BEETALOO SREBA SCOPE OF WORKS

TERRESTRIAL ECOSYSTEMS

Terrestrial Ecosystems studies for the Beetaloo Sub-basin Strategic Regional Environmental and Baseline Assessment

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NORTHERN TERRITORY GOVERNMENT

Acronyms	Full form
AAPA	Aboriginal Areas Protection Authority
BRRG	Beetaloo Regional Reference Group
Code of Practice	Code of Practice: Onshore Petroleum Activities in the Northern Territory 2019
DEPWS	Department of Environment Parks and Water Security
EPBC Act	Environment Protection and Biodiversity Conservation Act (Commonwealth)
EPM	Ecological Protected Matter
ERIN	Environmental Resources Information Network
Final Report	The Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory
GBA	Geological and Bioregional Assessment Program (Commonwealth)
GDE	Groundwater dependent ecosystem
GIS	Geographic information system
IBRA	Interim Biogeographic Regionalisation for Australia
MNES	Matters of National Environmental Significance
NESP	National Environmental Science Program
NT	Northern Territory
NVIS	National Vegetation Information System
RE	Regional ecosystem
SOP	Standard operating procedure
SREBA	Strategic Regional Environment and Baseline Assessment
TPWC Act	Territory Parks and Wildlife Conservation Act (Northern Territory)

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Cover Image: Common Planigale *(Planigale maculata)*, Anderz Zimmy

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BACKGROUND

In April 2018, the Northern Territory Government accepted all 135 recommendations of the Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory.

The Final Report and details about the Inquiry are available at: frackinginquiry.nt.gov.au/inquiry-reports/final-report

A number of the recommendations relate to undertaking a Strategic Regional Environmental and Baseline Assessment (SREBA). A SREBA is a set of studies to address knowledge gaps and establish appropriate baselines against which the potential impacts of proposed onshore gas activities may be assessed. SREBA baseline studies cover six broad domains: water quality and quantity; aquatic ecosystems; terrestrial ecosystems; greenhouse gases; environmental health; and social, cultural and economic studies.

The Northern Territory Government has subsequently developed a SREBA Framework, which describes the objectives and content of a SREBA, including governance and implementation arrangements, and has detailed guidance notes describing how baseline studies should be undertaken in each domain.

The Framework is available at: hydraulicfracturing.nt.gov.au/resources/sreba

The Northern Territory Government has also determined that a SREBA is required in the Beetaloo Sub-basin, which is the most prospective onshore gas basin in the Northern Territory. The Framework was written to be generally applicable to a SREBA undertaken in any region of the NT, and recognises that a more detailed, region-specific Scope of Works is required for each baseline study before it commences.

OBJECTIVES

This Scope of Works describes how the terrestrial ecosystem baseline studies for the Beetaloo sub-Basin SREBA will be undertaken, consistent with the approach set out in the SREBA Framework. The terrestrial ecosystem baseline studies will be coordinated where applicable with other SREBA study domains. In particular, there are strong linkages and synergies between the terrestrial and aquatic studies. The Scopes of Work clearly demarcate the different biological components of these studies. However, they will overlap and complement each other in several ways, such as using the same spatial boundary; building sampling designs from the same regional ecosystem mapping; and sampling in the same locations where possible.

In order to address the requirements relevant to terrestrial ecosystems described in the Final Report, as well as information requirements for the robust assessment of onshore gas development proposals, the terrestrial ecosystem baseline studies for the Beetaloo SREBA should address the following attributes:

- Ecological communities, including riparian communities.
- Terrestrial vascular plant species.
- Terrestrial vertebrate species, including waterbirds.
- Terrestrial invertebrate species.
- Threatened species and their habitat, and other matters protected by legislation (EPMs)[1].
- Other significant species and their habitat, including those with high cultural value.

While weeds are an important environmental issue, the requirement for a regional baseline weed assessment (Recommendation 8.2) has been addressed through the Code of Practice (DENR 2019) and associated guideline Weed Management Planning Guide: Onshore Petroleum Projects. Weeds will not be addressed by further targeted surveys as part of the terrestrial baseline surveys, although the presence of weed species will be recorded during regional ecosystem mapping and site-based biodiversity surveys.

The outputs that should be derived through collection, analysis and synthesis of these baseline data are:

- Regional ecosystem mapping.
- Description of regional biogeographic patterns for terrestrial biodiversity.
- Spatial distribution models for significant species and communities.
- Identification and mapping of high conservation value areas.
- Evaluation of the sensitivity of significant species to development.
- Description of suitable indicators and methods for regional monitoring.

Analyses and synthesis will integrate baseline data derived from both terrestrial and aquatic studies. Researchers in both baseline studies will therefore coordinate and consult each other to ensure that findings are effectively synthesised in the final SREBA report.

ALIGNMENT with Geological and Bioregional Assessment Program

A range of studies have recently been undertaken in the Beetaloo sub-Basin as part of the Commonwealth Geological and Bioregional Assessment (GBA) Program[2].

Ecological studies undertaken by the GBA were aligned with the requirements of the Beetaloo SREBA and include:

- Preparation of a draft regional ecosystem map and partial ground-validation.
- Biodiversity survey site stratification and selection, based upon preliminary regional ecosystems mapping.
- Desk top assessment and compilation of existing ecological information, and data on matters of national significance.
- Preliminary flora surveys.
- Preliminary surveys for invertebrates.
- Targeted surveys for some significant species.
- Preliminary distribution modelling for threatened species.

The terrestrial ecosystem baseline studies of the SREBA will build on the work undertaken by GBA, and use consistent methodology, unless otherwise determined through consultation with DEPWS.

[1] For example, migratory species and other Matters of National Environmental Significance (MNES) under the Environment Protection and Biodiversity Conservation Act. Collectively these are referred to as Ecological Protected Matters (EPMs)

[2] bioregionalassessments.gov.au/assessments/geological-and-bioregional-assessment-program/beetaloo-gba-region

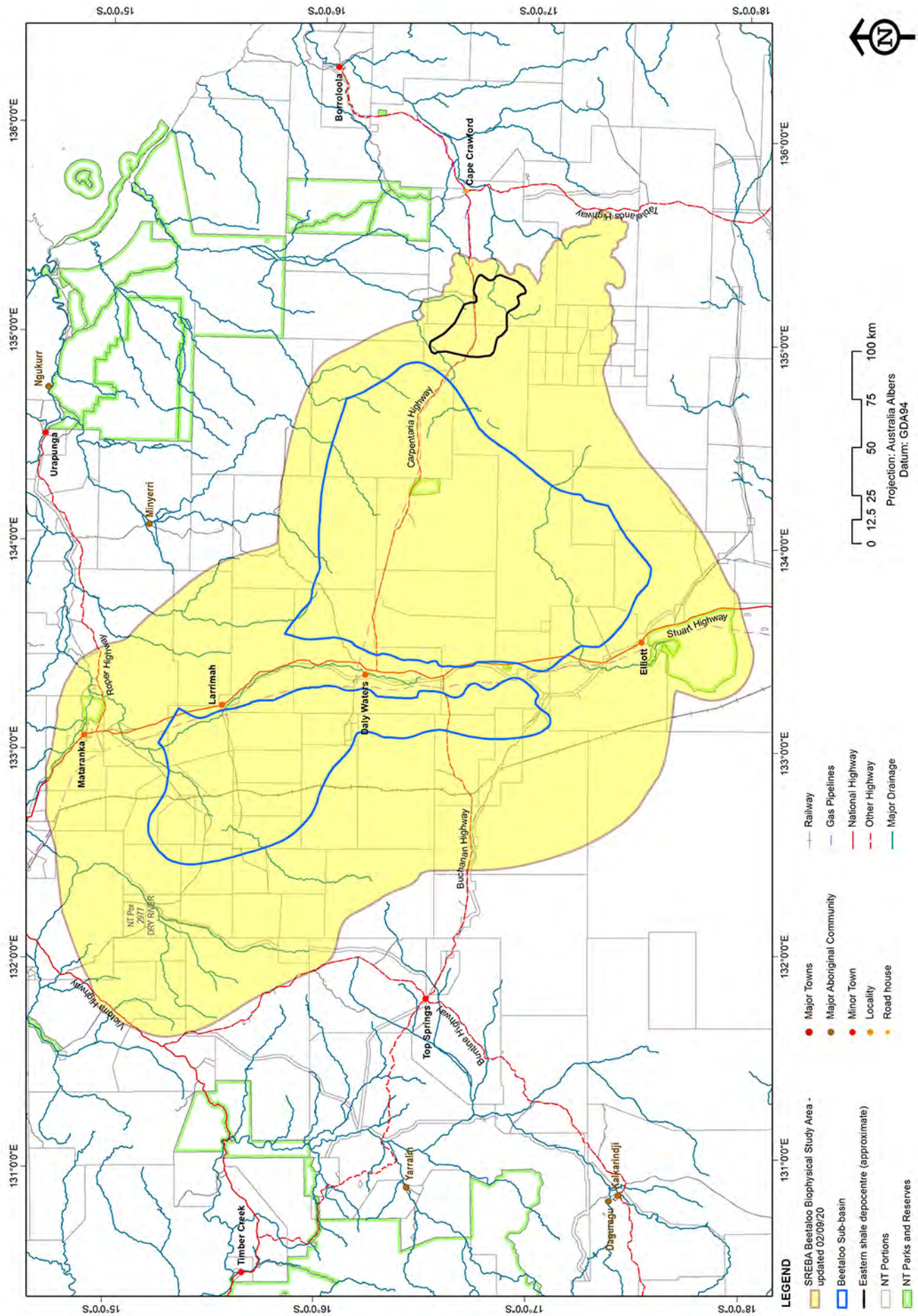

Figure 1. Study area for the terrestrial ecosystem baseline studies of the Beetaloo SREBA.

METHODS

Spatial boundaries

The study boundary for the ecological domains of the Beetaloo SREBA (Fig. 1) generally follows that used in the GBA Program, which was determined through consultation between ecological and hydrological experts in GBA and DEPWS. The study area boundary was drawn to delimit the spatial distribution of terrestrial and aquatic ecological values on which gas development in that region could feasibly have an impact, including predictable indirect impacts. This included consideration of:

- Geological sub-basin boundaries delimiting the gas resource. Recent data suggest similar prospective geology occurs to the south east of the sub-basin boundary shown in Fig 1., so the SREBA boundary has been extended in this vicinity relative to that used by GBA .
- IBRA region and sub-region boundaries, notably the Newcastle and Birdum subregions of the Sturt Plateau bioregion (environment.gov.au/land/nrs/science/ibra).
- Catchment boundaries, notably including Lake Woods and the internal drainage system feeding it.
- The distribution of groundwater dependent ecosystems that may feasibly be subject to impact, notably including springs and riparian ecosystems in the northwest, north and southeast of the study area, which are likely to be the surface expression of aquifers overlying the prospective gas basins.
- Inclusion of sufficient geographic extent to provide adequate regional context to assist the assessment of the significance of ecological values and any potential impact on them. This explains, for example, why the study boundaries are relatively expansive to the west of the Beetaloo Sub-basin boundary, so as to capture the regional extent of poorly known ecosystems that occur across much of the sub-basin.

Within the Beetaloo SREBA study area, stratification of representative sampling within and outside of the Beetaloo Sub-basins will be necessary in order to interpret the significance of biological attributes occurring within the sub-basins in a geographically appropriate ecological context.

Data collation and review

Building on environmental and ecological information compiled by the GBA, existing relevant environmental and ecological data will be collated and reviewed. These data will be used to inform environmental mapping; identify the likelihood of occurrence of, and potentially suitable habitat for, significant species for targeted survey; and inform site selection and planning for targeted and general biodiversity survey. Relevant information sources include:

- Climate surfaces.
- Geological mapping.
- Land resource and vegetation mapping.
- Topographic mapping and digital elevation models (DEM).
- Northern Territory NR Maps.
- Atlas of Living Australia.
- Site data from soil, vegetation and wildlife surveys held by DEPWS .
- Predictive distribution models for significant species developed by ERIN (environment.gov.au/about-us/environmental-information-data) and NESP (Pintor *et al* 2018).
- Regional ecosystem mapping, flora and fauna surveys and threatened species modelling undertaken by the Geological and Bioregional Assessment program for the Beetaloo Biophysical Study Area.

Existing data, with relevant metadata, will be collated and provided to DEPWS in formats compatible with their data management systems.

Environmental mapping

Environmental mapping will be undertaken for the whole Beetaloo SREBA study area in order to:

- Provide the environmental stratification for regionally representative, site-based sampling of biodiversity.
- Provide a basis to design sampling for, and predict the Distribution of, threatened or significant taxa.
- Allow ecosystems or habitats described at a local (project) scale to be placed in a regional context.
- Delineate the location and extent of rare or significant ecosystems.
- Provide a regional baseline layer for the analysis of potential cumulative impacts.

The Queensland Regional Ecosystem framework will be used to classify and map "regional ecosystems" (Sattler & William 1999, Neldner *et al* 2019a). Regional ecosystems are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. This well-established approach provides a hierarchical landscape classification that recognises major variation in land zones (also called landscape classes in the NT), vegetation structure and ecologically dominant upper stratum species. It is suited to mapping at a relatively broad (bioregional) scale and describes ecosystems at a scale that is likely to be useful for predicting the distribution of many plant and animal taxa.

The approach and methods for regional ecosystem mapping will follow (Neldner *et al* 2019b). For the Beetaloo SREBA, a map resolution of at least 1:100,000 is required, with a scale of attribute classification equivalent to the plant association (Level 5; NVIS Technical Working Group 2017). Some regionally restricted ecosystems that are likely to have a distinctive biodiversity will be mapped and classified at a finer scale with a minimum polygon size appropriate to their local patch size. These may include wetlands, riparian zones, groundwater-dependent ecosystems, monsoon rainforest patches, karst features or heaths, and this requirement will follow expert advice from DEPWS.

Systematic regional biodiversity survey

The occurrence and distribution of selected biodiversity attributes will be comprehensively mapped across the Beetaloo SREBA study area.

Target taxa

It is not feasible to sample all elements of biodiversity, so the taxonomic groups included in the regional surveys have been carefully selected, using the following criteria:

1. Existence of established sampling methods for the taxonomic group, that provide sufficiently high detection probability for robust analysis of geographic patterns and detection of change in community composition over time.
2. Sampling methods must not have access or resource constraints (cost, personnel or time) that prevent them being effectively applied over a large number of sites.
3. The group should not be subject to high stochastic variability in distribution and abundance.
4. Groups must be taxonomically tractable, and/or taxonomic expertise must be available to resolve taxa to species, or consistently to morphospecies.
5. Species within groups are likely to be sensitive to environmental change potentially arising from the development of an onshore gas industry in the study region.
6. The group is likely to be a useful indicator for distribution patterns and temporal trends of other taxonomic groups.

The set of terrestrial biota occurring in the Beetaloo study area that meets all or most of these criteria, and which will be included in systematic regional surveys, is shown in Table 1.

Group	Components
Plants	All vascular plants
Terrestrial vertebrates	Mammals Birds Reptiles Frogs
Terrestrial Invertebrates	Ants Beetles – Carabidae, Curculionidae Other insect orders, such as Mutillidae may be included if sampling detection rates are suitable.

Table 1. Components of biodiversity that will be sampled in regional terrestrial biodiversity surveys for the Beetaloo SREBA.

Aboriginal knowledge and values

The Social Cultural and Economic studies will collaborate with the Terrestrial studies to undertake desktop research of existing literature to identify potentially culturally important species and habitats within the Beetaloo SREBA study area.

The researchers conducting Social, Cultural and Economic studies will consult with relevant local Aboriginal people and organisations in relation with indigenous ecological knowledge and with the agreement of the knowledge holders, document information about flora, fauna and habitats and cultural value. Where appropriate, this information and advice will be used to inform additional priority species or sites for targeted ecological assessment, and assist with the selection of representative survey sites.

There will be opportunities for participation by local Aboriginal people in the studies, including in field research and data collection which will be identified through consultation. The Aboriginal Areas Protection Authority will be engaged to provide advice on access to sites for ecological studies.

Site selection

Regional survey sites will be located within a carefully stratified design based on the preliminary regional ecosystem mapping. In general, all regional ecosystems will be represented by multiple survey sites that also encompass the spatial extent of each ecosystem (particularly across the significant north-south climate gradient in the study area). Other considerations in developing the stratified survey design include:

- Sites should be spatially independent (individual animals being surveyed cannot move among sites during the sampling period). While it is desirable to minimise spatial autocorrelation (by ensuring sites are widely spaced), logistic considerations mean that sites may be loosely clustered. Nevertheless, there should be 2km minimum spacing between any sites wherever possible.
- Access considerations will inevitably bias the location of sites. Care must be taken of unwanted consequences, such as atypical disturbance effects close to roads and tracks. Helicopter access to some remote sites is likely to be required to ensure adequate stratification.
- In addition to 'natural' environmental variation, the occurrence of many species will also be influenced by landscape condition at each site, particularly the effects of land clearing, fire, grazing pressure (stock and feral animals) and weeds. In general, sites will be selected to be within relatively large areas of habitat in 'best on offer' condition, as determined by reference to relevant spatial information (fire scar mapping, distribution of stock water points, and distance from infrastructure and settlement) and validated by field inspection. In some regional ecosystems, availability of 'good' condition sites may be limited, and sites in sub-optimal condition may be required to meet the necessary replication; in this case condition will be introduced as an explicit factor in the stratification. In all cases, land condition attributes will be scored for each site, so this can be included in analysis as a covariate in analyses.
- Except for extremely spatially restricted ecosystems, there should be a minimum of five survey sites in each regional ecosystem and the number of sites will increase with the heterogeneity and spatial extent of each ecosystem (with a logarithmic rather than linear increase with area).
- Due to the required sampling time per site, more vegetation sites can be sampled than fauna sites.

The number of full plot-based floristic sampling sites required to provide an adequate baseline assessment of floristic diversity across the study area will vary as a function of area of extent and heterogeneity of the regional ecosystem (REs). In general, five sites per RE will be sampled. Based upon preliminary regional ecosystem mapping undertaken by DEPWS for the Geological and Bioregional Assessment (GBA) Program, approximately 120 regional ecosystem units are present within the Beetaloo Basin study area. Therefore, approximately 600 full floristic plot-based survey sites will be needed to provide an adequate baseline assessment of the floristic diversity of the study area. It is noted that forty-six floristic survey sites have been completed during the GBA survey.

Spatial distribution patterns of many fauna groups are mediated by environmental features at a coarser scale than for flora. In general, ecologically similar regional ecosystem units can be aggregated by up to a factor of five for fauna site stratification. Therefore, a total of approximately 120 fauna survey sites will be needed to provide an adequate baseline assessment of the fauna diversity of the Beetaloo Basin study area.

The stratified regional survey design for a SREBA will be subject to review and approval by DEPWS, prior to sampling commencing.

Sample methods

Vegetation

Ecological characterisation of vegetation and floristic diversity of the Beetaloo SREBA study area will be undertaken through a combination of rapid assessment and systematic plot-based floristic sampling.

Rapid vegetation assessment sites have a limited set of attributes recorded, notably vegetation structure, a small number of dominant species and a reduced suite of landform/soil attributes. They can be sampled rapidly and opportunistically (when under-sampled vegetation units are encountered) and can also be sampled outside the limited season suitable for full floristic sampling. Large numbers of rapid vegetation assessment sites are integral to improving the accuracy of the regional ecosystem mapping. Rapid vegetation assessments should be undertaken in two ways:

i. Whilst travelling between full floristic plots (see below), changes in vegetation community structure and floristics should be evaluated and related back to the preliminary regional ecosystem mapping. The location and nature of changes in community attributes should be recorded as far as is practicable whenever encountered for the purposes of map refinement and validation.
ii. Targeted sampling should be undertaken of preliminary regional ecosystem map units for which there are limited or no ground data. Vegetation structure and species composition should be scored at multiple sites with a complete a floristic inventory of the site undertaken to characterise the vegetation. These sites will assist the development of the regional ecosystem typology and further assist the development of a comprehensive stratification of regional ecosystems for full-floristic sampling.

Plot-based floristic surveys and vegetation description will follow Brocklehurst *et al*. (2007) using a plot size of 400m^2. To maximise information on floristic composition, sampling will be concentrated in the late wet and immediate post-wet period. Full floristic sampling may only be possible in a subset of survey sites due to logistical constraints, in which case survey design should ensure that this subsample is also representative. Plant identification must be supported by voucher specimens where required.

Floristic and structural data from both plot-based full floristic and rapid assessment sites will be used to validate and refine the preliminary regional ecosystem map for the Beetaloo SREBA study area.

Terrestrial vertebrates

Systematic survey methods for terrestrial vertebrates are well established in the Northern Territory (e.g. Woinarski *et al*. 2010, Gillespie *et al*. 2015). Site-based sampling will follow methods described in the current Standard Operating Procedures (SOP) used by Flora and Fauna Division of DEPWS, which includes a combination of the following sampling methods in 0.25 ha plot:

- Motion-detecting cameras (mammals, some birds and reptiles).
- Live animal traps (Elliott, cages; mammals, some reptiles).
- Drift fences with pits and funnels (reptiles, frogs and some mammals).
- Diurnal and nocturnal timed searches (reptiles, frogs, some mammals and birds).
- Repeated visual and aural census (birds).
- Harp trapping, call playback and passive recording (bats).

These methods are designed to maximise detection probabilities of a large range of vertebrate species across a standardised set of plots. They allow detection probabilities and patterns of occurrence through occupancy modelling or regression analyses to be assessed for each species, and patterns of species assemblage composition to be compared within and between faunal groups across environmental gradients. Given time and resource constraints, there is generally a trade-off between sample intensity at a site (trap-nights, bird counts, etc.) and total number of sites and this can be optimised to meet specific objectives (Einoder *et al*. 2018). Sites will be sampled for vertebrates over a four-day/night period, with motion-detecting cameras deployed for a minimum of five weeks.

Most elements of the vertebrate biota are likely to show marked seasonal variation in detectability and/or occupancy. In general, detectability of most vertebrate species is higher at the end of the wet season and early dry season, due to elevated activity levels resulting from increased moisture availability, temperatures and food activity. Therefore most terrestrial vertebrate field sampling will be undertaken from the end of the wet season (March-April) through the early dry season to July. Favourable sampling conditions diminish more rapidly in more arid, higher latitude regions, and these patterns should also be factored into seasonal stratification of field sampling.

There are taxonomic uncertainties and potentially undescribed cryptic taxa for a number of mammal, reptile and frog genera. Where possible, non-destructive tissue samples will be taken from representative captured animals to ensure accurate identification (or recognition of new taxa).

Terrestrial invertebrates

Ants and beetles will be sampled at the same set of terrestrial vertebrate fauna survey sites. Sampling methods for ants and beetles will generally follow those described in Oberprieler *et al*. (2019). Ants, and carabid and curculionid beetles, will also be sampled using the array of larger pit traps used for vertebrate surveys. Samples will be identified to consistent morphospecies (or named species where this is possible), supported by a reference collection. Where possible, species identity should be supported by DNA barcoding.

Environmental attributes

In addition to vegetation description, environmental attributes will be scored for each survey site, which will contribute to the mapping and classification of regional ecosystems, and may be used as covariates in analyses of the environmental determinants of biogeographic patterns, as well as predictive modelling of species' distribution. Environmental attributes should also be informative about landscape condition at the site. A core set of environmental attributes is described in the current SOP used by Flora and Fauna Division of DEPWS and the core attributes for land resource (Hill and Napier 2015) and vegetation (Lewis *et al* 2007) surveys, and this should be modified as required following expert advice from DEPWS.

Analysis

Analysis of data from regional biodiversity surveys will include:

- Identification of floristic and faunal assemblages.
- Calculation of summary biodiversity metrics (e.g. richness, diversity) at a site, assemblage and regional ecosystems scale.
- Evaluation of the distribution of floristic and faunal assemblages in relation to regional ecosystems, and to environmental covariates measured and derived at a site scale.
- Evaluation of the environmental determinants of summary biodiversity metrics.
- Identification of assemblages and ecosystems with biodiversity values that may be relevant to impact assessment (e.g. high richness or diversity, large number of endemic or preferential species, spatially restricted extent).
- Predictive spatial models within the SREBA boundary for floristic and faunal assemblages, and appropriate summary biodiversity metrics.

Targeted survey for significant species

Target taxa

In the context of the Beetaloo SREBA, significant species include:

- Matters of National Environmental Significance (MNES) under the EPBC Act, i.e. species listed as threatened; migratory species listed under international agreements.
- Species listed as threatened under the NT Territory Parks and Wildlife Conservation Act (TPWCA).
- Species listed as data-deficient or near-threatened under the TPWCA where available ecological information indicates that additional data is likely to confirm that they are threatened, or are short-range endemics.
- Species that are short-range endemics according to the criteria adopted by DEPWS.
- Species that may form significant aggregations.
- Species of high cultural value within the Beetaloo SREBA region.

Significant species currently known from, or likely to occur in, the Beetaloo study area are presented in Table 2, based upon the above criteria and analysis of existing data and information for the Beetaloo study region by DEPWS.

Several significant species, including Fawn Antechinus, Northern Quoll, Pale Field Rat, Partridge Pigeon, and Yellow-spotted Monitor, can be effectively sampled with the methods employed at general fauna survey sites. However, general regional surveys are not effective for providing detailed information about the distribution of species that are rare, have highly restricted distributions, or are poorly detectable by the methods described above. In these cases, targeted surveys tailored to the ecology of each species will be undertaken.

The Grey Falcon, Bare-rumped Sheathtail Bat, Red Goshawk, Masked Owl, Painted Honeyeater, Princess Parrot, Plains Death-adder, Merten's Water Monitor and Mitchell's Water Monitor, have broad and sparse distributions, and targeted surveys are not practical. These species may also be sampled at general fauna survey sites. The Grey Falcon, Red Goshawk, Painted Honeyeater and Partridge Pigeon can also be sampled at targeted threatened bird survey sites.

Merten's Water Monitor and Mitchell's Water Monitor are riparian species and can be recorded during aquatic studies.

The Northern Brush-tailed Phascogale, Night Parrot and Australian Painted Snipe are highly intractable species and targeted surveys for them are unlikely to yield additional data within the scope of the SREBA. Using the regional ecosystem mapping, revised desk-top habitat suitability maps will be prepared for these species, overlain with habitat condition indicators.

Common name	Scientific name
Mammals	
Bare-rumped Sheathtail Bat	*Saccolaimus saccolaimus nudicluniatus*
Greater Bilby	*Macrotis lagotis*
Fawn antechinus	*Antechinus bellus*
Ghost Bat	*Macroderma gigas*
Northern brush-tailed phascogale	*Phascogale pirata*
Northern Quoll	*Dasyurus hallucatus*
Pale Field Rat	*Rattus tunneyi*
Birds	
Australian Painted Snipe	*Rostratula australis*
Crested Shrike-tit (northern)	*Falcunculus frontatus*
Curlew Sandpiper	*Calidris ferruginea*
Waterbirds and migratory waders	*numerous species*
Grey Falcon	*Falco hypoleucos*
Gouldian Finch	*Erythrura gouldiae*
Masked Owl	*Tyto novaehollandiae kimberli*
Night Parrot	*Pezoporus occidentalis*
Painted Honeyeater	*Grantiella picta*
Partridge Pigeon	*Geophaps smithii*
Princess Parrot	*Polytelis alexandrae*
Red Goshawk	*Erythrotriorchis radiatus*
Reptiles	
Merten's Water Monitor	*Varanus mertensi*
Mitchell's Water Monitor	*Varanus mitchelli*
Plains Death-adder	*Acanthophis hawkei*
Yellow-spotted Monitor	*Varanus panoptes*

Table 2. Significant species previously recorded in, or highly likely to occur in, the Beetaloo SREBA study area.

Note: no significant plant species are currently known from the study area, and species of high cultural value are not identified.

Based upon the availability of effective survey methods, which can also practically be implemented within the Beetaloo SREBA study area, the following species have been identified for targeted survey:

- Bilby
- Crested Shrike-tit (northern)
- Gouldian Finch
- Ghost Bat
- Waterbirds and migratory waders

Regional biodiversity surveys may indicate the presence of significant species that were not identified in the initial selection process. Culturally significant species may be identified through consultation with Aboriginal Traditional owners and desktop research. In these cases, the criteria described above should be applied to determine if additional targeted surveys are required for these species.

Sample methods

Preliminary habitat suitability maps for each of the target species will be prepared, based upon the preliminary regional ecosystem mapping, known habitat requirements and previous distribution modelling. These maps will be used to inform survey design through stratification of targeted survey site selection across the most relevant habitats.

Crested Shrike-tit will be surveyed using the call-playback method developed by DEPWS. At each site, call-playback surveys should be undertaken during two mornings and two afternoons during the same survey period. Each survey instance lasts 40 minutes and involves call-playback at each corner of a 150 x 150m plot with walking transects and plot searches between each corner. Surveys should be conducted at regional fauna survey sites that occur in potential habitat for these species. In addition, a set of additional 'satellite' bird survey sites should be sampled to increase sampling effort and coverage for these species.

Gouldian Finch will be surveyed at small waterholes during morning and afternoon surveys for up to three days during the same survey period. Waterhole surveys involve an observer sitting approximately 15-20m from the edge of the water while recording all birds that come into the site during the survey. Gouldian finches may also be detected during bird censuses at general fauna survey plots. Methods for surveying Crested Shrike-tit and Gouldian Finch are further detailed in the SOP developed by DEPWS.

Surveys for Greater Bilby will use a combination of aerial surveys and ground-based tracking surveys. Aerial methods were developed by DEPWS with reference to Southgate *et al*. (2005) and Southgate *et al*. (2018).

Aerial surveys involve flying ~30-50m above the ground at ~30-40kmh along transects across potentially suitable habitat, with one observer seated on either side of the helicopter. Putative bilby sign is then ground-truthed or checked by hovering over the sign if the helicopter cannot land. Ground-based tracking surveys should follow the standardised 2 ha plot surveys (Moseby *et al*. 2011), which involve walking over a 200 x 100m plot for 25 minutes while recording any tracks, scats, burrows, diggings or other sign of animals observed and assigning these to the lowest taxonomic rank possible. Methods for surveying Bilbies are further detailed in the SOP developed by DEPWS.

Ghost Bats will be surveyed using a combination of automated timed call playback broadcast and video recording methods developed by DEPWS. Call broadcasting is used attract bats, which are then detected on video as they fly past to investigate. Surveys should be undertaken in regions of the study area considered to have high likelihood of sink holes or caves (potential roost sites), based upon preliminary regional ecosystem mapping and desktop habitat assessment.

Waterbird and migratory wader surveys will be conducted at a representative range of wetland types and sizes in the late wet-early dry transition and late dry season. Aerial surveys are the most efficient means of surveying waterbirds across large, remote areas. Transects should be flown across wetlands, with the number, length and orientation of transects to be determined by wetland characteristics. Counts of all waterbird species identifiable from aerial surveys should be recorded, with ground validation where required and practical.

Analysis

Spatial distribution models will be developed for each significant targeted species within the Beetaloo study area. The appropriate analytical technique will depend on the nature of the species data and the spatial data used as environmental predictors and include occupancy modelling (MacKenzie *et al*. 2002) or presence-based approaches such as MaxEnt (Elith *et al*. 2011). In all cases modelling should quantify the uncertainty associated with the predicted distribution.

The significance of the occurrence and predicted distribution of significant species will be evaluated in the context of the species' broader distribution, occurrence and habitat requirements. Where possible, analyses should delineate the extent of ecosystems within Beetaloo study area that are likely to important for the persistence of the species in the region.

DELIVERABLES AND REPORTING

The Terrestrial Ecosystems Baseline Report for a SREBA will contain detailed descriptions of the methods, results, analyses and synthesis products. The Report should also catalogue all data collated during the project, including all extraneous sources of contributing data and information, with appropriate metadata and where it can be accessed. Information products and outputs that should be reported from the terrestrial ecosystems baseline studies are described in Table 3. Summary outputs from the assessment should be in formats that are readily available, and comprehensible, to a broad audience (such as web-enabled, interactive maps).

Component	Deliverable
Regional ecosystem mapping	Maps (1:100,000 with some at 1:25,000 for spatially limited habitats) showing: the distribution of vegetation communities; the distribution of surface-expression GDEs (including groundwater-dependent vegetation, springs and seepage areas, and groundwater-fed pools and streams) with associated hierarchical attributes in ESRI compatible GIS format. Technical descriptions of the regional ecosystems following Neldner *et al* (2019a and 2019b) and NVIS (2017). Analyses of regional ecosystem extent (and condition) within the study area and where possible, reference to the extent of related ecosystems within the NT.
Regional biogeographic patterns for terrestrial biodiversity	Evaluation of patterns of species richness in relation to regional ecosystems, and to measured and remote-sensed environmental covariates. Description and evaluation of distribution patterns of floristic and faunal assemblages in relation to regional ecosystems, and to measured and remote-sensed environmental covariates. Identification of assemblages and ecosystems with biodiversity values that may be relevant to impact assessment (e.g. high richness or diversity, large number of endemic or preferential species, spatially restricted extent).
Significant species and communities	Spatial distribution models of each significant species, with quantification of associated uncertainty in the models. Delineation of the extent of ecosystems within the Beetaloo study area that are likely to important for the persistence of the species in the region. Evaluation of the significance of the occurrences and predicted.

Table 3. Information products and outputs from the terrestrial ecosystems baseline studies.

Synthesis

In order to inform the assessment of potential impacts of development in the Beetaloo Basin, further synthesis of the baseline data collected during surveys and from the above analyses should be undertaken, as follows. Close collaboration between the Terrestrial Ecosystem and Aquatic Ecosystem studies is required during the synthesis, due to overlap in relation to describing ecological values and identifying high conservation value areas. Collaboration with the Social, Cultural and Economic studies is also required for the description of species and habitats of high cultural value.

Areas of high conservation value

Areas of high conservation value contain biological or ecological values considered outstandingly significant at the regional, national, or global level.

High conservation value areas should be identified within the Beetaloo Sub-basin in the context of the broader SREBA study area, following criteria developed for the Northern Territory (Ward & Harrison 2009) that include:

- Concentration of threatened species
- Concentration of endemic species
- Wildlife aggregations
- Botanical significance

These criteria may need to be modified in consultation with DEPWS to apply them effectively at the regional scale of the Beetaloo Basin. Information from the aquatic ecosystems and cultural studies of the SREBA will also be required to assess all of these criteria. Identification of areas of high conservation value should also include consideration of requirements for buffers and/or corridors in order to ensure maintenance of ecosystem processes and viability of local populations of significant species.

Sensitivity of significant species

Biological attributes within the Beetaloo sub-basin that are likely to have high sensitives to onshore shale gas development will be identified and described. The risk of cumulative impacts on significant species and ecological communities of habitat loss, fragmentation, or other forms of ecological disruption that could accompany any onshore shale gas development will be assessed.

The specific assessment approach will need to be designed in consultation with DEPWS once the species and ecosystems involved are known. Important considerations include:

- Published data and research on the effects of clearing and fragmentation on related or analogue species in comparable environments in northern Australia, nationally or globally.
- Sensitivity to potential impact is likely to be higher for species that:
  - are dependent on a large area of continuous vegetation during one or more stages of its life cycle,
  - are habitat specialists and/or have regionally restricted distributions,
  - have a significant correspondence at a regional scale between core habitat and the potential development footprint of the gas field.
- An important step in this process may be the development of locally relevant conceptual models that integrate current understanding of terrestrial ecosystems and the ecology of threatened species. Guidance on the development of evidenced-based conceptual models of ecosystems is provided by several sources including Olander *et al*. (2018) and BOM (2016). Advice on the use of conceptual models in impact assessment is provided by CoA (2015).
- The Geological and Bioregional Assessment Program 2021 is currently developing tools for assessing potential cumulative direct and indirect impacts of on-shore shale gas development on ecological values in the Beetaloo Basin. The approach develops causal network models that provide consistent ways to understand and evaluate impacts of development activities on these values. The data collected during the SREBA will allow this assessment to be applied to a broader range of values and with better resolution than currently considered by GBA.
- The sensitivity of terrestrial ecosystems or species to hazards arising from potential future onshore gas development needs to be distinguished from, and considered in combination with, effects arising from other major sources of disturbance such as long-term pastoral use, adverse fire regimes or climate change.
- The assessment must identify levels of uncertainty in both the input data and models and the subsequent sensitivity assessment.

Monitoring

Building on the baseline data collection and analyses, monitoring programs will be designed for any significant species or other biodiversity attributes that are likely to be affected from impacts associated with onshore gas development. This will include selection of suitable indicator taxa or other biodiversity attributes, spatial distribution of suitable sampling sites and appropriate methodology for each recommended monitoring program.

Data management

All data collected during the SREBA terrestrial ecosystem baseline studies must be provided to DEPWS, with comprehensive metadata.

In general, all SREBA data will become open-access, except where access is restricted according to criteria described in the SREBA Framework. For terrestrial ecosystem data, this is likely to apply only in very limited cases where open access to locality data may genuinely increase threats to a species, or where data may identify culturally sensitive sites.

All data and derived products associated with the SREBA should be supplied in formats compatible with NT Government corporate database systems (refer to Biodiversity Information Group (Flora & Fauna) and Geospatial Services Branch (Rangelands), DEPWS for further information). Where these data are spatially located, these should be supplied in ESRI compatible GIS formats (file geodatabase or shapefile) in GDA 94 datum and preferably geographic coordinate systems.

Metadata, including a full data dictionary and lineage as well as the spatial and temporal extents of data compliant with AS/NZS ISO 19115:2005 should be supplied for each individual data-set (spatial and non-spatial) associated with the SREBA.

Data will be curated and organised under a data management plan developed for the Terrestrial Ecosystem component in consultation with DEPWS. The data management plan should identify owners and data custodians for all datasets, and any data restrictions.

PROJECT TIMEFRAME

Milestone	Completion date
Regional ecosystem mapping ground-truthing and general flora and fauna surveys commenced	April 2021
Progress report for first round of field surveys	August 2021
Progress reporting for 2021 activities	January 2022
Progress report following completion of field surveys	July 2022
Progress reporting on 1st 18 months	June 2022
Final report and provision of all final datasets	November 2022

ROLES AND RESPONSIBILITIES

All researchers including contractors or consultants carrying out these studies will report to DEPWS as the project manager for the SREBA program of work. Preliminary findings, data, and final results will be reported to DEPWS, and all material and data will become the intellectual property of the Northern Territory Government.

Compliance requirements

Permits

All fauna survey work requires a permit under the Territory Parks and Wildlife Conservation Act 1976, and animal ethics approval from a registered Animal Ethics Committee. Refer to the links below for further information:

- nt.gov.au/environment/animals/wildlife-permits/permits-take-interfere-with-wildlife
- cdu.edu.au/research-and-innovation/industry-collaboration/animal-ethics

Access permissions

Permission must be obtained from the relevant landowners before entering properties and undertaking fieldwork. This includes pastoral properties, Indigenous managed/owned lands, parks and reserves and crown land.

For aboriginal lands, a permit to undertake field work must be sought through the relevant Land Council, and permission to access specific areas should be secured from appropriate traditional owners and community councils.

The engagement of local traditional owners as cultural monitors for on-country field work may be required to ensure observation of appropriate protocols and avoid culturally sensitive areas. Prior to field surveys, areas in the study area with restricted access should be identified through consultation with AAPA and relevant Land Councils. This will be undertaken by the DEPWS SREBA management team.

Communication and stakeholder engagement

The SREBA Engagement Manager is the focal point for all stakeholder engagement and communication for the program. The SREBA Engagement Manager will liaise with landholders and relevant Land Councils to obtain permissions for access. Research teams can then directly contact individual landholders to arrange access, and will be required to observe landholder protocols such as advance notice, vehicle hygiene requirements and site inductions. Research teams will be provided with a briefing pack that includes vehicle hygiene certification documents, SREBA key contact details, specific landholders requirements, SREBA Factsheets, and other relevant documentation.

The SREBA management team will liaise directly with the Aboriginal Areas Protection Authority (AAPA) to obtain clearances and certificates for field work, and field work teams will abide by the conditions of certificates or guidance provided by AAPA. Teams may also be required to provide information during community consultations, and work with local ranger groups and community members for data collection.

The SREBA stakeholder engagement plan outlines the strategies for engaging with key stakeholders. Researchers carrying out the terrestrial ecosystem studies will be required to contribute to stakeholder engagement activities coordinated through the SREBA management team, including:

- Field reports with summary survey results sent to landholders upon completion of field work.
- Radio interviews and information sessions to inform the community about the studies, what will be done, how the information will be used and where people can find further information.
- Closed social media groups for interested parties to receive updates and briefings on progress, field visits summaries and alerts for upcoming activities.
- Presentation to the Beetaloo Regional Reference Group (BRRG) at the commencement of the studies to inform the group of the scope, scale and timing of the studies and to seek feedback.
- Progress report presentations to the BRRG to update the group and provide any preliminary results.
- Final results, findings, models and monitoring plans presented to the BRRG at the completion of the studies.
- Final results, findings, models and monitoring plans presented in scientific seminars.
- Results, finding and models and monitoring plans published on the DEPWS website and made publicly available in user-friendly formats.

Researchers carrying out the terrestrial ecosystem studies will provide updates to the DEPWS SREBA management team on progress and issues on a regular basis.

PROJECT RISKS

Risks	Mitigation measures
Failure to secure adequate landholder access for field work	A robust stakeholder engagement plan is being developed by DEPWS For most regional ecosystems, representative sampling can occur on more than one property
Unfavourable weather conditions limiting effectiveness of field sampling	There is flexibility on the works program to rearrange field work to limit some of these effects
WHS risks, especially associated with remote filed work	Established WHS standards and SOPs for remote area fieldwork
Resources are inadequate to undertake all the work to the extent required	DEPWS has extensive experience designing and costing this kind of work, and has undertaken careful feasibility assessment and prioritization of scope components.
Availability of appropriate expertise	DEPWS possesses extensive expertise in ecosystem mapping, and the design, collection and analyses of terrestrial flora and fauna data for most of the taxonomic groups. Additional relevant expertise is available elsewhere in the NT and Australia more broadly.

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