BEETALOO SREBA SCOPE OF WORKS

AQUATIC ECOSYSTEMS

Aquatic 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
ANAE	Australian National Aquatic Ecosystem
BRRG	Beetaloo Regional Reference Group
Code of Practice	Code of Practice: Onshore Petroleum Activities in the Northern Territory 2019
DEM	Digital elevation model
DEPWS	Department of Environment Parks and Water Security
eDNA	Environmental DNA
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
GISERA	Gas Industry Social & Environment Research Alliance
HEVAE	High ecological value aquatic ecosystem
IBRA	Interim Biogeographic Regionalisation for Australia
MNES	Matters of National Environmental Significance
NESP	National Environmental Science Program
NT	Northern Territory
QDES	Queensland Department of Environment and Science
SREBA	Strategic Regional Environment and Baseline Assessment
TPWC Act	Territory Parks and Wildlife Conservation Act (Northern Territory)

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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 regarding the Inquiry are available at: frackinginquiry.nt.gov.au/inquiry-reports/final-report

A number of the recommendations contained in the Final Report relate to the need to undertake a Strategic Regional Environmental and Baseline Assessment (SREBA) prior to any onshore gas development. A SREBA is a set of studies to address knowledge gaps and establish appropriate baselines against which the potential impacts of proposed 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 also produced 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 (NT). The Framework provides a general overview of how a SREBA should be 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 aquatic ecosystem baseline studies for the Beetaloo Sub-basin SREBA will be undertaken, consistent with the approach set out in the SREBA Framework. The aquatic ecosystem baseline studies will be coordinated where applicable with other SREBA study domains; in particular there are strong linkages and synergies with the water and terrestrial ecosystem studies. The Scope of Works for each component of the SREBA describe the different requirements for each of these studies; however, they will overlap and complement each other in several ways. For example they will use the same spatial boundary; develop sampling designs from the same spatial base (regional ecosystem mapping); sample in the same locations where possible; and use related environmental attributes such as water quality and water regime attributes. The terrestrial study will provide baseline data on terrestrial flora and fauna (including waterbirds) and ecological condition of riparian habitats, whereas the aquatic study will provide data on biota with a predominantly aquatic life stage, including fish, invertebrates and aquatic plants. The SREBA water project will focus on physical aspects of aquatic environments, such as flow and flood frequency, and catchment-scale rainfall-runoff modeling. The aquatic study will collect data on some water quality parameters at each site. The data will be used to characterise sites and as predictor variables for modeling the composition of biological communities. The SREBA water quality and quantity study for the Beetaloo sub-basin will focus on water quality of groundwater systems rather than surface waters, and help identify groundwater dependent sites for ecological assessment by the aquatic biodiversity study.

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

- identification and delineation of aquatic habitats, and ecological units.
- aquatic vascular plants and macroalgae.
- fish and turtle species.
- aquatic macroinvertebrate species.
- stygofauna;
- threatened species and their habitat, and other matters protected by legislation (EPMs); and
- other significant species and their habitat, including those with high cultural value.

The key outputs that should be derived through collection, analysis and synthesis of this baseline study are:

- mapping and classification of aquatic ecosystems within the SREBA boundary;
- description of assemblages of aquatic biota and evaluation of environmental determinants, including key aquatic refuges;
- identification of High Ecological Value Aquatic Ecosystems (HEVAEs) and aquatic areas of high cultural value;
- identification of dry season refuges;
- spatial distribution models for significant aquatic species and assemblages;
- evaluation of the sensitivity of significant species/ ecosystems to development; and
- description of indicators and methods for regional monitoring.

Analyses and synthesis should integrate baseline data derived from water, terrestrial and aquatic studies. Researchers in all relevant project teams will therefore need to coordinate and consult each other to ensure that findings are effectively synthesised in the final SREBA report.

ALIGNMENT with the 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 . Some of this work aligns with the requirements of the Beetaloo SREBA and includes:

- preparation of a draft regional ecosystem map and partial on-ground validation;
- preliminary identification of groundwater dependent ecosystems through existing data layers and remotely-sensed metrics;
- desk top assessment and compilation of existing ecological information and preliminary assessment of ecological protected matters;
- preliminary surveys of fish, turtles, macroinvertebrates and algae;
- preliminary surveys of stygofauna; and
- preliminary threatened species distribution modeling.

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

METHODS

Spatial boundaries

The study area 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 both aquatic and terrestrial 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 (Eastern shale depocentre), 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 boundaries of groundwater-dependent ecosystems that may feasibly be subject to impact, particularly springs and aquatic ecosystems in the northwest, north and southeast of the study area, which are likely to have a hydrological connection to aquifers overlying the prospective gas basins; and
- 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 boundary extends far 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-basin and associated shale depocentres will be necessary 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 significant aquatic ecosystems 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 (GeoFabric and coded topographic mapping feature classes) and digital elevation models (DEM);
- remotely sensed data and derived products (Landsat, Sentinel, Water Observations from Space);
- mapping of groundwater dependent ecosystems (e.g. Atlas of groundwater dependent ecosystems);
- Northern Territory NR Maps;
- atlas of Living Australia, including museum voucher specimens;
- site data for aquatic species held by DEPWS and Museum and Art Gallery of the Northern Territory and the North Australian Freshwater Fish Project (NAFF) (Pusey *et al*. 2017);
- existing wetland mapping and descriptions (e.g. Directory of Important Wetlands in Australia; Duguid *et al*. 2005; Kennard 2010);
- predictive distribution models for significant species developed by ERIN (environment.gov.au/about-us/environmental-information-data) and NESP (Pintor *et al* 2018);
- aquatic flora and fauna surveys and threatened species modelling undertaken by the Geological and Bioregional Assessment program for the Beetaloo study area; and
- Gas Industry Social and Environmental Research Alliance (GISERA) study of the stygofauna and microbial assemblages of the subterranean groundwater dependent ecosystems of the aquifers associated with the Beetaloo Sub-basin[3].

Existing data, with relevant metadata, will be collated and provided to DEPWS in appropriate formats for incorporation into data management systems established for the SREBA.

[3] gisera.csiro.au/project/characterisation-of-the-stygofauna-and-microbial-assemblages-of-the-beetaloo-sub-basin-nt/

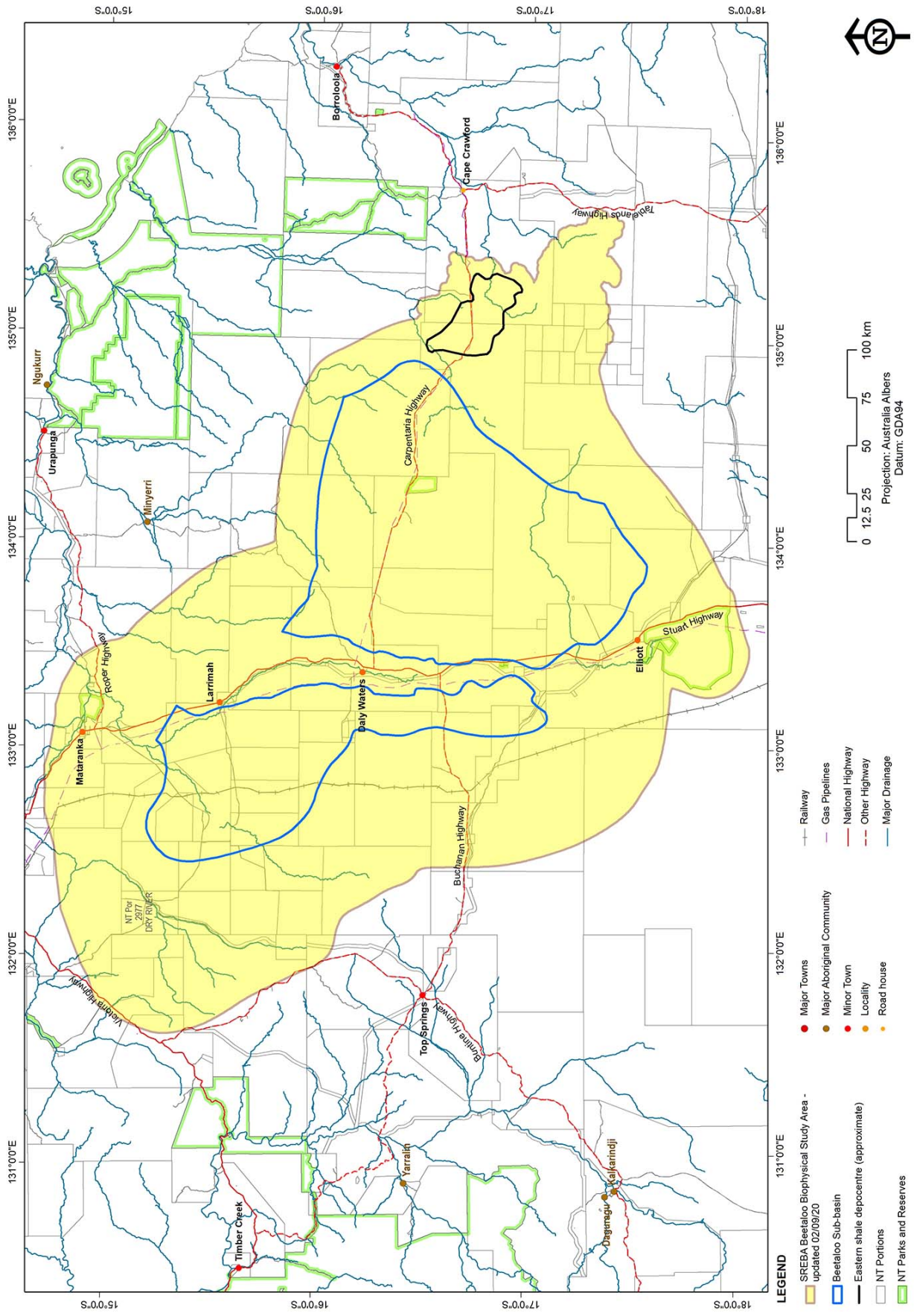

Figure 1. Study area for the aquatic ecosystem baseline studies of the Beetaloo SREBA.

Mapping and classification of Aquatic Ecosystems

Accurate, fine-scale mapping of aquatic ecosystems is essential to:

- provide the environmental stratification for regionally representative, site-based sampling of aquatic biota;
- delineate the location and extent of High Ecological Value Aquatic Ecosystems (HEVAE's);
- predict the distribution of threatened or significant aquatic taxa and assemblages; and
- allow aquatic ecosystems or habitats described at a local scale to be placed in a regional context.

Candidate aquatic ecosystems will be delineated at a broad scale by mapping of regional ecosystems in the Beetaloo SREBA study area as part of the Terrestrial Ecosystems studies. This will allow identification of high-level aquatic ecosystem types and development of a preliminary typology of systems present within the study area. As many aquatic ecosystems will have very small areas, these features must be mapped at a finer scale than the default resolution for regional ecosystems.

More detailed mapping and classification of these candidate aquatic ecosystems will be required to provide a comprehensive typology of aquatic ecosystems present within the study area in line with the Australian National Aquatic Ecosystem (ANAE) classification framework.

Mapping of candidate aquatic ecosystems from regional ecosystem mapping will be verified and refined by reference to:

- existing datasets on wetlands (e.g. Directory of Important Wetlands Australia, Duguid *et al*. 2005);
- datasets showing persistent vegetation greenness and water presence/persistence over time developed from remotely-sensed data (e.g. Water Observations from Space, Geosciences Australia and equivalent surface water indices developed by DEWPS in conjunction with collaborative partners (QDES) for higher resolution satellite imagery); and
- hydrogeological mapping and modelling of groundwater hydrology and groundwater/surface water interactions (in consultation with the water baselines studies of the SREBA).

Time series analysis of remotely sensed data will also allow derivation of indicative aquatic ecosystem attributes, such as extent, persistence (water regime) and connectivity.

Once delineated, a classification for refined aquatic ecosystems within the Beetaloo SREBA study area will be developed using the Interim Australian National Aquatic Ecosystem (ANAE) Classification Framework (AETG 2012a), based on available information including geophysical/biophysical mapping, remotely sensed data and existing site data. Key attributes for determining preliminary ecosystem classes may include landform, substrate, dominant vegetation, and water regime and landscape context. Where available, data and models from the water domain of the SREBA will be used to preliminarily attribute the water source sustaining the aquatic ecosystem (surface and/or groundwater). This will be confirmed via field data collection in the regional survey phase.

Systematic regional aquatic ecosystem survey

The systematic regional survey aims to provide a comprehensive description of the physical and biological attributes of aquatic ecosystems across the Beetaloo SREBA study area by sampling a representative sample of ecosystem types and carefully selected components of the aquatic biodiversity.

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:

- 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.
- Sampling methods must not have severe access or resource constraints (cost, personnel or time) that prevent them being effectively applied over a large number of sites.
- The group should not be subject to high stochastic variability in distribution and abundance.
- Groups must be taxonomically tractable, and/or taxonomic expertise must be available to resolve taxa to species, or consistently to morphospecies.
- Species or groups should be likely to be sensitive to environmental change potentially arising from the development of an onshore gas industry in the study region.
- The group is likely to be a useful indicator for distribution patterns and temporal trends of other taxonomic groups.

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

Group	Considerations
Plants	Aquatic vascular plants and macroalgae.
Fish	Includes taxa that can be reliably systematically surveyed at sites using a combination of standard sampling methods. The freshwater sawfish will be detected at a larger spatial scale using eDNA methods.
Reptiles	Freshwater turtles.
Aquatic macroinvertebrates	The level of taxonomic resolution will vary between and within phyla/orders. Species-level identification to be sought for dominant taxa including chironomid diptera, decapod crustacea, odonates and water beetles. Minor taxa including oligochaetes and water mites will not be identified to species.
Stygofauna	Limited to taxa that can be systematically and reliably sampled from groundwater bores using standard techniques (pumping, phreatic nets).

Table 1. Biota that will be sampled in regional aquatic biodiversity surveys for the Beetaloo SREBA.

Site selection

Sites will be sampled within the SREBA study region under a carefully stratified design based on the consideration described in the Framework. The stratified regional survey design for a SREBA will be subject to review and approval by DEPWS, prior to sampling commencing.

Surface aquatic ecosystems

Site selection for sampling surface aquatic ecosystems will follow a hierarchical stratification, based upon major drainage systems, followed by available waterbody types. The Beetaloo SREBA study area straddles five major drainage systems: the Daly, Roper, Limmen Bight, and the Western Plateau. Regional ecosystem mapping, remote sensing of water distribution and persistence, and previous surveys indicate the presence of numerous water bodies of different types, sizes and permanency across these drainage systems. Based upon preliminary stratification across major drainage systems and aquatic ecosystem types with replication (Table 2), approximately 80-100 geographically dispersed survey sites will be targeted for sampling. Site selection will build on preliminary surveys undertaken for the Geological Bioregional Assessment.

Further replicated subsampling within these 'sites' (i.e. along watercourses etc.) may be warranted. Intra-annual variation in assemblage composition of macroinvertebrates and fish will be examined at a small set (~10) of sites with year-round accessibility; inter-annual variability in all faunal groups will be examined at a set of 20 sites in the second year of the study.

Water body type	Drainage systems				No. sites
	Daly	Roper	Limmen Bight	Western Plateau	
Perennial streams	0	5	0	0	~5
Ephemeral streams	5	5	5	5	~20
Springs	5	10	10	5	~30
Palustrine wetlands	5	5	5	5	~20
Lacustrine wetlands	0	0	0	5	~5

Table 2. Preliminary stratification of surface aquatic ecosystem units across major drainage systems and habitat types, based upon their availability within each basin in the Beetaloo SREBA study area.

Stygofauna

Site selection for sampling subterranean aquatic ecosystems will follow a hierarchical stratification, based firstly on the two broad geological basins (Wiso and Georgina) that drain into the Daly and Roper catchments. Secondly, these basins lie beneath two main Cambrian limestone aquifers, the Anthony Lagoon Beds (and lateral equivalents) and the Gum Ridge Formation (and lateral equivalents). Due to uncertainties regarding the level of connectivity between these two aquifer systems, they should be treated as two discrete (unconnected) strata for the purposes of survey design. This approach will provide more robust information compared to a sampling strategy based on the assumption of strong connectivity between the two aquifers. Thirdly, these systems drain in a northerly direction across the SREBA study area and this geographic and climatic gradient may influence stygofauna diversity. Based upon these strata with appropriate replication (Table 3), approximately 60 geographically dispersed sites will be targeted for sampling. Site selection will build on preliminary surveys undertaken by Rees *et al*. (2021), during which 26 existing bores in this region were sampled for stygofauna.

Water body type	Drainage systems		
		Daly (Wiso)	Roper (Georgina)
Anthony Lagoon Beds	**North**	~5	~5
	Central	~5	~5
	South	~5	~5
Gum Ridge Formation	**North**	~5	~5
	Central	~5	~5
	South	~5	~5
Total sites		30	30

Table 3. Preliminary stratification for stygofauna across broad geological basins, main Cambrian limestone aquifers and latitude, subject to availability of suitable bores within each basin.

Sample methods

Due to the high inter-annual variability in aquatic systems in the Northern Territory, as well as additional unpredictability in wetting-drying cycles in arid and semi-arid regions, temporal (multi-year and/or multi seasonal) sampling should be undertaken where feasible, particularly where water regimes have high intra- and/or inter-annual variation, and where the target taxa are known to have high seasonal variation in presence, abundance and/or detectability. Intra-annual variation in assemblage composition of macroinvertebrates and fish will be examined at a subset (~10) of sites with year-round accessibility; inter-annual variability in all faunal groups will be examined at a set of 20 sites in the second year of the study.

For aquatic ecosystems with high seasonality, sites will generally be sampled after filling, late in the filled phase, and during the drying phase. Where repeat sampling is not feasible, the majority of sampling will be conducted during the period where biodiversity in target groups is likely to be at a maximum, based on expert advice (such as during recessional flows in the wet-dry transition for macroinvertebrates, or towards the end of the dry season when aquatic biota are concentrated in dry-season refuges).

Where possible, aquatic vegetation, vertebrates and macroinvertebrates will be sampled at the same set of sites. However, due to their restriction to perennial water bodies, fish will be sampled at a smaller subset of sites and aquatic ecosystem types than macroinvertebrates and vegetation.

Aquatic vegetation

Aquatic vegetation and macro-algae will be sampled using a systematic plot or transect-based approach, to provide an inventory of species at each site and a characterisation of the wetland habitat types present within the study area. Given the links between riparian and aquatic habitats from a wetland hydro-system perspective, aquatic assessment sites should be co-located in proximity to terrestrial riparian sites surveyed for the Terrestrial Ecology study.

Vertebrates

Appropriate survey techniques for fish will depend on the characteristics of aquatic ecosystems in the Beetaloo SREBA study area. Fish surveys will be undertaken predominantly by back-pack electrofishing, supplemented by fyke netting, seine and gill netting, and spotlighting/visual survey where applicable. Some reaches of the upper Roper River within the study area may be suitable for boat-based electrofishing. Each site will be sampled for fish using multiple, standardised electro-fishing shots. Nets, when used, will be deployed in a standard configuration and for a standard duration. Most captured specimens will be released unharmed at the site of capture after identification; some specimens will be vouchered to aide in resolution of poorly known taxa.

Turtles will be sampled with a combination of methods (depending upon local habitat conditions):

- Seine nets;
- Fyke nets;
- Dip netting;
- Baited turtle traps; and
- Underwater video stations.

For taxa with poorly resolved systematics, tissue samples and voucher specimens will be collected for genetic analyses to resolve cryptic species. Emphasis will be placed on taxa that potentially contain significant species (see Section 4.5).

The use of eDNA for sampling some target taxa will be considered where this method is sufficiently proven to provide timely, cost-effective and robust measures of presence or absence of target taxa.

Aquatic invertebrates

Sampling for macroinvertebrates will generally follow the NT protocols for AUSRIVAS (Lloyd and Cook 2001), Standardised sampling will be conducted by area- or time-based sweeps using a dip net in different habitats present at the site (e.g. riffle and edge habitats). Other methods will be used where appropriate and feasible, including light-traps (caddisfly adults) and aerial sweep–netting (dragonfly adults).

Identification of macroinvertebrates will be to genus or species level wherever possible. This is required to adequately describe patterns of richness and endemism at the regional scale and provide sufficient power to detect changes due to potential impacts from development. High resolution identification is impractical for all macroinvertebrate families and will be limited to major taxonomic groups including chironomid diptera, decapod crustacean, water beetles and odonates. Genomic methods may be used to identify immature forms, provided that relevant sequence reference data is available.

Stygofauna

Stygofauna sampling will be limited to taxa that can be reliably sampled from existing groundwater bores using standard techniques (pumping, phreatic nets). Stygofauna sampling will focus on existing bores, rather than new bores, as these are numerous in the study area and likely to support representative local stygofaunal diversity. A combination of sampling methods will be used depending upon the bore configuration. Where possible, water pumping and phreatic nets will be used to collect whole and fragments of organisms. Water samples will also be collected at all bores for eDNA analyses. eDNA analyses will be used to survey for occurrence of the large blind shrimp, Parisia unguis, previous identified from the region. eDNA will also be used to detect the presence of Crustacea, more generally, where this cannot be determined by microscopy.

Physical attributes and condition

Environmental attributes will be scored for each survey site, which will contribute to refining the mapping and classification of aquatic ecosystems, and which may be used as covariates in analyses of the environmental determinants of biogeographic patterns, as well as predictive modelling of species' distribution. The condition of the fringing zone of aquatic habitats will be assessed at each site.

The methods will employ techniques largely compatible with standard vegetation and flora survey methodology for the NT (Brocklehurst *et al*. 2007) and detail full structural and floristic assessments of the vegetation where practicable. As well as characterising the physical attributes of the site and its disturbance history using this standard approach, an expanded set of specific biophysical parameters following accepted wetland condition assessment methodologies (e.g. Eyre *et al*. 2015; Department of Environment and Science 2020) will be included in the assessment. This is intended to more completely characterise the attributes of the sites important to aquatic biodiversity and will broadly include:

- Categorical characterisation of the hydrological regime of the wetland;
- Measures of the degree of modification to the hydrological regime and connectedness of the wetland including built infrastructure;
- Evidence of channel or bank destabilisation;
- Presence of wetland pest plants and degree of wetland vegetation cover modification.

An attribute set that is appropriate to the aquatic ecosystem types present in the Beetaloo SREBA study area will be developed prior to field sampling commencing, to be approved by DEPWS.

Analysis

Analysis of data from regional biodiversity surveys will include:

- identification of aquatic flora and fauna assemblages;
- calculation of summary biodiversity metrics (e.g. richness, diversity) at a site, assemblage and regional ecosystems scale;
- evaluation of the distribution of these assemblages in relation to aquatic ecosystem units 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);
- refinement of the classification and mapping of aquatic ecosystems in the study area, including a detailed typology based on biological and physical attributes.

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 2000;
- species listed as data-deficient or near-threatened under the NT Territory Parks and Wildlife Conservation Act 2000, 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; and
- species of high cultural value within the Beetaloo SREBA region.

Based upon existing data compiled for the GBA program, the Gulf Snapping Turtle (Elseya lavarackorum) and Largetooth Sawfish (Pristis pristis) will be the subject of targeted surveys. Additional species of high ecological and/or cultural value that will be subject to targeted survey may be identified during the initial stages of this project.

Sample methods

Preliminary habitat suitability maps for each of these species will be prepared, based upon the preliminary regional ecosystem mapping, known habitat requirements and current distribution modelling, to inform survey design.

Targeted sampling will be undertaken across a gradient of habitat suitability. Sampling design will incorporate appropriate sampling methods and consider sampling effort and seasonal timing to maximise detection probabilities of targeted species.

Conventional sampling methods for turtles and fish outlined in Section 4.4.3 will be used for these species. In addition, eDNA methods will be trialled, and if effective, deployed for further assessment of the occurrence of these species.

Regional biodiversity surveys may indicate the presence of significant species that were not identified in the initial selection process. In this case, the criteria and other considerations outlined in the SREBA Framework should be applied to determine if additional targeted survey is required for these species in consultation with DEPWS.

Analysis

Spatial distribution models will be developed for each significant targeted species within the Beetaloo SREBA 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 presence-based approaches such as MaxEnt (Elith *et al*. 2011). In all cases, modelling will quantify the uncertainty associated with the predicted distribution.

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

DELIVERABLES AND REPORTING

The Aquatic Ecosystems Baseline Report for a SREBA will contain detailed descriptions of the methods, results, analyses and synthesis products, as well as cataloguing 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 from the aquatic ecosystems baseline studies that will be reported are described in Table 4. Summary outputs from the assessment will be in formats that are readily available, and comprehensible, to a broad audience (such as web-enabled, interactive maps).

Component	Deliverable
Regional biogeographic patterns for aquatic biodiversity	Typology of aquatic ecosystems aligned with the ANAE framework. Mapping of the extent and distribution of aquatic ecosystem types. Evaluation of patterns of species richness in relation to aquatic ecosystems, and to measured and remote-sensed environmental covariates. Description and evaluation of distribution patterns of floristic and faunal assemblages in relation to aquatic ecosystems. 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, communities and sites	Identification of HEVAE types present within the study area and maps of their extent and distribution. Identification of aquatic ecosystems of high cultural value. 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 distributions of significant species in the context of their broader distributions, occurrences and habitat requirements.

Table 4. Information products and outputs from the aquatic ecosystems baseline studies.

Synthesis

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 will be undertaken. Close collaboration between Water, Aquatic Ecosystem and Terrestrial Ecosystem domains is required during the synthesis, due to close links between the former two in relation to water-dependent ecosystems, and between the latter two in relation to describing ecological values and identifying high conservation value areas.

Areas of high conservation value

Areas of high conservation value contain biological or ecological values considered 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; and
- botanical significance.

These criteria may need to be modified in consultation with DEPWS to apply them effectively at the regional scale of the Beetaloo Sub-basin Other criteria such as those developed by the Aquatic Ecosystems Task Group (AETG) for the identification of High Ecological Value Aquatic Ecosystems (HEVAE) will be considered (AETG 2012b). These criteria include (1) diversity, (2) distinctiveness, (3) vital habitat including dry season refugia, (4) naturalness, and (5) representativeness. One or several attributes are assessed for each criterion in each assessment unit using either empirical or modelled data. Decision rules will be developed for identifying threshold values for HEVAEs.

Identification of areas of high conservation value will also include consideration of requirements for buffers and/or corridors in order to ensure maintenance of ecosystem processes and viability of local populations of threatened species.

Sensitivity of significant ecosystem types, sites or 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 of habitat loss, fragmentation, or other forms of ecological disruption, that could accompany any onshore shale gas development on significant species and ecological communities will be assessed.

The Geological and Bioregional Assessment Program 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 studies will allow this assesment to be applied to a broader range of values and with better resolution than currently considered by GBA.

The assessment will identify levels of uncertainty in both the input data and models and the subsequent sensitivity assessment. The sensitivity of aquatic 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, water extraction, other disruptions to flow or climate change.

Monitoring

Building on the baseline data collection and analyses, monitoring programs will be designed for any significant species, HEVAEs 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, suitable spatial distribution of suitable sampling sites and appropriate methodology for each recommended monitoring program.

Data management

All data collected during the SREBA aquatic 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 aquatic ecosystem data, this is likely to apply in 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 as prescribed by DEPWS. 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 dataset (spatial and non-spatial) associated with the SREBA.

Data will be curated and organised under a data management plan developed for the Aquatic 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
Preliminary mapping of aquatic ecosystems and site selection for regional surveys	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
Final report and provision of all final datasets	November 2022

ROLES AND RESPONSIBILITIES

Aboriginal knowledge and values

The Social Cultural and Economic studies will collaborate with the Aquatic Ecosystems 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 vegetation, 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.

Compliance requirements

Permits

All vertebrate and some invertebrate fauna surveys require a permit under the Territory Parks and Wildlife Conservation Act, 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

Fish sampling using restricted equipment (such as Fyke nets and electrofishing equipment) requires an S17 Special Research Permit from the Director of Fisheries (Department of Industry, Tourism and Trade).

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 willl 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 some 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.

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 landholder requirements, SREBA Factsheets, and other relevant documentation.

The SREBA management team will liaise directly with the Aboriginal Areas Protection Authority (AAPA) to obtain clearances for field work, and field work teams will abide by the conditions 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 aquatic ecosystem studies will be required to contribute to stakeholder engagement activities coordinated through the SREBA management team, which may include:

- 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 reporting 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 aquatic ecosystem studies will provide updates to the DEPWS SREBA management team on progress and any 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.
Unfavourable weather conditions limiting effectiveness of field sampling	There is flexibility in the works program to rearrange field work to limit some of these effects.
Field WHS incidents	Well established WHS standards and SOPs for remote area fieldwork in line with NT Government WHS policies and procedures.
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, Department of Industry Tourism and Trade (DITT) and the Museum and Art Gallery of the NT (MAGNT) possesses extensive expertise in ecosystem mapping, and the design, collection and analyses of data for most of the relevant taxonomic groups. Additional relevant expertise is available elsewhere in the NT and Australia more broadly.

REFERENCES

AETG (2012a) *Aquatic Ecosystems Toolkit, Module 2: Interim Australian National Aquatic Ecosystem Classification Framework*. Australian Government, Department of Sustainability, Environment, Water, Population and Communities. **environment.gov.au/system/files/resources/08bfcf1a-0030-45e0-8553-a0d58b36ee03/files/ae-toolkit-module-2-anae-classification.pdf.**

AETG (2012b) *Aquatic Ecosystems Toolkit. Module 3: Guidelines for Identifying High Ecological value Aquatic Ecosystems (HEVAE)*. Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra. **environment.gov.au/system/files/resources/ab0c5b5a-9e21-4573-9823-641996b58961/files/ae-toolkit-module-3-identifying-hevae.pdf**

Brocklehurst P, Lewis D, Napier D and Lynch D (2007) *Northern Territory Guidelines and Field Methodology for Vegetation Survey and Mapping*. Technical Report No. 02/2007D. Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory.

Department of Environment and Science, Queensland (2020) Index of Wetland Condition (IWC). WetlandInfo website, accessed 1 February 2021. **wetlandinfo.des.qld.gov.au/wetlands/resources/tools/assessment-search-tool/index-of-wetland-condition-iwc/**

Duguid A, Barnetson J, Clifford B, Pavey C, Albrecht D, Risler J and McNellie M (2005) *Wetlands in the arid Northern Territory. A report to the Australian Government Department of Environment and Heritage on the inventory and significance of wetlands in the arid NT*. Northern Territory Government Department of Natural Resources, Environment and the Arts. **nt.gov.au/__data/assets/pdf_file/0018/262224/wetlands-in-the-arid-nt.pdf.**

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE and Yates CJ. (2011) A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, 17: 43-57. doi:10.1111/j.1472-4642.2010.00725.x

Eyre, TJ, Kelly AL, Neldner VJ, Wilson BA, Ferguson DJ, Laidlaw MJ and Franks AJ (2015) *BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2*. Queensland Herbarium, Department of Science, Information Technology, Innovation and Arts, Brisbane.

Kennard MJ (ed) (2010) *Identifying high conservation value ecosystems in northern Australia*. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Charles Darwin University, Darwin.

Lloyd J and Cook S (2001) *Northern Territory AUSRIVAS; Australian River Assessment Scheme: sampling and processing manual*. Northern Territory Department of Lands, Planning and Environment.

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. (dataset). **dx.doi.org/10.4225/28/5a9f31e23e80b**

Pusey BJ, Burrows DW, Kennard MJ, Perna CN, Unmack PJ, Allsop Q and Hammer MP (2017) Freshwater fishes of northern Australia. *Zootaxa*, 4253, 1–104

Rees G, Oberprieler S, Nielson D, Watson G, Shackleton M, Davis J (2021) *Characterisation of the Stygofauna and Microbial Assemblages of the Beetaloo Sub-basin, Northern Territory*. CSIRO, Australia.

Ward S and Harrison L (2009). *Recognising sites of conservation significance for biodiversity values in the Northern Territory*. Department of Natural Resources, Environment, the Arts and Sport, Darwin, Northern Territory. **hdl.handle.net/10070/240660**

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