | 56.2 | 10.6 | | | 4.7 | | 11.9 | | | | | | | | 46.2 | | | 44.3 | | |
| Clim_76-05_p20 | | | 0.7 | | | | 3.5 | 4.8 | | | | | | | | | | | 1.2 | | | | | | | |
| Clim_76-05_p21 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Clim_76-05_p22 | 25.4 | 5.1 | | 67.0 | | 19.8 | | | 62.7 | 70.0 | 9.7 | 31.2 | 1.0 | | 60.5 | | | 61.6 | | | 39.9 | 80.9 | 50.1 | 17.3 | 63.0 | 25.8 |
| dermed_250m | 2.8 | | | | | | 4.0 | | | | | 7.7 | | | | | | | | | | | | | | 1.3 |
| geoscaus_distcst_250m | | | 44.4 | | | | | | | 4.3 | | | | | | | | | | | | | | | | |
| geoscaus_distout_250m | | | 8.0 | | 10.9 | | | | | | | | | | | | 1.0 | | 3.2 | | | | | 0.2 | 5.1 | |
| geoscaus_distsrc_250m | | | | | | | | | | | | | | | | | 8.3 | | | | | | | | | |
| geoscaus_runanmean_250m | | | | | | | 0.5 | | | | | | | | | | | | | | | | | 4.3 | 1.1 | |
| geoscaus_runperen_250m | | | | | | | | | | | | | | | | | | | | | | | | | 4.6 | |
| geoscaus_toprug_250m | | | | | | | | | | | | 2.6 | 8.3 | | | | | | | | | | | | | |

| Variable \ Species | *Acanthophis hawkei* | *Antechinus bellus* | *Calidris ferruginea* | *Dasyurus hallucatus* | *Elseya lavarackorum* | *Erythrotriorchis radiatus* | *Erythrura gouldiae* | *Falco hypoleucos* | *Falcunculus frontatus* | *Geophaps smithii* | *Grantiella picta* | *Macroderma gigas* | *Macrotis lagotis* | *Pezoporus occidentalis* | *Phascogale pirata* | *Polytelis alexandrae* | *Pristis pristis* | *Rattus tunneyi* | *Rostratula australis* | *Saccolaimus saccolaimus nudicluniatus* | *Trachiopsis victoriana* | *Trichosurus vulpecula* | *Tyto novaehollandia* | *Varanus mertensi* | *Varanus mitchelli* | *Varanus panoptes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| geoscaus_vconf_250m | | | 17.5 | | | | | | | | | | | | | | | | | | | | | | | |
| prjcov_250m | 6.3 | 0.2 | | | | | | 20.5 | | | 4.5 | | | 6.1 | | | | 1.8 | | | | 0.9 | | | | |
| segcatslope_250m | | | | | 6.3 | | | | | | | | | | | | | | | | | | | | | |
| segelmean_250m | | | | | 6.2 | | | | | | | | | | | | 5.0 | | | | | | | | | |
| segmxdownslope_250m | | | | | | | | | | | | | | | | | 2.1 | | | | | | | | | |
| segrunancv_250m | | | | | | | | | | | | | | | | | 1.4 | | 7.8 | | | | | 1.4 | 0.5 | |
| slope_250mm | | | 5.1 | | | | | | | | | | | | | | | | | | | | | 2.6 | 1.5 | |
| watdist_250m | | | 2.4 | | 4.1 | | | | 5.2 | 1.3 | | | | 1.8 | | | | | | | | | | 1.6 | | |
| wiamin_250m | 0.6 | | | | | | | | | | | | | 2.3 | | | | | | | | | | | | |

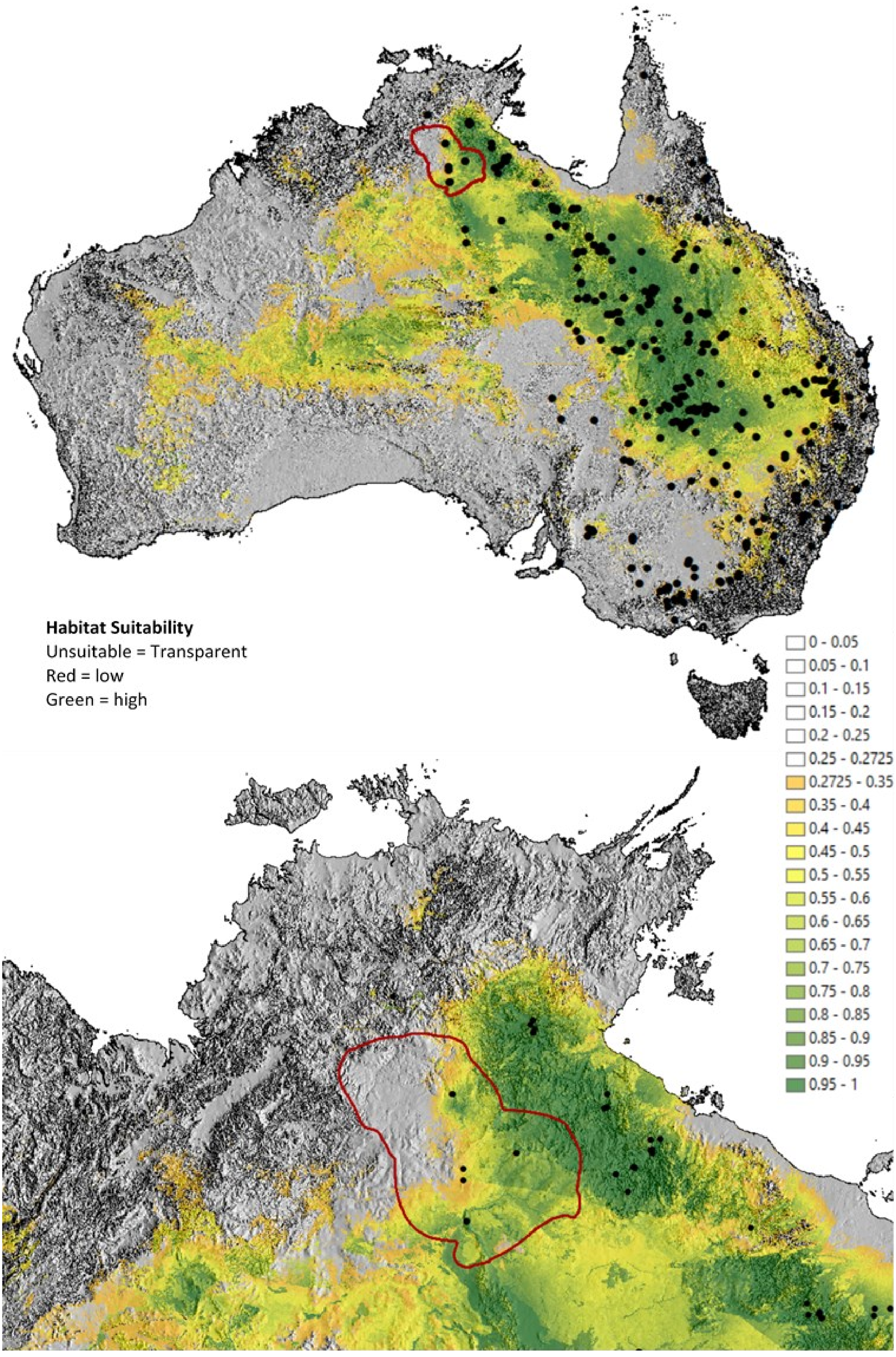



Figure 2.2. Thresholded habitat suitability for *Grantiella picta*.

## 2.4. References

de Barros Ferraz, K.M.P.M., de Siqueira, M.F., Alexandrino, E.R., Da Luz, D.T.A., Do Couto, H.T.Z., 2012. Environmental suitability of a highly fragmented and heterogeneous landscape for forest bird species in south-eastern Brazil. *Environmental Conservation* 39, 316–324.

Elith, J., Phillips, S.J., Hastie, T., Dudík, M., Chee, Y.E., Yates, C.J., 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* 17, 43–57.

Jorge, M.L.S., Galetti, M., Ribeiro, M.C., Ferraz, K.M.P., 2013. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. *Biological Conservation* 163, 49–57.

Phillips, S.J., 2005. *A brief tutorial on Maxent*. AT&T Research.

Phillips, S.J., Anderson, R.P., Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190, 231–259.

Phillips, S.J., Dudík, M., 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31, 161–175.

Pintor, A., Graham, E., Kennard, M., VanDerWal, J., 2018. *Expert vetted distribution models and biodiversity hotspot maps of terrestrial and freshwater taxa of conservation concern in northern Australia*. James Cook University, Griffith University, and Australian Government National Environmental Science Program (NESP), Northern Australia Environmental Resources Hub. dx.doi.org/10.4225/28/5a9f31e23e80b.

Vale, C.G., Tarroso, P., Brito, J.C., 2014. Predicting species distribution at range margins: testing the effects of study area extent, resolution and threshold selection in the Sahara–Sahel transition zone. *Diversity and Distributions* 20, 20–33.

Wilford, J., 2012. A weathering intensity index for the Australian continent using airborne gamma-ray spectrometry and digital terrain analysis. *Geoderma* 183, 124–142.

# Chapter 3. Aquatic Biodiversity

## 3.1. Surface Waters

### 3.1.1. Introduction

The aim of this study was to provide baseline data on the biodiversity of the aquatic systems within the GBA Beetaloo Extended Survey Area (BESA), NT. This region, as defined by the Huddlestone-Holmes *et al*. (2020) *Geological and Bioregional Assessment Stage 2* report, includes both the Beetaloo Sub-basin and the area immediately beyond this (the BESA) where potential environmental and hydrological impacts associated with the emerging shale gas industry, may occur (Figure 3.1). The Pepper inquiry (Pepper *et al.* 2018) into hydraulic fracturing activities in the petroleum industry in the NT emphasised that there was a 'major lack of detailed knowledge of the aquatic ecology and biodiversity of surface and groundwater systems, particularly in the semi-arid and arid regions' of the NT. This study sought to obtain baseline information on the aquatic biodiversity of the BESA and to support the development of further surveys to be undertaken as part of the SREBA.

The BESA extends across a N-S climatic gradient from the tropics in the north to semi-arid conditions in the south. The region has a distinct Wet Season (when most of the rain falls) from November to March and a Dry Season, from April to October, with hot summers and warm winters. Interannual variability in rainfall in this region is high and increases with latitude. The Wet Seasons that preceded this project, in 2018 and 2019, were both considered to be poor, i.e. below average rainfall totals were recorded and stream networks within the BESA are ephemeral, and only hold water and flow in response to Wet Season rains. The exceptions are the perennial systems on the northern edge of the BESA, including the Roper River and the Mataranka Thermal Pools, because baseflows in these systems are provided by groundwater.

The major objective of GBA aquatic biodiversity survey program was to sample the range of aquatic ecosystems present, and the aquatic vertebrates (fishes and turtles) and aquatic invertebrates they support, across the BESA. Aquatic Ecological Protected Matters (EPMs) that occurred within the BESA were specifically targeted for sampling. These included the two Directory of Important Wetlands (DIWA) -listed sites: the Mataranka Thermal Pools and Lake Woods; and two EPM species, the Gulf snapping turtle, *Elseya lavarackorum/oneiros* (the EPBC-listed species is *Elseya lavarackorum* but the extant species has been recently revised to *Elseya oneiros*: https://apps.des.qld.gov.au/species-search/details/?id=18453) and the freshwater sawfish, *Pristis pristis*.

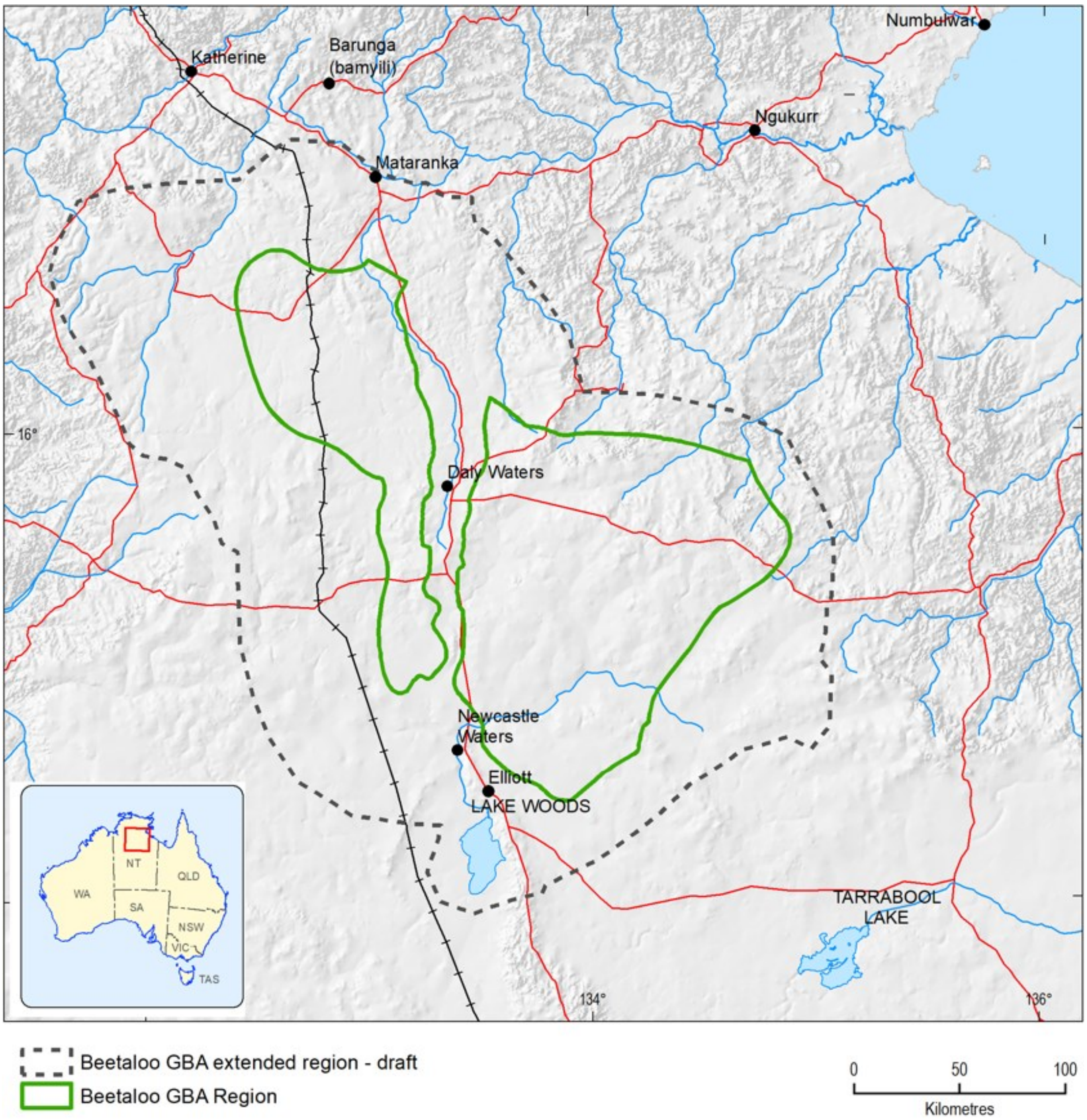



Figure 3.1. The Beetaloo GBA region and the extended region (BESA) as defined by Huddlestone-Holmes *et al*. (2020).

### 3.1.2. Methods

Previous sampling in the region has been ad hoc and Atlas of Living Australia (ALA) records indicate the presence of 237 aquatic species (6% of the total ALA species count for the region) not including algae, aquatic angiosperms, amphibians and waterbirds, as they were outside the scope of this survey (ALA 2020). Given the lack of prior knowledge of surface water systems, and their biodiversity, within the BESA, and the prevailing dry conditions in 2019, the first challenge was to locate sampling sites containing water across the north-south and east-west BESA gradients. Potential aquatic sampling sites were chosen on the basis of the information provided by remotely sensed datasets acquired as part of the Environmental Mapping program (see associated chapter). These included: i) the DD7 Water Body Count based on Landsat 5 and 7 imagery from 1987–2014; (ii) Water Observations from Space based on Landsat 5 and 7 imagery from 1987–2012; and (iii) Maximum Extent Water Bodies based on Landsat 5 and 8 imagery acquired from 1987–2018.

The list of surface water sites sampled are provided in Table 3.1. The COVID-19 pandemic resulted in travel restrictions to remote communities within the Northern Territory, and more generally across NT regions, from March to May 2020. As a result of these travel restrictions, fieldwork was delayed by three months. Following the lifting of travel restrictions within the NT, sampling of waterbodies in the southern part of the BESA was undertaken in June 2020 and sampling of waterbodies in the northern BESA was undertaken in August 2020. Many watercourses and waterbodies initially targeted for sampling were found to be dry, following two consecutive poor Wet Seasons. The 14 waterbodies that contained sufficient water for sampling included at least one of each of the major wetland classification types found in the region (except the non-floodplain palustrine category), providing a good representation of dry season aquatic refuges across the north-south climatic gradient of the BESA (Table 3.1). Further sampling was undertaken following a higher rainfall Wet Season in 2021. Previously dry waterbodies in the southern BESA filled and these were sampled as soon as access roads became passable in March 2021. All sites were only sampled once, with the exception of Clint's Gorge, in the northern BESA, and Longreach Waterhole, in the southern BESA, which were sampled in both 2020 and 2021 to provide some preliminary observations on interannual variability. The Roper River 12 mile site was sampled only for turtles in both 2020 and 2021, full sampling of the site only occurred in 2020.

Fishes, turtles and aquatic macroinvertebrates were sampled according to the standard sampling techniques provided in Appendix 9. The extent to which waterbodies had dried in 2020 meant that the probability of catching fish, in particular, was likely to be low. For this reason, an additional sampling method, that of environmental DNA (eDNA) was used. Fish constantly shed DNA into their environment. Accordingly, this method was used to provide a means of detecting species that had been present at the sampling site prior to the field sampling activity, but not detected by physical capture methods (such as netting and electrofishing) that were restricted to the day of sampling. Water was filtered and processed according to the protocol described for eDNA detection in Appendix 9.

The water quality variables measured at each waterbody included: Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), NOx (Nitrate/Nitrite), TN (Total Nitrogen), TKN (Total Kjeldahl Nitrogen), TP (Total Phosphorus) and chlorophyll *a*. Isotopic analysis was undertaken on water samples collected from the 2020 sampling sites to determine groundwater vs surface water dominance at likely drought refuges. Isotopic tracers in water, deuterium, $^{2}H/^{1}H$ (δ2H), and oxygen, $^{18}O/^{16}O$ ratios (δ18O), provide a robust and affordable method to obtain information on the relative contributions that groundwaters and surface waters make to waterbodies.

### 3.1.3. Results

Field reconnaissance resulted in the location of 21 surface waterbodies in the BESA that contained sufficient water for sampling in June and August 2020, and March and April 2021 (Figure 3.2). These sites included one waterbody within the Daly River catchment, 11 within the Roper River catchment, one within the Limmen Bight River catchment, and nine within the Victoria River-Wiso catchment. Flowing water was only present at northern sites in 2020: at three sites on the Roper River (Bitter Springs, Roper River – 12 Mile, Salt Creek) and one on the Cox River (Clint's Gorge). All other sites were standing (lentic) waterbodies located within dry river networks, and one (Dingo Hole Dam) was the last remaining waterhole on an ephemeral lake. Flowing water was present in Newcastle Creek (in the southern BESA) in March 2021 and four sites on the creek were sampled at this time. The dates of sampling are provided in Table 3.1. Photographs of each site, examples of the sampling methods used, and images of some of the species present, are provided in Appendix 10–11.

Table 3.1. Surface waterbodies sampled in the BESA in 2020 and 2021. Sites are listed to indicate the N-S gradient.

| Colour code: | Sites sampled in: | 2020 | 2021 | 2020, 2021 |
|---|---|---|---|---|

| Name of Station/Tenure | Name of Waterbody | Site Code | Date of visit | River/stream system | Drainage Basin | Coordinates | Wetland Classification |
|---|---|---|---|---|---|---|---|
| Manbulloo | King River waterhole | KRW | 19/08/2020 | King River | Daly | -14.83053 132.2497 | R |
| Mangarrayi Aboriginal Trust | Red Lily Lagoon | RLL | 24/08/2020 | Roper River | Roper | -14.90842 133.4392 | R |
| Elsey National Park | Bitter Springs | BS | 25/08/2020 | Roper Creek | Roper | -14.90955 133.08773 | S |
| Elsey National Park | Roper River 12 Mile | RR121,2 | 22/08/2020, 20/04/2021 | Roper River | Roper | -14.95148 133.21975 | R |
| Elsey National Park | Salt Creek Mataranka Falls | SCMF | 20/08/2020 | Salt Creek | Roper | -14.95805 133.25197 | R |
| Mangarrayi Aboriginal Trust | Warlock Ponds | WP | 21/04/2021 | Elsey Creek | Roper | -15.0856 133.12376 | R |
| Lakefield | Dingo Hole Dam | DHD | 21/08/2020 | Elsey Creek | Roper | -15.25612 132.89656 | I |
| Vermelha | Paddy Lagoon | PLV | 23/08/2020 | Strangways River | Roper | -15.3506 133.65454 | R |
| Tanumbirini | Ambullya waterhole | ABW | 30/06/2020 | Arnold River | Roper | -16.019667 134.4924 | R |
| Tanumbirini | Clint's Gorge | CGW1,2 | 1/07/2020, 22/04/2021 | Cox River | Limmen Bight | -16.01443 134.67061 | R |
| Kalala | Stuart's Swamp | SSW | 2/07/2020 | Birdum Creek | Roper | -16.219967 133.385633 | R |
| Amungee Mungee | Amungee Mungee | AMW | 28/06/2020 | Arnold River | Roper | -16.368767 134.323317 | R |
| Hayfield | Barmaranga waterhole | SHW | 29/06/2020 | Newcastle Creek | Victoria River -Wiso | -16.62455 133.616683 | FP |
| Hayfield | Milner's Lagoon | HML | 18/03/2021 | Newcastle Creek | Victoria River -Wiso | -16.680861 133.407917 | F |
| Hayfield | Johnston Lagoon | HJL | 17/03/2021 | Newcastle Creek | Victoria River -Wiso | -16.843444 133.414222 | F |
| Hayfield | Frew Pond | HFP | 17/03/2021 | Newcastle Creek | Victoria River -Wiso | -16.926778 133.364389 | F |
| Beetaloo | Beetaloo homestead lake | BSW | 27/06/2020 | Newcastle Creek | Victoria River -Wiso | -17.21195 133.799383 | R |
| Newcastle Waters | Newcastle Creek SH crossing | NWX | 16/03/2021 | Newcastle Creek | Victoria River -Wiso | -17.25964 133.455528 | R |
| Newcastle Waters | Newcastle Creek | NWW | 16/03/2021 | Newcastle Creek | Victoria River -Wiso | -17.38 133.413017 | R |
| Newcastle Waters | Longreach waterhole | LRW1,2 | 26/06/2020, 15/03/2021 | Newcastle Creek | Victoria River -Wiso | -17.61643 133.47391 | R |
| Newcastle Waters | Lake Woods channel | LWC | 14/03/2021 | Newcastle Creek | Victoria River -Wiso | -17.67075 133.539056 | FP |

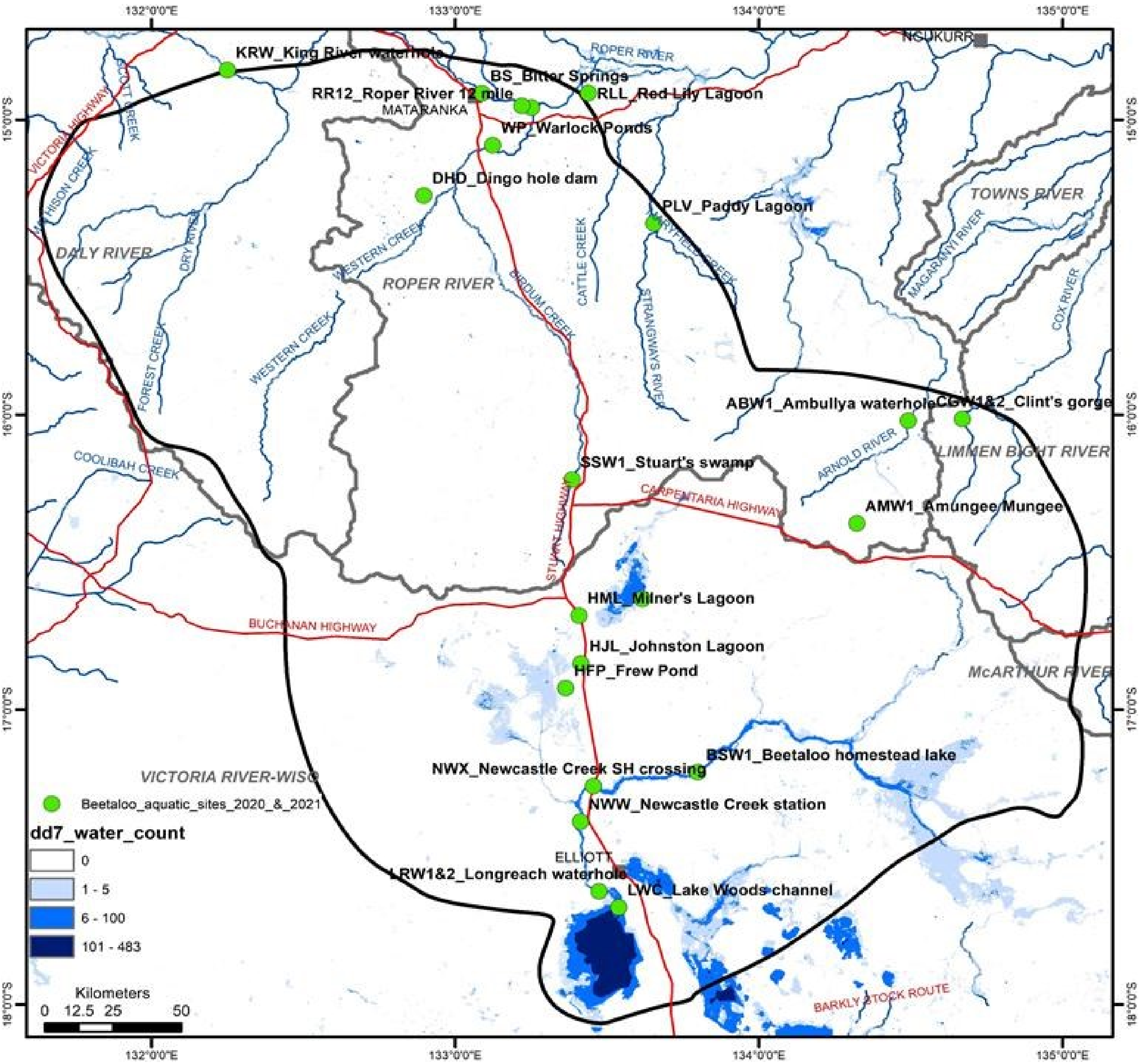



Figure 3.2. Locations of surface water sampling sites sampled in 2020 and 2021, across the BESA. The base map is from the DD7 Water Body Count based on Landsat 5 and 7 imagery from 1987–2014.

#### *3.1.3.1. Water Quality*

##### *3.1.3.1.1. Conductivity (EC)*

All sites contained freshwater (based on the criterion of EC<1.5 mS/cm) with the exception of the aptly named Salt Creek (EC=3.56 mS/cm). The freshest sites were the Beetaloo Homestead Lake and Barmaranga waterhole (Figure 3.3). These sites were almost dry at the time of sampling but were likely receiving some groundwater input. It was raining at the time of sampling at Milner's Lagoon, so the low EC was probably the result of both that event and recent rain in the region.

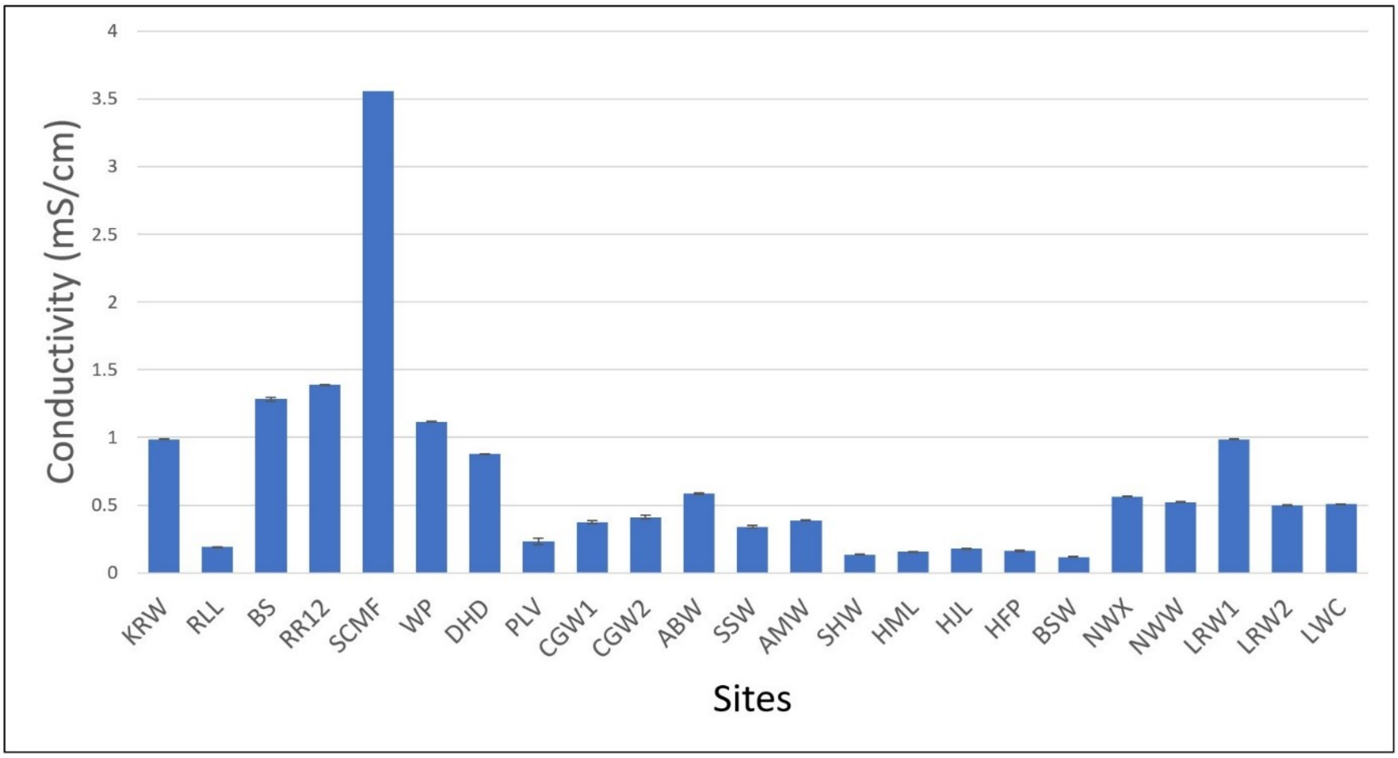



Figure 3.3. Conductivities (EC) recorded at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.

##### *3.1.3.1.2. pH*

All sites were close to circumneutral (pH=7) or alkaline (Figure 3.4). The elevated pH's recorded at Paddy's Lagoon, Johnston's Lagoon and Stuart Swamp were likely the result of high photosynthetic activity resulting from the extensive beds of aquatic macrophytes present in these waterbodies. The dense algal bloom present in Barmaranga waterhole was also probably contributing to the elevated pH at this site.

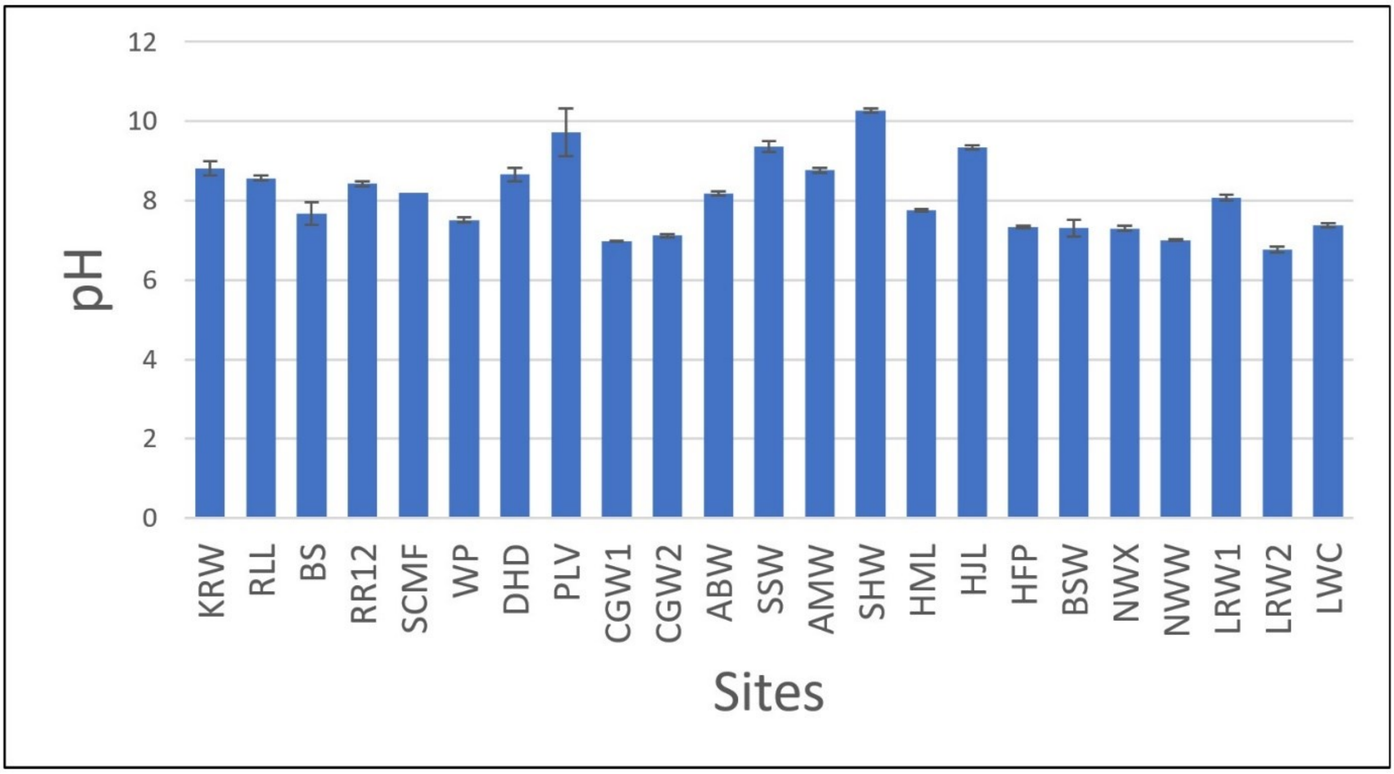



Figure 3.4. pH recorded at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.

#### *3.1.3.1.3. Dissolved Oxygen (DO)*

The very low dissolved oxygen (DO) concentrations recorded at Bitter Springs are indicative of the low DO groundwater discharging at this site (Figure 3.5). Much higher DO concentrations were recorded at sites with the greatest photosynthetic activity, due to the presence of phytoplankton blooms or dense beds of aquatic macrophytes. Note that repeated measurements of DO should be made over a 24 hour period as large diurnal changes can occur, particularly where photosynthetic activity is high. Although diurnal sampling of DO was not feasible in this study, the spot results still provide valuable information with respect to conditions present on the day of sampling.

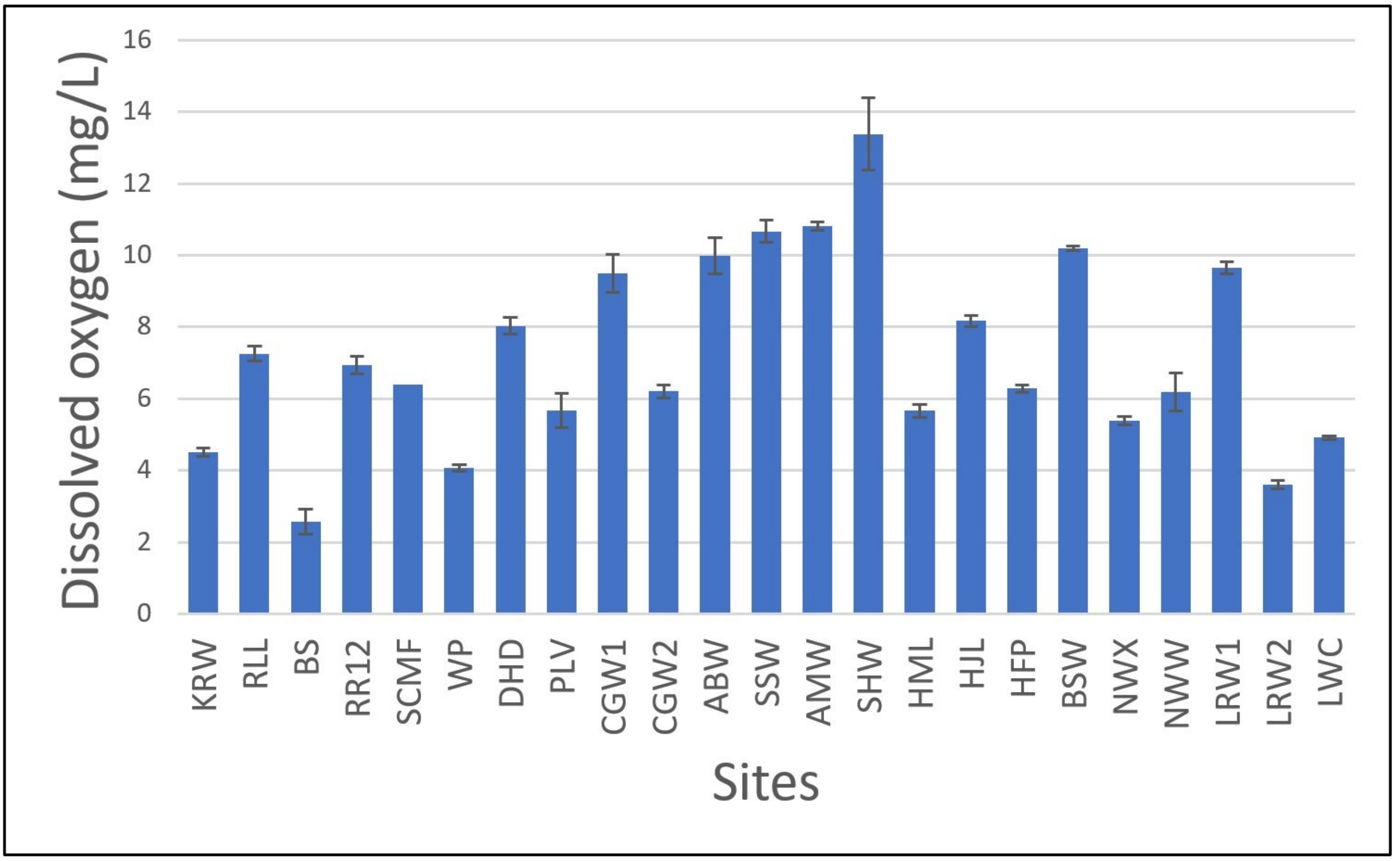



Figure 3.5. Dissolved oxygen concentrations (DO) recorded at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.

#### *3.1.3.1.4. Turbidity and algal biomass*

High to extremely high turbidities (>50NTU) were recorded at sites in the southern BESA (Figure 3.6). Sites on Newcastle Creek were highly turbid due to the suspension of fine particles from the clay-dominated sediments following Wet Season flows. High turbidities at other sites, such as Barmaranga waterhole, Amungee waterhole and Frew Pond were created by the dense algal blooms present at these sites, as indicated by the high concentrations of phytoplankton (>30µg/L chla) recorded (Figure 3.7b). The sites in the northern BESA tended to contain clear water and at Longreach waterhole, where we have a value for the dry and wet season, we see the typical trend in the region with lower turbidity in the dry compared to wet season. Accordingly, phytoplankton concentrations were low, but periphyton concentrations were high (periphyton > 15µg/L) (Figure 3.7a).

#### *3.1.3.1.5. Nutrients and algal biomass*

Overall, nutrient concentrations at all sites were low, however, in some cases this may be because nutrients have been incorporated into aquatic plant biomass (Appendix 12). The sites with the highest nutrient concentrations were Barmaranga waterhole, Johnston Lagoon, Milner's Lagoon and Frew Pond. Sites with the greatest periphyton biomass included Stuart's Swamp, Paddy's Lagoon and Bitter Springs which differed from those with the greatest phytoplankton biomass (e.g., Barmaranga waterhole, Clint's Gorge and Frew Pond; Figure 3.7 a, b). An isolated, almost dry pool at Barmaranga contained a cyanobacterial bloom.

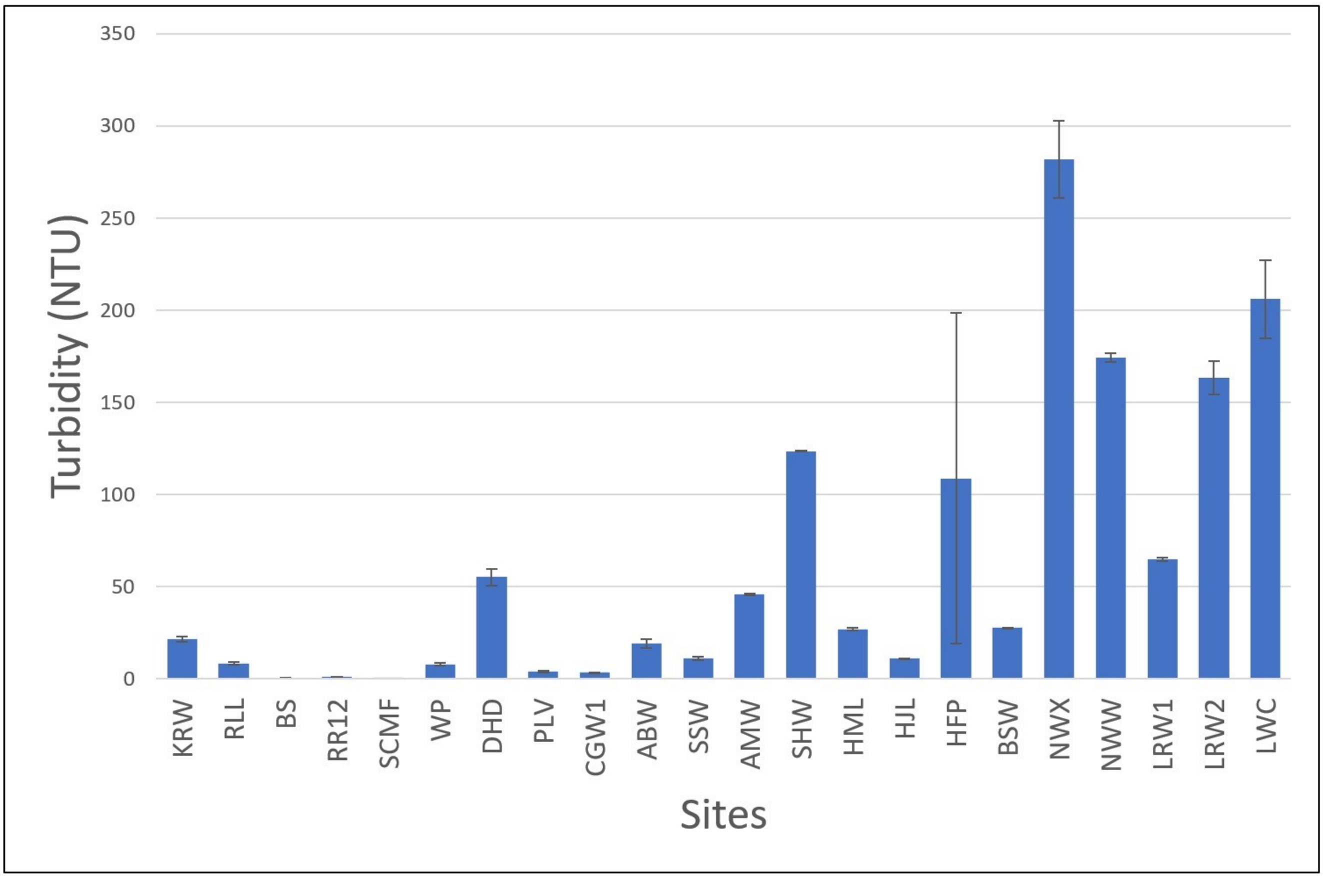



Figure 3.6. Turbidities (NTU) recorded at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.


Figure 3.7a. Periphyton concentrations at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.

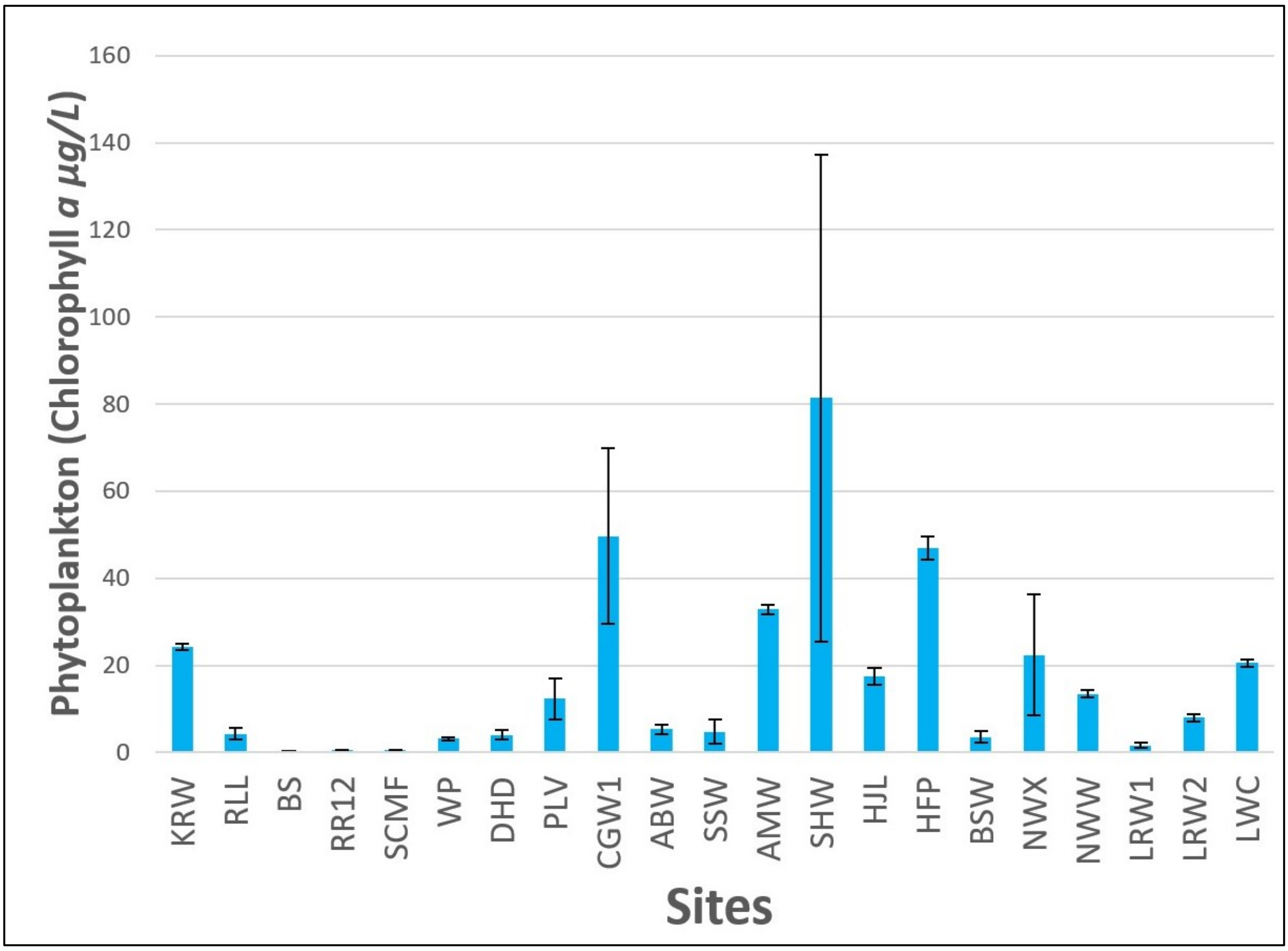
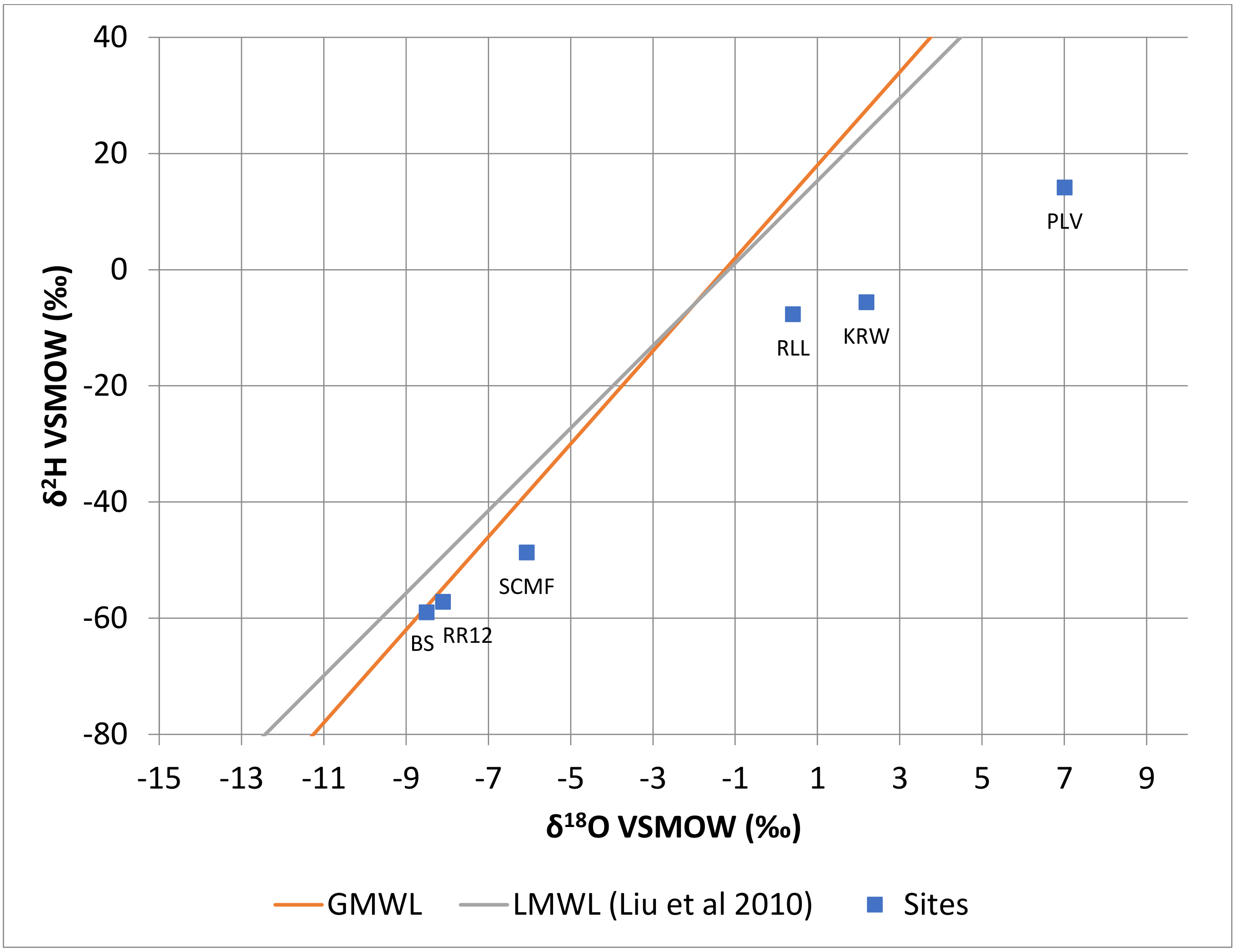



Figure 3.7b. Phytoplankton concentrations at BESA waterbodies at the time of sampling in 2020 and 2021. See Table 3.1 for explanation of site codes, site coordinates and sampling dates.

#### *3.1.3.1.6. Isotope Analysis*

Comparison of the $\delta^2$H vs. $\delta^{18}$O values (blue squares) in BESA waterholes sampled in 2020 (Figure 3.8) with the LMWL (Local Meteoric Water line) and the GMWL (Global Meteoric Water line) (Liu *et al.* 2010) indicate the sites most likely to be groundwater-dominated. These are the sites closest to the lines. Sites diverging from the lines are those most affected by evaporative loss during dry periods, indicating a reliance on rainfall, rather than groundwater. This analysis confirmed that Bitter Springs and the Roper River – 12 Mile sites are primarily supported by groundwater inputs. The Salt Creek (at Mataranka Falls) site is also largely dependent on groundwater. In contrast, the other sites sampled, particularly Paddy's Lagoon, are more affected by evaporative processes, indicating a greater dependence on rainfall as the major source of their water.




| Site Code, Sampling Date, Site Name and Coordinates | $\delta^{18}O$ VSMOW (‰) | $\delta^{2}H$ VSMOW (‰) |
|---|---|---|
| KRW, 19/08/20, Manbulloo King R -14.83053, 132.24970 | 2.19 | -5.61 |
| SCMF, 20/08/20, Salt Ck Mataranka Falls -14.95805, 133.25197 | -6.07 | -48.69 |
| RR12, 22/08/20, Roper River 12 Mile -14.95167, 133.21989 | -8.10 | -57.15 |
| PLV, 23/08/20, Paddy's Lagoon, Vermalho Station -15.35060, 133.65454 | 7.01 | 14.17 |
| RLL, 24/08/20, Red Lily Lagoon RR Floodplain -14.90842, 133.43920 | 0.40 | -7.65 |
| BS, 25/08/20, Bitter Springs -14.90955, 133.08773 | -8.50 | -58.96 |

Figure 3.8. Blue squares indicate the $\delta^{2}H$ vs. $\delta^{18}O$ values in BESA waterholes sampled in 2020. The LMWL (Local Meteoric Water Line) and the GMWL (Global Meteoric Water Line) (Liu *et al.* 2010) are provided for comparison. The sites most likely to be groundwater dominated lie close to the lines. Sites diverging from the lines are those most affected by evaporative loss during dry periods, indicating a reliance on rainfall, rather than groundwater.

### 3.1.4. Biota

#### *3.1.4.1. Turtles and other reptiles*

Five species of freshwater turtles were recorded in the BESA (Table 3.2). Worrell's turtle, *Emydura subglobosa worrelli*, was the most common species. A total of thirty animals were recorded from eight sites. Both Cann's turtle, *Chelodina canni*, (15 animals recorded from seven sites) and the northern snapping turtle, *Elseya dentata* (16 animals recorded from five sites) were reasonably common. Five Gulf snapping turtles, *Elseya lavarackorum/oneiros* (note that the EPBC-listed species is *Elseya lavarackorum* but the extant species has been recently revised to be *Elseya oneiros*: https://apps.des.qld.gov.au/species-search/details/?id=18453) were recorded from only one site (Roper River – 12 Mile). It is possible that this species was also present at Ambullya Waterhole and Clint's Gorge. However, confirmation of the occurrence of this species is dependant on the results of the genetic analysis that is currently underway. Only two northern long-necked turtles, *Chelodina rugosa*, were recorded, from two sites.

Molecular analysis is currently underway based on tissue samples collected from the BESA turtles, and a wider NT collection, to clarify species determinations and phylogenetic relationships. The specific aim is to clarify the taxonomic status of the Gulf snapping turtle, *Elseya lavarackorum/oneiros*.

Freshwater crocodiles were observed at sites in the northern BESA in the Roper (3) and Limmen Bight (1) catchments. The olive python was observed at sites in the Roper (1) and Victoria River-Wiso (2) catchments.

#### *3.1.4.2. Fishes*

Thirty species of fish, in 17 families, were recorded at BESA waterbodies (Table 3.3). Species richness was highest at sites in the northern-draining rivers, while the highest abundances occurred in both the northern and southern-draining rivers. The most abundant species recorded, the Northwest glassfish, *Ambassis* sp., was in the Beetaloo homestead waterhole, on Newcastle Creek, in the south-draining Victoria River-Wiso catchment. At the time of sampling (July 2020) this waterbody was very shallow and the presence of many fish-eating waterbirds indicated that large numbers of fish had probably been present at an earlier stage of drying.

The results of the eDNA analyses from waterbodies sampled in 2020 indicated the presence of species that were not collected by the live sampling methods used at site visits (Appendix 13). The most species-rich site was the flowing system, Roper River – 12 Mile (Table 3.4). Comparison of the results of this study with the 40 species recorded in ALA (2020) indicates that further species are likely to be recorded with repeated site visits, particularly in the early to mid-Dry Season.

The presence of the freshwater sawfish, *Pristis pristis*, an EPBC-listed species, was recorded by the Mangarrayi Rangers group at a drying pool near Red Lily Lagoon in April 2021.

Table 3.2. Turtles and other reptiles recorded at BESA surface water sites in 2020 and 2021. * indicates those sampled for DNA and D = specimens that were found dead.

| **Part 1** | **Catchment** | **Daly** | **Roper** | **Roper** | **Roper** | **Roper** | **Roper** | **Roper** | **Roper** | **Roper** | **Limmen** | **Limmen** | **Roper** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Site Code** | KRW | RLL | BS | RR12 | RR12-2 | SCMF | WP | DHD | PLV | CGW1 | CGW2 | ABW |
| | **Date** | 19/08/20 | 24/08/20 | 25/08/20 | 22/08/20 | 20/04/21 | 20/08/20 | 21/04/21 | 21/08/20 | 23/08/20 | 1/07/20 | 22/04/21 | 30/06/20 |
| **Species** | **Common name** | | | | | | | | | | | | |
| ***Emydura subglobosa worrelli*** | **Worrell's turtle** | 0 | 1D * | 5* | 2* | 8 (5*) | 0 | 1* | 0 | 0 | 0 | 0 | 8 |
| ***Elseya dentata*** | **Northern snapping turtle** | 0 | 0 | 0 | 4* | 4* | 0 | 0 | 0 | 0 | 2 | 5* | 1D * |
| ***Elseya lavarackorum*** | **Gulf snapping turtle** | 0 | 0 | 0 | 4* | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Chelodina canni*** | **Cann's turtle** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1D * | 1D * | 0 | 0 | 0 |
| ***Chelodina rugosa*** | **Northern long-necked turtle** | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 1 | 0 | 0 |
| ***Crocodylus johnstoni*** | **Freshwater crocodile** | 0 | + | 0 | + | + | 0 | 0 | 0 | 0 | 0 | 0 | + |
| ***Liasis olivaceus*** | **Olive Python** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| **Part 2** | Catchment | Roper | Roper | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso | VR Wiso |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Site Code** | SSW | AMW | SHW | HML | HJL | HFP | BSW | NWX | NWW | LRW1 | LRW2 | LWC |
| | **Date** | 2/07/20 | 28/06/20 | 29/06/20 | 18/03/21 | 17/03/21 | 17/03/21 | 27/06/20 | 16/03/21 | 16/03/21 | 26/06/20 | 15/03/21 | 14/03/21 |
| **Species** | **Common name** | | | | | | | | | | | | |
| ***Emydura subglobosa worrelli*** | **Worrell's turtle** | | | | | | | | | | | | |
| ***Elseya dentata*** | **Northern snapping turtle** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2* | 0 |
| ***Elseya lavarackorum*** | **Gulf snapping turtle** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Chelodina canni*** | **Cann's turtle** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Chelodina rugosa*** | **Northern long-necked turtle** | 1 | 2 | 1* | 3* | 6 (5*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Crocodylus johnstoni*** | **Freshwater crocodile** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Liasis olivaceus*** | **Olive Python** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 3.3. List of fishes recorded at BESA surface water sites in 2020 (dry year) and 2021 (wet year). Historic records include those accessed in ALA (2020), Allen *et al*. (2002) and records held by Dion Wedd (pers comm).

| **Codes:** | + Observed Presence or eDNA | *obs by Mangarrayi Rangers | dry year | wet year | historic record |
|---|---|---|---|---|---|

| **Part 1** | | **Catchment** | **D** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **L** | **L** | **R** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Site Code** | **KRW** | **RLL** | **BS** | **RR12** | **SCMF** | **WP** | **DHD** | **PLV** | **CGW1** | **CGW2** | **ABW** |
| **Family** | **Species** | **Common name** | | | | | | | | | | | |
| Ariidae | *Neoarius bernyi/graeffei* | Berny's Catfish | | | | 4 | | | | | | 4 | |
| Ariidae | *Neoarius midgleyi* | Midgley's catfish | | 4 | | | | | | | | | |
| Ambassidae | *Ambassis elongatus* | Yellow Fin Glassfish | | | 0 | 0 | | 25 | | | 0 | 0 | |
| Ambassidae | *Ambassis macleayi* | Macleay's Glassfish | 0 | 0 | 0 | 3 | | 6 | | | 0 | 4 | |
| Ambassidae | *Ambassis* sp | Northwest Glassfish | + | 2 | 0 | + | + | 1 | | | 0 | 0 | + |
| Ambassidae | *Parambassis gulliveri* | Giant Glassfish | | | | | | | | | | 8 | |
| Apogonidae | *Glossamia aprion* | Mouth almighty* | + | 6 | + | 3 | 2 | 14 | | | + | 1 | 5 |
| Atherinidae | *Craterocephalus stercusmuscarum* | Fly-specked hardyhead | | 5 | 0 | 10 | + | 10 | | + | + | 0 | + |
| Belonidae | *Strongylura krefftii* | Freshwater longtom | | 0 | 0 | 15 | 10 | 1 | | | 0 | 2 | 0 |
| Clupeidae | *Nematalosa erebi* | Bony bream | + | + | 0 | 100 | 15 | 0 | | | + | 13 | 50 |
| Latidae | *Lates calcarifer* | Barramundi | | 0 | 0 | + | + | + | | | 0 | 0 | 0 |
| Eleotridae | *Mogurnda mogurnda* | Northern purplespotted gudgeon | | 2 | + | 5 | 0 | 0 | | | 100 | 3 | + |
| Eleotridae | *Oxyeleotris lineolata* | Sleepy cod | + | 0 | 0 | 1 | 0 | 1 | | | + | 0 | 1 |
| Eleotridae | *Oxyeleotris selheimi* | Giant gudgeon | + | 17 | 0 | 0 | 0 | 11 | | | + | 0 | 8 |
| Gobiidae | *Glossogobius aureus* | Golden goby/flathead goby | | 0 | 0 | 0 | + | 0 | | | + | 1 | |
| Megalopidae | *Megalops cyprinoides* | Tarpon/Ox-eye herring | | | | 12 | 10 | | | | | | |
| Melanotaeniidae | *Melanotaenia australis* | Western rainbowfish | + | + | 0 | + | | | | | | | |
| Melanotaeniidae | *Melanotaenia splendida* | Eastern/Desert/Chequered rainbowfish | | 9 | 8 | + | 100 | 162 | | + | 3 | 2 | 7 |

| **Part 1** | | **Catchment** | **D** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **L** | **L** | **R** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Site Code** | **KRW** | **RLL** | **BS** | **RR12** | **SCMF** | **WP** | **DHD** | **PLV** | **CGW1** | **CGW2** | **ABW** |
| **Family** | **Species** | **Common name** | | | | | | | | | | | |
| Mugillidae | *Planiliza ordensis* | Mullet | | | | | 10 | | | | | | |
| Osteoglossidae | *Scleropages jardinii* | Northern saratoga | | 8 | 0 | 0 | 0 | 1 | | | | | |
| Plotosidae | *Neosilurus ater* | Black catfish | | 0 | 0 | 0 | 0 | 4 | | | | | |
| Plotosidae | *Neosilurus hyrtlii* | Hyrtl's catfish | + | 0 | 0 | + | + | 2 | | | + | 0 | 1 |
| Plotosidae | *Porochilus argenteus* | Silver catfish | | 0 | 0 | 0 | 0 | 0 | | | 0 | 1 | 0 |
| Plotosidae | *Porochilus rendahli* | Rendahl's catfish | | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 11 |
| Pristidae | *Pristis pristis* | Freshwater sawfish* | | + | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 |
| Terapontidae | *Amniataba percoides* | Barred grunter | | 0 | 0 | 20 | 10 | 4 | | | 0 | 0 | 1 |
| Terapontidae | *Hephaestus fuliginosus* | Sooty grunter | | 0 | 0 | 2 | 2 | 0 | | | 31 | 0 | 20 |
| Terapontidae | *Leiopotherapon unicolor* | Spangled perch | + | + | + | 15 | 2 | 82 | | + | 101 | 1 | 115 |
| Terapontidae | *Syncomystes butleri* | Butler's grunter | | | | | | | | | | | |
| Toxotidae | *Toxotes chatareus* | Seven-spot archerfish | + | 2 | | 20 | 10 | 37 | | + | + | + | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Richness** | **9** | **13** | **3** | **18** | **15** | **16** | **0** | **4** | **12** | **12** | **13** |
| **Total Abundance** | **0** | **51** | **8** | **206** | **171** | **361** | **0** | **0** | **235** | **36** | **219** |

| Codes: | + Observed Presence or eDNA | *obs by Mangarrayi Rangers | dry year | wet year | historic record |
|---|---|---|---|---|---|

**Part 2**

| | | Catchment<br>Site Code | R<br>SSW | R<br>AMW | VRW<br>SHW | VRW<br>HML | VRW<br>HJL | VRW<br>HFP | VRW<br>BSW | VRW<br>NWX | VRW<br>NWW | VRW<br>LRW1 | VRW<br>LRW2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Species** | **Common name** | | | | | | | | | | | |
| Ariidae | *Neoarius bernyi/graeffei* | Berny's Catfish | | | | | | | | | | | |
| Ariidae | *Neoarius midgleyi* | Midgley's catfish | | | | | | | | | | | |
| Ambassidae | *Ambassis elongatus* | Yellow Fin Glassfish | | | | | | | | | | | |
| Ambassidae | *Ambassis macleayi* | Macleay's Glassfish | | | | | | | | | | | |
| Ambassidae | *Ambassis* sp | Northwest Glassfish | | | | | | | | | | | |
| Ambassidae | *Parambassis gulliveri* | Giant Glassfish | 0 | 0 | + | | | | 350 | 11 | 12 | 241 | 7 |
| Apogonidae | *Glossamia aprion* | Mouth almighty* | | | | | | | | | | | |
| Atherinidae | *Craterocephalus stercusmuscarum* | Fly-specked hardyhead | 0 | + | + | | | | 0 | 0 | 0 | 0 | 0 |
| Belonidae | *Strongylura krefftii* | Freshwater longtom | + | 0 | + | | | | 0 | 0 | 0 | + | 0 |
| Clupeidae | *Nematalosa erebi* | Bony bream | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 |
| Latidae | *Lates calcarifer* | Barramundi | 0 | 3 | 0 | | | | + | 8 | 17 | 0 | 23 |
| Eleotridae | *Mogurnda mogurnda* | Northern purplespotted gudgeon | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 |
| Eleotridae | *Oxyeleotris lineolata* | Sleepy cod | + | 0 | 0 | | | | + | 0 | 0 | 0 | 0 |
| Eleotridae | *Oxyeleotris selheimi* | Giant gudgeon | | | | | | | | | | | |
| Gobiidae | *Glossogobius aureus* | Golden goby/flathead goby | | | | | | | | | | | |
| Megalopidae | *Megalops cyprinoides* | Tarpon/Ox-eye herring | | | | | | | | | | | |
| Melanotaeniidae | *Melanotaenia australis* | Western rainbowfish | | | | | | | | | | | |
| Melanotaeniidae | *Melanotaenia splendida* | Eastern/Desert/Chequered rainbowfish | | | | | | | | | | | |
| Mugillidae | *Planiliza ordensis* | Mullet | 60 | 3 | + | | | | + | 4 | 3 | + | 5 |
| Osteoglossidae | *Scleropages jardinii* | Northern saratoga | | | | | | | | | | | |
| Plotosidae | *Neosilurus ater* | Black catfish | | | | | | | | | | | |
| Plotosidae | *Neosilurus hyrtlii* | Hyrtl's catfish | | | | | | | | | | | |

**Part 2**

| Family | Species | Catchment / Site Code / Common name | R SSW | R AMW | VRW SHW | VRW HML | VRW HJL | VRW HFP | VRW BSW | VRW NWX | VRW NWW | VRW LRW1 | VRW LRW2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plotosidae | *Porochilus argenteus* | Silver catfish | 0 | 5 | 0 | | | | + | 0 | 2 | 0 | 0 |
| Plotosidae | *Porochilus rendahli* | Rendahl's catfish | 0 | 2 | 0 | | | | + | 1 | 7 | 0 | 2 |
| Pristidae | *Pristis pristis* | Freshwater sawfish* | 0 | | | | | | | | | | |
| Terapontidae | *Amniataba percoides* | Barred grunter | 0 | | | | | | | | | | |
| Terapontidae | *Hephaestus fuliginosus* | Sooty grunter | + | | | | | | | | | | |
| Terapontidae | *Leiopotherapon unicolor* | Spangled perch | 0 | | | | | | | | | | |
| Terapontidae | *Syncomystes butleri* | Butler's grunter | + | 76 | + | | | | 27 | 7 | 15 | 53 | 9 |
| Toxotidae | *Toxotes chatareus* | Seven-spot archerfish | | | | | | | | | | | |

| | SSW | AMW | SHW | HML | HJL | HFP | BSW | NWX | NWW | LRW1 | LRW2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Richness** | **5** | **6** | **5** | **0** | **0** | **0** | **7** | **5** | **6** | **4** | **5** |
| **Total Abundance** | **60** | **13** | | | | | **377** | **31** | **56** | **294** | **46** |

### *3.1.4.3. Aquatic Invertebrates*

The greatest number of species of aquatic invertebrates were recorded from flowing water sites in the northern BESA catchments (the Roper and Limmen Bight (Table 3.4). These were: 12 Mile on the Roper River, in Elsey National Park, and Clint's Gorge, on the Cox River, on Tanumbirini Station. Over 195 species from 87 families have been recorded to date, >20% of these are potentially new to science (verification is needed from taxonomic experts) and 40% were new records for the region (based on comparison with ALA (2020) records). These numbers will likely increase as further samples are processed and further sampling is undertaken as part of the SREBA. A total of six replicate invertebrate samples were collected at each site (except at HML which was not sampled). The results presented here are based on the processing of two samples per site. The Mollusca, Chironomidae, Trichoptera and Odonata have been verified by taxonomic experts and most of the molluscan samples have been lodged with the Museum and Art Gallery of the Northern Territory (MAGNT).

Table 3.4. Summary of species richness (number of species) of aquatic invertebrates recorded at BESA waterbodies in 2020 and 2021

**Part 1**

| ***Site Code*** | KRW | BS | RR12 | SCMF | WP | RLL | DHD | PLV | SSW | ABW | AMW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Catchment*** | D | R | R | R | R | R | R | R | R | R | R |
| ***Total species*** | 15 | 6 | 51 | 41 | 41 | 51 | 18 | 17 | 25 | 33 | 14 |

**Part 2**

| ***Site Code*** | CGW1 | SHW | HJL | HFP | BSW | NWX | NWW | LRW1 | LRW2 | LWC |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Catchment*** | L | VRW | VRW | VRW | VRW | VRW | VRW | VRW | VRW | VRW |
| ***Total species*** | 27 | 41 | 31 | 26 | 19 | 21 | 25 | 29 | 18 | 34 |

The most species-diverse groups of aquatic invertebrates recorded at BESA waterbodies were those that have an aerial life stage, i.e., those that can fly (Appendix 14). These included the Diptera (true flies), the Hemiptera (bugs), Coleoptera (beetles) and Odonata (dragonflies and damselflies). Hydrachnidia (water mites) were also speciose. Although they cannot fly, the larval stage is an external parasite on flying species (mainly Hemiptera), so is also aerially dispersed. Molluscs were represented by species that can remain dormant within dry sediments when waterbodies dry out. These included operculate snails and bivalves. The largest invertebrates (in terms of biomass) recorded were freshwater mussels, *Velesunio wilsonii* and atyid shrimps.

### 3.1.5. Groundwater Aquatic Biodiversity

A pilot survey of the aquatic biodiversity of groundwater systems in the BESA was undertaken by CSIRO and CDU researchers in 2019 and 2020. This was a separate study to the GBA program, funded by the Gas Industry Social and Environmental Research Alliance (GISERA). The aim was to characterise stygofaunal and microbial communities within the subterranean groundwater-dependent ecosystems of the BESA. The results of the study can be accessed at: https://gisera.csiro.au/project/characterisation-of-the-stygofauna-and-microbial-assemblages-of-the-beetaloo-sub-basin-nt/

### 3.1.6. Conclusions

The BESA contains a surface water fauna that is both rich, in terms of species numbers, and diverse, that is, it contains representatives of multiple trophic groups (aquatic invertebrates, fishes and turtles). The aquatic fauna is well adapted to surviving the seasonal and inter-annually variable aquatic conditions that prevail in the monsoonal and semi-arid climatic zones. However, the presence of perennial waterbodies within the BESA are critical for the persistence of turtles, fishes and some species of aquatic invertebrates. The fourteen waterbodies that contained water in 2020 under very dry conditions (after two low rainfall Wet Seasons) were important drought refuges. Further refuges may be found during the SREBA sampling program. The turtle and fish fauna are particularly dependent on the connectivity that occurs when the ephemeral river networks flow in response to Wet Season rains. Many of the species of surface water invertebrates in the BESA can fly between waterbodies or remain dormant within sediments until water returns. Overland flows and floods that occur following large monsoonal or cyclonic rain events are also important in providing aquatic dispersal pathways that aid in the recolonisation of waterbodies that may remain isolated for months or years during low rainfall periods.

## 3.2. References

Allen, G. R., Midgley, S. H., & Allen, M. (2002). Field guide to the freshwater fishes of Australia. Western Australian Museum.

Atlas of Living Australia occurrence download at https://doi.org/10.26197/5e61c1ccc93fb. Accessed 6 March 2020.

Huddlestone-Holmes CR, Frery E, Wilkes P, Bailey AHE, Bernadel G, Brandon C, Buchanan S, Cook SB, Crosbie RS, Evans T, Golding L, Gonzalez Dda, Gunning ME, Hall LS, Henderson B, Herr A, Holland K, Jarrett A, Kear J, Kirby J, Lech M, Lewis S, Macfarlane C, Martinez J, Northover S, Murray J, O'Grady A, Orr ML, Owens R, Pavey C, Post D, Sundaram B, Rachakonda P, Raiber M, Ransley T, Tetreault-Campbell S and Wang L (2020) Geological and environmental baseline assessment for the Beetaloo GBA region. Geological and Bioregional Assessment Program: Stage 2. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Liu, J., Fu, G., Song, X., Charles, S.P., Zhang, Y., Han, D. &Wang, S. (2010). Stable isotopic compositions in Australian precipitation. *Journal of Geophysical Research*, 115, 1–16.

Pepper R, Anderson A, Ashworth P, Beck V, Hart B, Jones D, Priestly B, Ritchie D and Smith R (2018) Final report of the scientific inquiry into hydraulic fracturing in the Northern Territory. https://frackinginquiry.nt.gov.au/inquiry-reports/final-report. Viewed 10 May 2021

# Chapter 4. Synthesis

## 4.1. Introduction

The aim of the Beetaloo GBA region Baseline Survey Program was to provide baseline data on the biodiversity of the GBA Beetaloo Extended Survey Area (BESA), NT. This region, as defined by the Huddlestone-Holmes *et al*. (2020) Geological and Bioregional Assessment Stage 2 report includes both the Beetaloo Sub-basin and the area immediately beyond this (the BESA) where potential environmental and hydrological impacts associated with the emerging shale gas industry may occur (Figure 4.1). The BESA extends across a north-south climatic gradient from tropical conditions in the north to semi-arid conditions in the south. The region has a distinct Wet Season (when most of the rain falls) from November to March and a Dry Season, from April to October, with hot summers and warm winters. Interannual variability in rainfall in this region is high and increases with latitude. The 2018 and 2019 Wet Seasons that preceded this baseline survey were both considered to be poor, i.e., below average rainfall totals were recorded. In a poor Wet Season, productivity will be lower; many species will be active for narrower periods of time, and the availability of reproductive material (upon which identification is often based) of annual plants will be lower. These factors indicate the importance of undertaking biodiversity surveys over multiple seasons, and multiple years, to ensure that seasonal and interannual variability is encompassed. This will be achieved by combining the results of the GBA program described here, with further surveys undertaken as part of the NT Government's Strategic Regional Environmental and Baseline Assessment (SREBA).

This program sought to obtain baseline data and support the development of further surveys to be undertaken as part of the SREBA. The program was delivered through the collaboration of researchers at Charles Darwin University (CDU), Griffith University (GU) and the NT Department of Environment, Parks and Water Security (DEPWS), formerly the Department of Environment and Natural Resources (DENR). The survey program was developed through discussions with the Commonwealth Department of Agriculture, Water and the Environment (DAWE) and NT DEPWS personnel to ensure that it informed the broader SREBA as required by the NT Government.

The program was undertaken as a series of themes specifically: Environmental Mapping; Terrestrial Biodiversity; Species Distribution Modelling of Ecological Protected Matters (EPM) species; and Aquatic Biodiversity. The main results of the program are described in the preceding chapters. This chapter provides a synthesis and summary of the program findings.

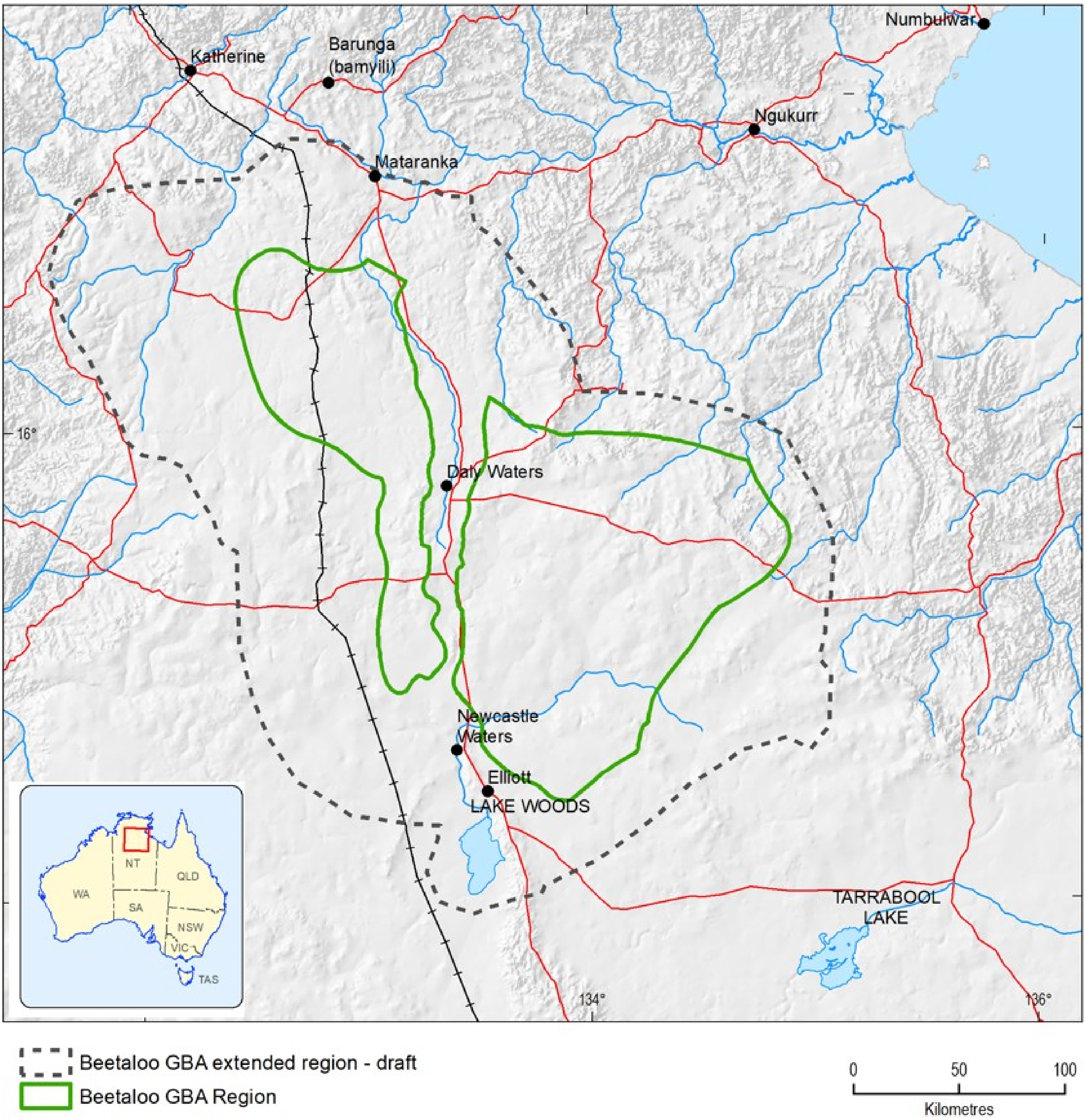



Figure 4.1. The Beetaloo GBA region and the extended region (BESA) as defined by Huddlestone-Holmes *et al*. (2020).

The survey program ran from 1 January 2020 to 30 June 2021. The COVID-19 pandemic resulted in travel restrictions to remote communities within the Northern Territory, and more generally across NT regions, from 27 March 2020. As a result of these travel restrictions, fieldwork was delayed by three months and some re-scoping of initial aims was undertaken.

## 4.2. Terrestrial Biodiversity

### 4.2.1. Environmental Mapping, Terrestrial Vegetation and Wetlands

The aims of this work were to produce:

1. A preliminary environmental base map of land zones and structural classes to inform the development of regional ecosystems and associated map products; and
2. A map of surface water features for the purpose of wetland and Groundwater Dependent Ecosystems (GDEs) mapping.

#### *4.2.1.1. Key Findings*

- Draft Regional Ecosystem mapping has been developed for the BESA at a scale of approximately 1:100,000, with some spatially restricted ecosystems mapped to a minimum polygon size of approximately one hectare (equivalent to 1:25,000 scale).
- The regional ecosystem typology is supported by a total of 9,180 vegetation sites compiled for the GBA study area from existing data and the 2020 field program.
- A total of 1,664 plant taxa (at all ranks) have been recorded from the BESA. Some records represent significant range extensions of taxa within the BESA or the NT.
- No plant species listed under a threatened category in the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), or the Territory Parks and Wildlife Conservation Act (TPWCA), have been recorded within the BESA to date. A total of 89 taxa regarded as Near Threatened or Data Deficient under the TPWCA have been recorded from the BESA. A total of 55 endemic taxa to the NT have been recorded from the BESA, none of which are currently of conservation significance.
- One hundred and one definitive vegetation types (DVTs) have been recognised as occurring within the BESA to date. These represent 151 preliminary Regional Ecosystems (REs) based on the best available current estimates of their distribution across land zones and bioregions within the study area.
- 17 DVTs are considered to be wetlands and likely to support aquatic Groundwater Dependent Ecosystems (GDEs). An additional 16 DVTs/REs are likely Groundwater Dependent Vegetation (GDV) types requiring some access to groundwater to meet their ecological requirements. Further mapping of these ecosystems is being undertaken as part of SREBA.
- Waterbody mapping used a number of data sources to produce a baseline map of wetlands within the study area, and these were assigned to wetland classes consistent with the Australian National Aquatic Ecosystem (ANAE) classification scheme.

### 4.2.2. Terrestrial Environmental Protected Matters

The aim of this program was to undertake field surveys to improve the knowledge base on the distribution and habitat associations of: the northern crested shrike-tit, *Falcunculus frontatus whitei*, the Gouldian finch, *Erythrura gouldiae*, the greater bilby, *Macrotis lagotis*, and the ghost bat, *Macroderma gigas*. Each of these species is listed as threatened nationally under the EPBC Act. Although it was not possible to undertake waterbird surveys within the timeframe of the program, existing published and unpublished data were collated, including data currently held in the NT Fauna Atlas and an additional seven sources.

#### *4.2.2.1. Key Findings*

- Gouldian finches were recorded at nine sites on Tanumbirini Station, seven sites on Kalala Station and two sites on Forrest Hill Station (at a range of formal survey sites (n = 4)), call-playback survey sites (n = 4) and incidental or reconnaissance site visits (n = 10). They were recorded in six BESA habitat types and at one location where the habitat has not yet been classified.
- Crested shrike-tits were recorded at one known site and two new sites on Manbulloo Station, and at two new sites on Forrest Hill Station. Crested shrike-tits were recorded in two BESA habitat types and at one site outside the mapped habitat extent.
- Bilby sign classified as active (evidence that the site was occupied at the time of survey) was recorded at ten locations during the aerial survey and sign that was classified as inactive (evidence that the site was not occupied at the time of the survey, but had been previously) was recorded at nine locations. Greater bilby sign was recorded in four BESA habitat types.
- Ghost bats were not surveyed within the BESA but additional data from the Katherine region were incorporated into revised environmental mapping for the species.
- Yellow-spotted monitors (an NT-listed threatened species) were recorded incidentally twice on Tanumbirini Station in one BESA habitat type.
- Published and unpublished data for waterbirds and migratory waterbirds for Lake Woods and Sturt Plateau wetlands have been synthesised from a range of sources. Lake Woods, is listed in the national Directory of Important Wetlands Australia (DIWA) and recognised as an Important Bird Area (IBA) by Birdlife International. Longreach Waterhole and the Roper River near Elsey National Park are recognised as important waterbird sites within the NT.
- Eighty-one species have been recorded within the BESA from 7,325 species level records. Two EPBC-listed threatened species, the Curlew Sandpiper, *Calidris ferruginea*, and the Australian Painted-snipe, *Rostratula australis*, have been recorded in the BESA. Fifteen species of migratory shorebird have been recorded in the BESA.
- Wetlands within the BESA are potentially very important for waterbirds and migratory species, but further surveys are needed to build upon the current patchy spatial and temporal datasets.

### 4.2.3. Terrestrial Fauna

The aim of this program was to interrogate existing data collated in the NT Fauna Atlas to create a preliminary list of faunal species for the BESA and a determination of their status under the TPWC Act (TPWC) and EPBC Act (EPBC).

#### *4.2.3.1. Key Findings*

- 494 terrestrial vertebrate species recorded in the NT Fauna Atlas occur in the BESA. This includes 125 bird species, 25 frog species, 61 mammal species and 129 reptile species.
- Seventeen vertebrate and one invertebrate species recorded in the BESA are listed as threatened under the TPWC Act and 15 vertebrate species are listed as threatened under the EPBC Act. Forty vertebrate species and two invertebrate species recorded in the BESA

are listed as data deficient or near threatened under the TPWC Act. Twenty-one species listed as migratory under the EPBC Act have been recorded in the BESA.

### 4.2.4. Invertebrates (Ants)

The aims of this program were to undertake preliminary ant surveys at 20 BESA sites; to use the CSIRO Darwin collection to assess broader distributional patterns of the species collected; and to use CO1 barcoding to help resolve species boundaries to inform assessments of biogeographical significance.

The CO1 results are not yet available and so are not reported on here. However, they will be made available on the GBA website when they become available.

#### *4.2.4.1. Key Findings*

- A total of 232 species from 27 genera were collected from 20 new survey sites located in Elsey National Park, Forrest Hill Station and Hayfield-Shenandoah Station
- Most of the species belong to taxonomically unresolved complexes, but 24 of the 76 assessable species are known only from the Beetaloo region, with 23 of these recorded for the first time during this survey

## 4.3. Modelled distributions of EPM species

The aim of this program was to use Maxent to develop distribution models for 26 species or subspecies recognised as Environmentally Protected Matters (EPM) species in the BESA, based on available occurrence records.

#### *4.3.1.1. Key Findings*

- Predicted habitat suitability and occurrence records have been developed for 26 species across Australia and within the BESA.
- The models have been refined after checking for any potential issues and determination of the level at which the distinction between a species presence or absence should be made.

## 4.4. Aquatic Biodiversity

### 4.4.1. Surface Waters

The aim of this program was to sample the range of aquatic ecosystems, and the aquatic vertebrates (fishes and turtles) and aquatic invertebrates they support, across the BESA. Aquatic Ecological Protected Matters (EPMs) that occurred within the BESA were specifically targeted for sampling. These included the two Directory of Important Wetlands (DIWA)-listed sites: the Mataranka Thermal Pools and Lake Woods; and two EPM species, the Gulf snapping turtle, *Elseya lavarackorum/oneiros* and the freshwater sawfish, *Pristis pristis.*

#### *4.4.1.1. Key Findings*

- A total of 21 surface waterbodies were sampled across the BESA in June and August 2020, and March and April 2021. Flowing water was only present at northern sites in 2020, three sites on the Roper River (Bitter Springs, Roper River – 12 Mile, Salt Creek) and one on the Cox River (Clint's Gorge). All other sites were standing (lentic) waterbodies located within dry river networks, and one (Dingo Hole Dam) was the last remaining waterhole on an ephemeral lake.
- The 14 waterbodies that contained sufficient water for sampling in 2020 (following two poor Wet Seasons) provided a good representation of dry season and drought refugia. Warloch Ponds, on Western Creek, a tributary of the Roper River, also acts as a drought refuge, but was not sampled until 2021.
- All sites contained freshwater (based on the criterion of EC less than 1.5 mS/cm) except Salt Creek at Mataranka Falls (EC of 3.56 mS/cm).
- Isotope analysis confirmed that Bitter Springs, the Roper River – 12 Mile site and Salt Creek (at Mataranka Falls) site are largely dependent on groundwater inputs and so are likely to contain permanent water through the most severe of droughts. The other sites sampled in 2020 were dependent on rainfall as the major source of their water.
- Five species of freshwater turtles were recorded in the BESA: Worrell's turtle, *Emydura subglobosa worrelli*, Cann's turtle, *Chelodina canni*, the northern snapping turtle, *Elseya dentata*, the Gulf snapping turtle, *Elseya lavarackorum/oneiros* (an EPBC-listed species) and northern long-necked turtles, *Chelodina rugosa.*
- Worrell's turtle, *E. subglobosa worrelli*, was the most common species, i.e., recorded in the highest numbers from the greatest number of sites.
- Molecular analysis is currently underway based on tissue samples collected from the BESA turtles, and a wider NT collection, to clarify species determinations and phylogenetic relationships. The specific aim is to clarify the taxonomic status of the Gulf snapping turtle.
- A total of 30 species of fish, in 17 families, were recorded from BESA waterbodies. Species richness was highest at sites in the northward-draining rivers. Additional species are likely to be recorded with repeated site visits, particularly in the early to mid-Dry Season.
- The presence of the freshwater sawfish, *Pristis pristis*, an EPBC-listed species, was recorded by the Mangarrayi Rangers at a drying pool in Red Lily Lagoon (on the NE border of the BESA) in April 2021.
- Over 195 species of aquatic invertebrates from 87 families have been recorded from the BESA to date. More than 20% of these are potentially new to science and 40% are new records for the region, based on comparison with Atlas of Living Australia (ALA) records.
- Aquatic invertebrate species richness was highest at perennial flowing water sites in the northern BESA. Species composition at all sites was dominated by strong-flying species of Coleoptera (beetles), Hemiptera (water bugs) and Odonata (dragonflies). The mobility of these species confers resilience, they can fly away from waterbodies when they dry and return when they refill following rainfall events and floods. In contrast, molluscan species are resistant to drying events by persisting within wetland sediments.

### 4.4.2. Groundwaters

The stygofaunal and microbial communities within the subterranean groundwater-dependent ecosystems of the BESA were characterised by CSIRO and CDU researchers in a separate study funded by the Gas Industry Social and Environmental Research Alliance (GISERA. The results of the study can be accessed at: https://gisera.csiro.au/project/characterisation-of-the-stygofauna-and-microbial-assemblages-of-the-beetaloo-sub-basin-nt/

## 4.5. Conclusions

This baseline survey program has greatly increased the knowledge of biodiversity within the BESA. The combined results of this GBA program and the SREBA will provide the information needed to identify areas of high conservation value and to predict the potential impacts of resource development on biodiversity within the region. It will inform future environmental impact assessments and support the development of ecological monitoring programs.