Stantec

Memo

Project:	Targeted Yinnietharra Rock-dragon Survey	**Project No:**	30451359
To:	Claire McGuire Electrostate Malinda Pty Ltd for Delta Lithium Limited Level 2 – 18 Richardson St West Perth 6005	**Date:**	9 September 2024
From:	Caitlin Roberts Stantec Australia Pty Ltd 226 Adeliade Terrace, Perth, 6000		

Targeted Yinnietharra Rock-dragon Survey and Species Distribution Model

1. Introduction

1.1 Project and Survey Context

Electrostate Malinda Pty Ltd (Electrostate) is seeking to develop the Yinnetharra Lithium Project (the Project), located 110 kilometres (km) north-east of Gascoyne Junction in the Gascoyne region of Western Australia (Figure 1-1). Electrostate commissioned Stantec Australia Pty Ltd (Stantec) to undertake a dual-phase Detailed Terrestrial Vertebrate Fauna and Invertebrate Short-range Endemic (SRE) Fauna Survey (the Detailed Survey). Following on from this, Stantec were engaged to complete a Targeted Yinnietharra Rock-dragon (*Ctenophorus yinnietharra*) Survey (the Targeted Survey), with the species identified during a previous desktop assessment as possibly occurring in the Detailed Survey Area. The species is listed as Vulnerable under State (*Biodiversity Conservation Act 2016*) and Federal (*Environment Protection and Biodiversity Conservation Act 1999*) legislation

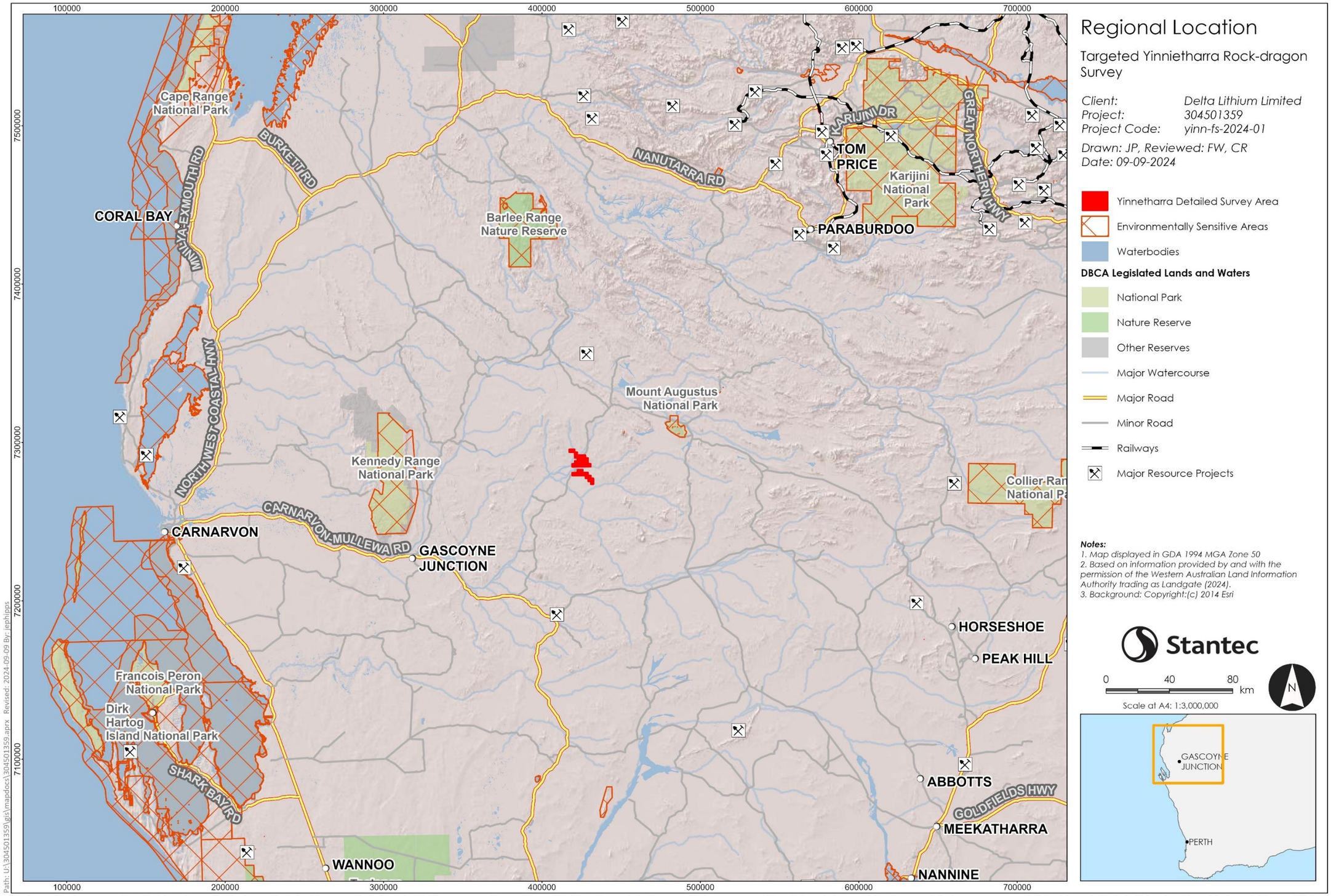
During Phase 1 and 2 of the Detailed Survey, 17 targeted searches were undertaken for the Yinnietharra Rock-dragon, however it was not recorded from within the Detailed Survey Area. During Phase 2, one individual was observed opportunistically along Cobra-Dairy Creek Road, approximately 15 km south west of the Detailed Survey Area. Given there is limited information available on species ecology, distribution, and habitat preferences, Stantec was commissioned to undertake a Targeted Survey of the Detailed Survey Area and broader region where the species has been recorded historically (the Regional Survey Area).

This memorandum outlines the results of the Targeted Survey and species distribution modelling (SDM) and adheres to relevant technical guidance for terrestrial fauna surveys, and Yinnietharra Rock-dragon (DSEWPaC 2011; EPA 2020). It comprises an appendix to the Detailed Terrestrial Vertebrate Fauna and Invertebrate SRE Fauna Technical Report, which consolidates the results of the Detailed Survey and Targeted Survey.

1.2 Objectives

The specific objectives of the Targeted Survey included the following:

- Complete predictive habitat modelling in the form of a SDM for the Yinnietharra Rock-dragon to map its potential distribution;
- Complete a targeted survey for the Yinnietharra Rock-dragon to better understand the species occurrence, distribution and habitat associations within the Detailed Survey Area and the broader region; and
- Assess the likelihood of the Yinnietharra Rock-dragon occurring within the Detailed Survey Area based on Targeted Survey results and habitat requirement



Regional Location

Targeted Yinnietharra Rock-dragon Survey

Client: *Delta Lithium Limited*
Project: *304501359*
Project Code: *yinn-fs-2024-01*

Drawn: JP, Reviewed: FW, CR
Date: 09-09-2024

- Yinnetharra Detailed Survey Area
- Environmentally Sensitive Areas
- Waterbodies

DBCA Legislated Lands and Waters

- National Park
- Nature Reserve
- Other Reserves
- Major Watercourse
- Major Road
- Minor Road
- Railways
- Major Resource Projects

Notes:
1. Map displayed in GDA 1994 MGA Zone 50
2. Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2024).
3. Background: Copyright:(c) 2014 Esri

Stantec

0 40 80 km

Scale at A4: 1:3,000,000

N

Figure 1-1: Regional location of the Detailed Survey Area

1.3 Yinnietharra Rock-dragon

The Yinnietharra Rock-dragon is a rock-dwelling agamid lizard known only from areas of southern Yinnetharra Station, and a single location from Minnie Creek Station (DBCA 2022). Published records of the species are over 30 years old, with the exception of the Minnie Creek record from 2006 (DBCA 2022). However, there are anecdotal reports of herpetologists visiting Yinnetharra Station within the last five years and recording the species (S. Wilson, pers. comm. 2024). Due to the Yinnietharra Rock-dragon's limited distribution and small population size, it is vulnerable to any stochastic events, which may impact the species (DEWHA 2008).

The Yinnietharra Rock-dragon is an understudied reptile with a limited distribution, and consequently little is known about the species. Published definitions of suitable Yinnietharra Rock-dragon habitat are also limited, with the *Approved Conservation Advice for Ctenophorus Yinnietharra* (DEWHA 2008) stating that ground surveys to determine the species habitat preferences are a high research priority. Current habitat descriptions state that species, occupies tall open shrublands, where it inhabits low granite outcrops which are often less than 1 m^2 in area (Cogger *et al.* 1993; G. Shea and M. Peterson pers obs in DEWHA 2011). The Yinnietharra Rock-dragon is a habitat specialist, inhabiting granite outcrops composed of Archaean (>2.5 billion years ago) gneissic biotite granites and granodiorite (Cogger *et al.* 1993). It does not appear to occupy the massive granite outcrops in the same area, which are instead inhabited by the widely distributed Ring-Tailed Dragon (*Ctenophorus caudicinctus*) (G. Shea and M. Peterson pers obs in DEWHA 2011). Herpetologists have suggested that the Yinnietharra Rock-dragon and Ring-tailed Dragon do not co-occur (S. Wilson, pers. comm. 2024).

2. Methods

2.1 Species Distribution Modelling

2.1.1 Application

SDMs are a widely used machine learning technique that aim to understand the ecological niche (i.e., preferred habitat) of an organism, and utilise abiotic and biotic variables to model their potential persistence across a landscape (Elith and Leathwick 2009). A variety of models, such as Maximum Entropy (MaxEnt), can be used to identify these potential factors and subsequently map potential distribution of a species across the landscape. These models have been used successfully to understand the distribution of reptile species globally (Biber *et al.* 2022), including understudied species limited by knowledge gaps in habitat requirements and ecological drivers (Ahmadzadeh *et al.* 2013; Torkkola *et al.* 2021).

Stantec developed SDMs for the Yinnietharra Rock-dragon to:

- understand the environmental factors that drive distribution and habitat selection;
- spatially map the probability of which the species would occur in a given area; and
- use the outputs to guide the on-ground Targeted Survey.

2.1.2 Data Processing

Data in the form of presence and pseudo-absence points were used to fit the SDMs for the Yinnietharra Rock-dragon. Pseudo-absences are defined as points that represent locations where a species is assumed to be absent, used as verified absence data is often difficult to obtain and may be biased due to the timing and methods of data collection (Barbet-Massin *et al.* 2012). Presence records of the Yinnietharra Rock-dragon were sourced from the Department of Biodiversity, Conservation, and Attractions' (DBCA) Threatened and Priority Fauna database and subject matter expert (SME) Steve Wilson.

Pseudo-absence points were randomly generated through the *dismo* R software package, which provides functions for species distribution modelling (Hijmans *et al.* 2017), and involves predicting the geographic distribution of a species based on environmental variables. The software was used to create a total of 5,000 background points across the SDM Study Area. There are limited published records of the Yinnietharra Rock-dragon, and only presence points that were acquired from DBCA and SMEs were used for initial modelling, equating to 23 confirmed records.

A range of environmental variables were explored and tested to inform species distribution modelling, to understand the habitat requirements for the Yinnietharra Rock-dragon and drive on-ground targeted searches. A total of 24 variables were selected, a process based on consultation with internal and external SMEs, to ensure relevance to the modelling (Table 2-1). Datasets were sourced from open-access directories (Grundy *et al.* 2015; Harwood *et al.* 2018; Mokany 2022) or calculated

by Stantec from publicly available datasets. To improve the resolution of the datasets, a resampling method was applied, through a bilinear interpolation, resulting in an increase from their native resolution (250 m to 90 m) to 50 m^2. Pearson's correlation test was selected to identify the similarity between variables, where those that exceeded >0.7 (or <-0.7) collinearity were removed from the analysis or model selection, resulting in 17 remaining environmental variables (Appendix B).

2.1.3 Modelling Approach

Two models were developed for pre-field and post-field assessments for the following purposes:

- Pre-field – to drive on-ground Targeted Survey by predicting potential Yinnietharra Rock-dragon occurrence and habitat; and
- Post-field – used to finalise the model and to provide a more refined understanding of broad-scale persistence of the Yinnietharra Rock-dragon in the SDM Study Area.

An ensemble modelling approach was selected for both pre-field and post-field assessments, to systematically test multiple algorithms at once and combine predictions from multiple assessed models, with four algorithms within the *tidysdm* R software package (Leonardi *et al.* 2023). These models comprise MaxEnt, Random Forest, XGBoost, and Generalised Linear Model. Evaluation of these models was done through a spatial cross-validation approach, whereby presence and pseudo-absence points were randomly assigned into three groups with an 80/20 split for testing and validation purposes (Mahoney *et al.* 2023). Each model's accuracy was evaluated using the area under the receiver operator curve (AUC) to understand the model's capability for predicting in areas without known occurrences. AUC values range between 0 to 1, whereby a value closer to 1 signifies a better performing model, while a value closer to 0.5 suggests the model is no better than chance.

For pre-field modelling, a total of 13 models were generated to test for initial accuracy. Seventeen environmental variables were initially incorporated into the models, based on the outcomes of the Pearson's correlation. One of these models showed the highest accuracy (AUC = 0.80 ± 0.08), which was a combination of the XGBoost and MaxEnt algorithms (Figure 2-1). Variables that contributed to the highest model prediction, comprised climatic (EPA, ADM, and TXM) and soil geochemical variables (Phosphorus and Sand Content).

Post-field modelling was completed after the Targeted Survey and incorporated new Yinnietharra Rock-dragon records that were collected. During this process, additional data investigation was carried out to identify the models with the highest prediction accuracy. The top two models were combined through a weighted sum approach, where each AUC score was used as their respective weights. A threshold of 0.60 was then used to filter the final surface into a binary map of suitable (1) and non-suitable (0) areas. These estimates were then used to predict the total suitable habitat (ha) throughout the SDM Study Area.

Table 2-1: Environmental variables tested for the Yinnietharra Rock-dragon to inform modelling.

Component	Dataset	Description	Native Resolution*	Units	Citation
Climate	ADM	Mean annual aridity index - 30-year average centered on 1990.	250m	Proportion	(Harwood *et al.* 2018)
	TXM	Maximum temperature - annual mean.	250m	Celsius	
	EPA	Annual potential evaporation.	250m	Celsius	
	PTI	Minimum monthly precipitation.	250m	mm	
	PTX	Maximum monthly precipitation.	250m	mm	
Ecological Diversity	Soil Bacteria Beta diversity (NMDS Axis 1)	Beta diversity of soil bacteria.	90m	unitless	(Roman-Dobarco *et al.* 2022)
	Fungi Beta diversity (NMDS Axis 1)	Interpolated beta diversity of fungi.	90m	unitless	
	Plant Beta Diversity Richness	Plant community species richness.	90m	Count	(Mokany *et al.* 2022)
	Reptile Diversity Richness	Reptile community species richness.	90m	Count	(Mokany 2022)
Hydrology	Distance to Water Courses	Surface illustrating the distance to the nearest water courses.	90m	m	Stantec, 2024
Soils	Total Organic Carbon	Mean percent content between 0-200 cm in depth.	90m	%	(Malone and Searle 2021)
	Total Phosphorus Content		90m	%	
	Available water capacity		90m	%	

Component	Dataset	Description	Native Resolution*	Units	Citation
	Clay content		90m	%	
	Depth of regolith		90m	%	
	Sand Content		90m	%	
	Silt Content		90m	%	
	Rock outcrop occurrence	Occurrence of rocky outcrops.	90m	Binary	
Topography	Slope	Slope of the landscape.	90m	degrees	Stantec, 2023
	Curvature	Curvature of the landscape.	90m	degrees	
	Aspect*	Directional aspect of the landscape	90m	unitless	
	Digital Elevation Model*	Model summarising the topographical elevation of the continent of Australia.	90m	unitless	
Geostatistics	Sentinel Bands 1-12 PCA Axis 1	Principal component analysis of all Sentinel bands.	90m	unitless	Stantec, 2023
	Sentinel Bands 1-12 PCA Axis 2		90m		

* All datasets converted from native resolution to 50m[2].

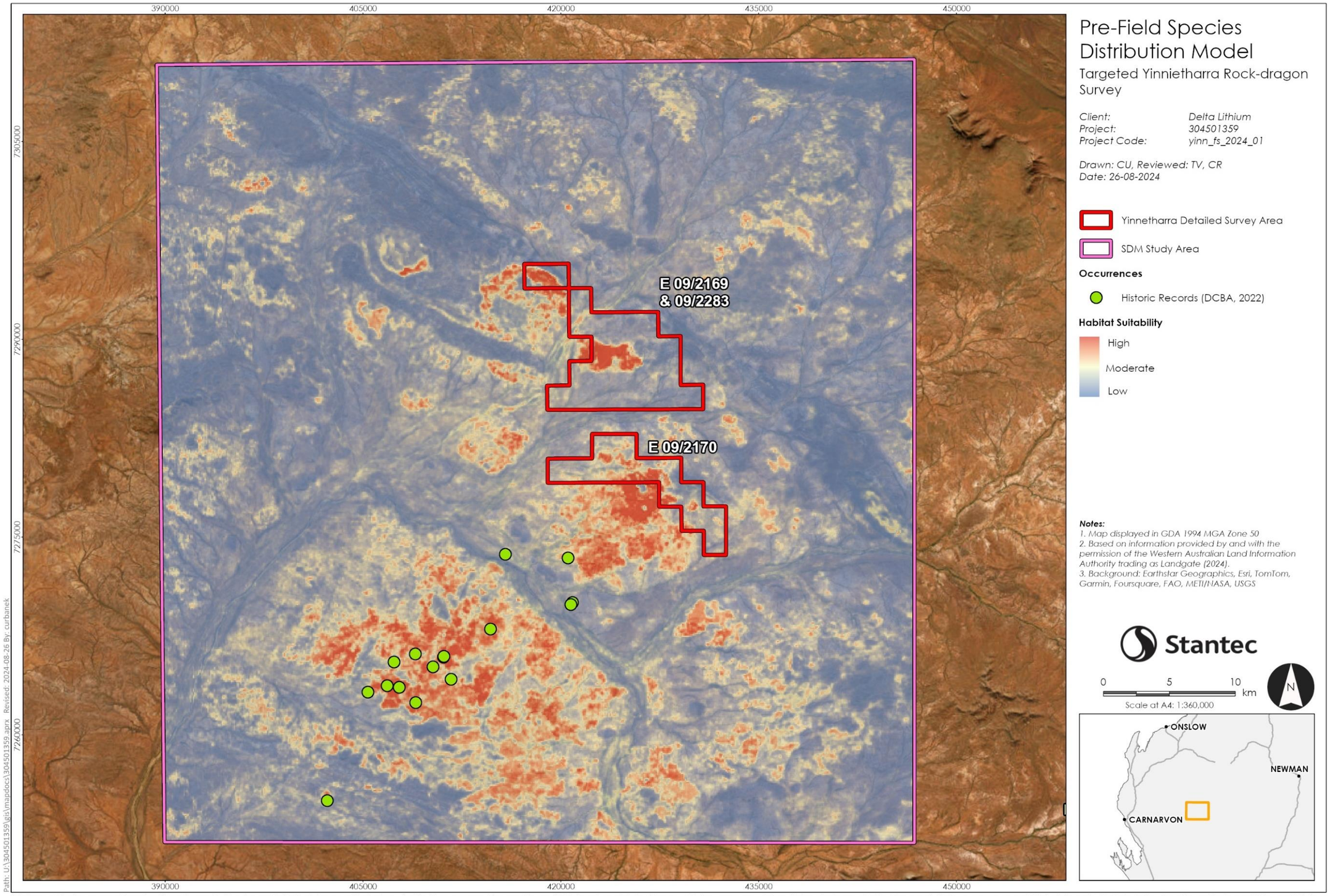


Figure 2-1: Pre-field species distribution model showing the habitat suitability of the Yinnietharra Rock-dragon (red shows high suitability and blue shows low suitability habitat).

2.2 Field Survey

2.2.1 Overview and Guidance

Targeted methods were employed for the Yinnietharra Rock-dragon Targeted Survey, aligning with the following relevant regulatory guidelines:

- Technical Guidance: Sampling Methods for Terrestrial Vertebrate Fauna (EPA 2016);
- Technical Guidance: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA 2020); and
- Survey Guidelines for Australia's Threatened Reptiles (DEWHA 2011).

Given the limited survey guidance available for the Yinnietharra Rock-dragon, methods were further refined following consultation with reptile experts Ray Llyod (Subconsultant Principal Zoologist), Paul Doughty (Curator of Herpetology at WA Museum), and Steve Wilson (Herpetologist and Information Officer at the Queensland Museum).

2.2.2 Personnel

The Targeted Survey was conducted by experienced Stantec zoologist Caitlin Roberts and specialist herpetologist Steve Wilson. Caitlin has four years' experience conducting fauna surveys across Western Australia. Steve has over 50 years' experience conducting reptile surveys and has authored several widely used Australian reptile field guides. Additionally, Steve had previously visited Yinnetharra Station and recorded the Yinnietharra Rock-dragon.

2.2.3 Survey Locations

The Targeted Yinnietharra Rock-dragon Survey was conducted of the following Survey Areas (Figure 2-1):

- Detailed Survey Area: three tenements held by Electrostate (E09/2169, E09/2170, and E09/2283), which comprise the Detailed Survey Area,; and
- Regional Survey Area: three tenements held by Reach Resources (E09/2388, E09/2354, and E09/2375), and one tenement held by Ashcroft Resources (E09/2552)

2.2.4 Timing and Weather

The Targeted Survey was conducted between April 30th and May 3rd, 2024. The optimal time to survey reptiles in the Gascoyne region is from September to April, when temperatures are higher, and reptiles are most active (EPA 2020). The nearest Bureau of Meteorology (BOM) weather station with recent rainfall data is Cobra Airstrip (7209), located 36.6 km north east of the Survey Areas. The Survey Areas received 3.4 mm of rain on April 29th, however conditions were dry for the duration of the Survey (BoM 2024). The nearest BOM weather station with recent temperature data is Carnarvon Airport (6011), located 250 km south west of the Survey Areas. During the Targeted Survey daily maximum temperature ranged from 30.6 to 36.1°C and daily minimum temperatures 15.2 to 21.4 °C (BoM 2024). Overall, conditions were clear, warm and dry, therefore suitable for surveying reptiles.

2.2.5 Targeted Searches

Fifteen targeted searches for the Yinnietharra Rock-dragon were conducted on foot at 13 locations, five within the Detailed Survey Area and eight within the Regional Survey Area (Figure 2-3). Targeted searches were conducted for a minimum of 30 minutes, however time spent at a location varied depending on the extent of outcropping present. Targeted searches consisted of looking in rock crevices and gently lifting rocks and exfoliating granite. Targeted search locations were selected based on the following:

- Occurrence of low granite outcrops (identified from satellite imagery and during Phase 1 and Phase 2 of the Detailed Survey);
- Areas identified in the SDM pre-field assessment as having a high probability of supporting Yinnietharra Rock-dragon; and
- Proximity to historic Yinnietharra Rock-dragon records.

In addition to searches on foot, access tracks within the Survey Areas were driven at a slow speed (~30km/h) with an observer searching for lizards basking on rocks. This had previously proven an effective method for detecting Yinnietharra Rock-dragons when weather conditions are suitable for basking (warm and sunny conditions; S. Wilson, pers. comm. 2024).

2.2.6 Habitat Assessments

Habitat assessments were conducted at targeted search locations and opportunistically where Yinnietharra Rock-dragon were recorded during the Targeted Survey to gain a better understanding of the species' preferences (Figure 2-3). This data was then used to create criteria for assessing the suitability of habitat for the Yinnietharra Rock-dragon. At each assessment location, the following key habitat parameters were recorded:

- Landscape and geological (substrata) features;
- Vegetation cover, condition and species composition;
- The presence or absence of woody debris, leaf litter, hollows, outcropping or other habitat structures;
- Ground cover and composition;
- Hydrological features, such as the presence or absence of drainage line and surface water; and
- Types of disturbance and levels of disturbance.

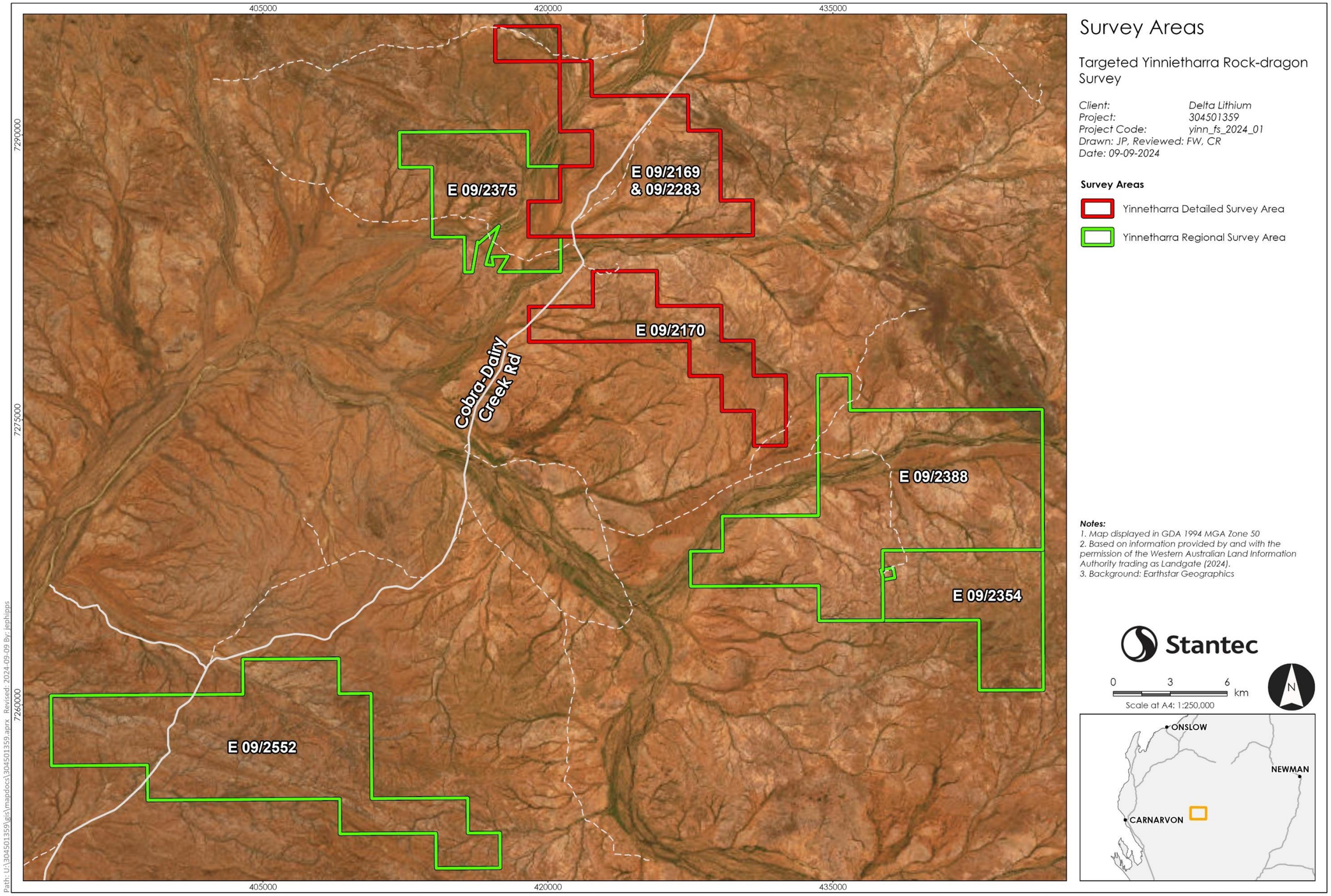


Figure 2-2: Location of the Survey Areas.

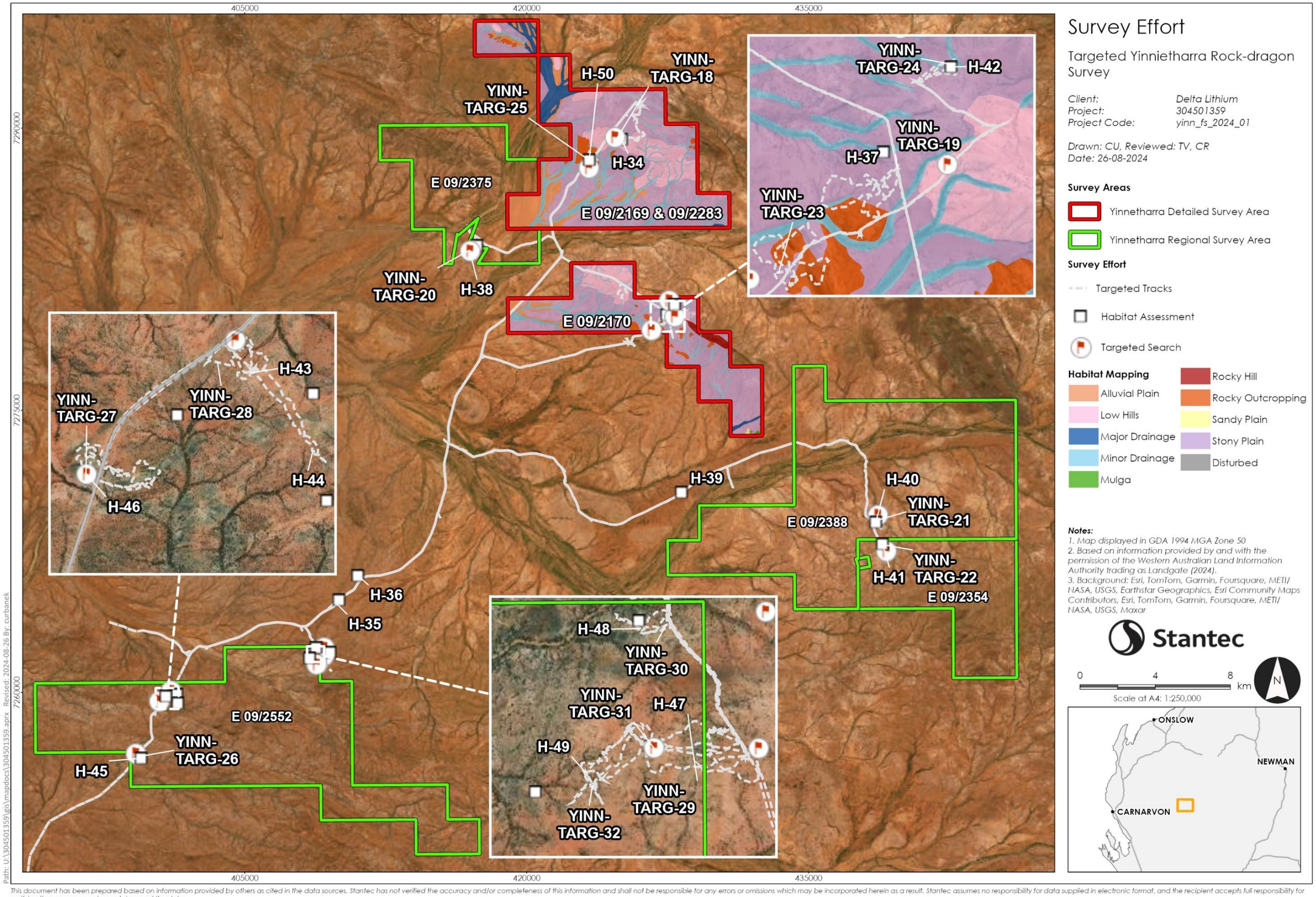


Figure 2-3: Survey effort including locations of targeted searches and habitat assessments for the Yinnietharra Rock-dragon.

2.3 Limitations and Constraints

The Targeted Survey was constrained by limited access to tenements on which the Yinnietharra Rock-dragon had been historically recorded. Of the 28 historic Yinnietharra Rock-dragon records within 20 km of the Survey Areas, only two occurred on tenements where land access was permitted. Stantec was unable to visit many locations where the species may occur, limiting efforts to ground truth species distribution modelling. In addition, lack of access to potential Yinnietharra Rock-dragon populations may have decreased the number of data points (Yinnietharra Rock-dragon records) that could be inputted into the SDM to refine accuracy.

3. Results

3.1 Species Distribution Modelling

A total of 10 post-field models were generated based on the results from the on-ground Targeted Survey. Based on the 10 models tested, two were identified as suitable for assessment (Table 3-1) and comprised of the MaxEnt, and XGBoost algorithms (Appendix C). The two models represented a climate-based model, which only tested datasets that represent bioclimatic variables (e.g., temperature, precipitation, evaporation), and a biophysical based model, which only tested physical (e.g., topography) and biological (e.g., ecological diversity, hydrology, soil geochemistry) variables.

The climate only based model was observed to have a high accuracy (MaxEnt - AUC = 0.87 ± 0.04) in relation to other models tested and is presented in Appendix C Figure C 1. From this model, the mean annual aridity (ADM), mean maximum temperature (TXM), and annual potential evaporation (EPA) datasets were identified as having the highest contribution to the model's performance (Table 3-1), while the remaining climate datasets showed minimal influence in model predictions. All three datasets showed a negative relationship to the predicted distribution of the Yinnietharra Rock-dragon.

The biophysical based model was observed to have a high accuracy (MaxEnt & XGBoost - AUC = 0.91 ± 0.05) in relation to all models tested and is presented in Appendix C Figure C 2. From this model, the Reptile Richness and Fungal Diversity were identified as having the highest contribution to the model's performance (Table 3-1). Reptile Richness showed a positive relationship to predicted distribution, while Fungal Diversity showed a negative relationship to the distribution of the Yinnietharra Rock-dragon.

These two models were combined into a final weighted ensemble model, presented in Figure 3-1. According to this model, the highest habitat suitability for the Yinnietharra Rock-dragon is found in the south western section of the landscape, aligning with both historical records and data from the Targeted Survey. According to the SDM Study Area, 20,035 ha were identified as highly suitable habitat for the species. Of this, a total of 1,471 ha of highly suitable habitat occurred within the Regional Survey Area. However, no areas within the Detailed Survey Area were classified as having a high habitat suitability. Some moderately suitable habitats are present in isolated southern sections of the Detailed Survey Area and in the north west section of the SDM Study Area, outside of the designated Survey Areas. However, the majority of the Detailed Survey Area was classified as having low suitability habitat (Figure 3-1).

Table 3-1: Summary output of the two highest performing models, showing the relationship (+/-) to predicted distribution.

Model	Model Accuracy	Algorithms	Datasets	Dataset Importance	Relationship
Biophysical	0.91 ± 0.05	MaxEnt & XGBoost	Reptile Richness	0.39	Positive (+)
			Fungal Diversity	0.30	Inverse (-)
			PCA-2	0.11	Positive (+)
			Geology	0.09	Positive (+)
Climate	0.87 ± 0.04	Maxent	ADM	0.44	Inverse (-)
			EPA	0.26	Inverse (-)
			TXM	0.15	Inverse (-)
			PTX	0.11	Positive (+)

Note: refer to Table 2-1 for dataset information.

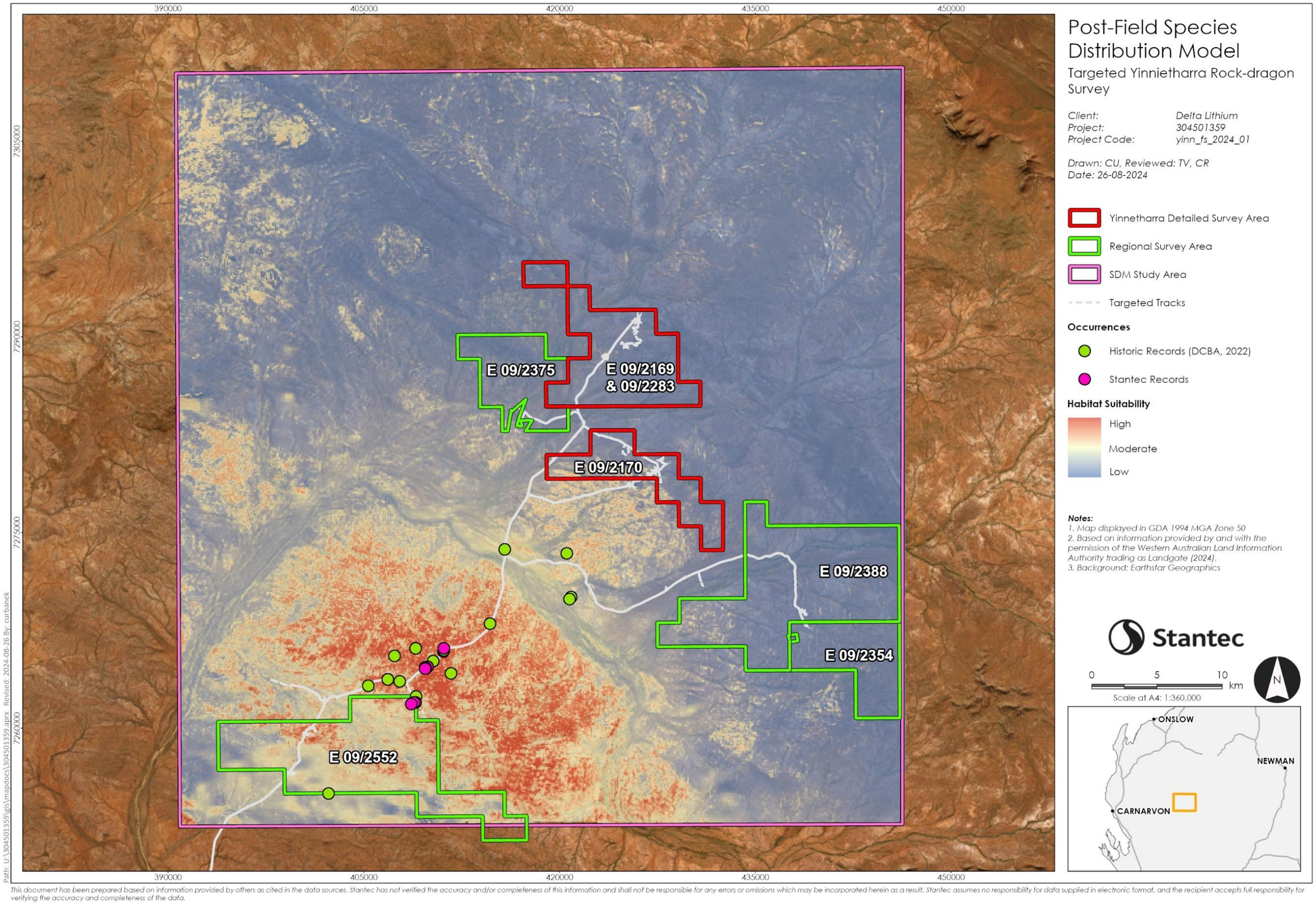


Figure 3-1: Ensemble post-field species distribution model, showing the habitat suitability of the Yinnietharra Rock-dragon based on the combined climate and biophysical model outputs (red shows high suitability and blue shows low suitability habitat).

3.2 Field Survey

3.2.1 Targeted Survey

The Yinnietharra Rock-dragon was not recorded within the Detailed Survey Area. Instead, another rock-dwelling species, the Ring-tailed Dragon, was frequently recorded during targeted searches and observed basking from a slow-moving vehicle during the Target Survey. Within the Regional Survey Area, the Yinnietharra Rock-dragon was recorded at one location on tenement E09/2552, approximately 450 m south of the nearest historical record from 1984 (Plate 3-1; Figure 3-2). Additionally, the species was recorded opportunistically at one location along the public gazetted Dairy Cobra-Creek Road basking on rocks (Figure 3-2). Further targeted survey work was not undertaken at this location as Stantec did not have land access permission.

On tenement E09/2552 three targeted searches were undertaken over two days covering an area of approximately 8 ha. Within this area, a total of 12 Yinnietharra Rock-dragons were recorded comprising of three males, six females, and three juveniles. During the first targeted search (TARG-29; Figure 2-3) only a single female was recorded, however this search took place late in the morning when temperatures were still increasing. Given it had not reached the prime temperature for reptile activity, the field team decided to return later that day to conduct further searches.

During the two subsequent searches at this location (TARG-31 and TARG-32; Figure 2-3), Yinnietharra Rock-dragons were readily observed basking on granite outcrops (Plate 3-1). When approached, Yinnietharra Rock-dragons would complete a long run across the plain to the next patch of outcropping. This long run was quite a distinctive behaviour and made them readily identifiable compared to the other *Ctenophorus* species that occur in the region. Yinnietharra Rock-dragons were also observed basking and seeking refuge in woody *Acacia* shrubs. Several juveniles were found by carefully overturning pieces of exfoliating granite.

Seven Yinnietharra Rock-dragons were also observed opportunistically at one location along Cobra-Dairy Creek Road (four males, three females, one juvenile). The location was near a concentration of historic records of the species and the site where Steve Wilson had previously recorded the species (Figure 3-2). Although not included in the Regional Survey Area, a habitat assessment was conducted from the roadside to document suitable Yinnietharra Rock-dragon habitat. Results of this habitat assessment are presented in Section 2.2.6. and Appendix A.

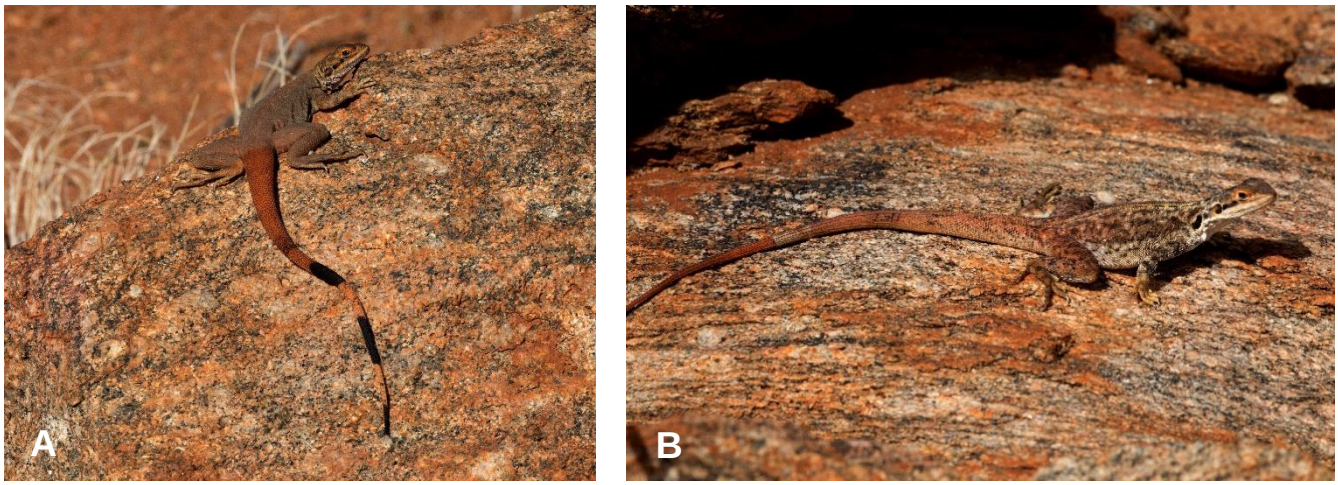


Plate 3-1: (A) Male and (B) female Yinnietharra Rock-dragons recorded during the Targeted Survey (photos supplied by Steve Wilson).

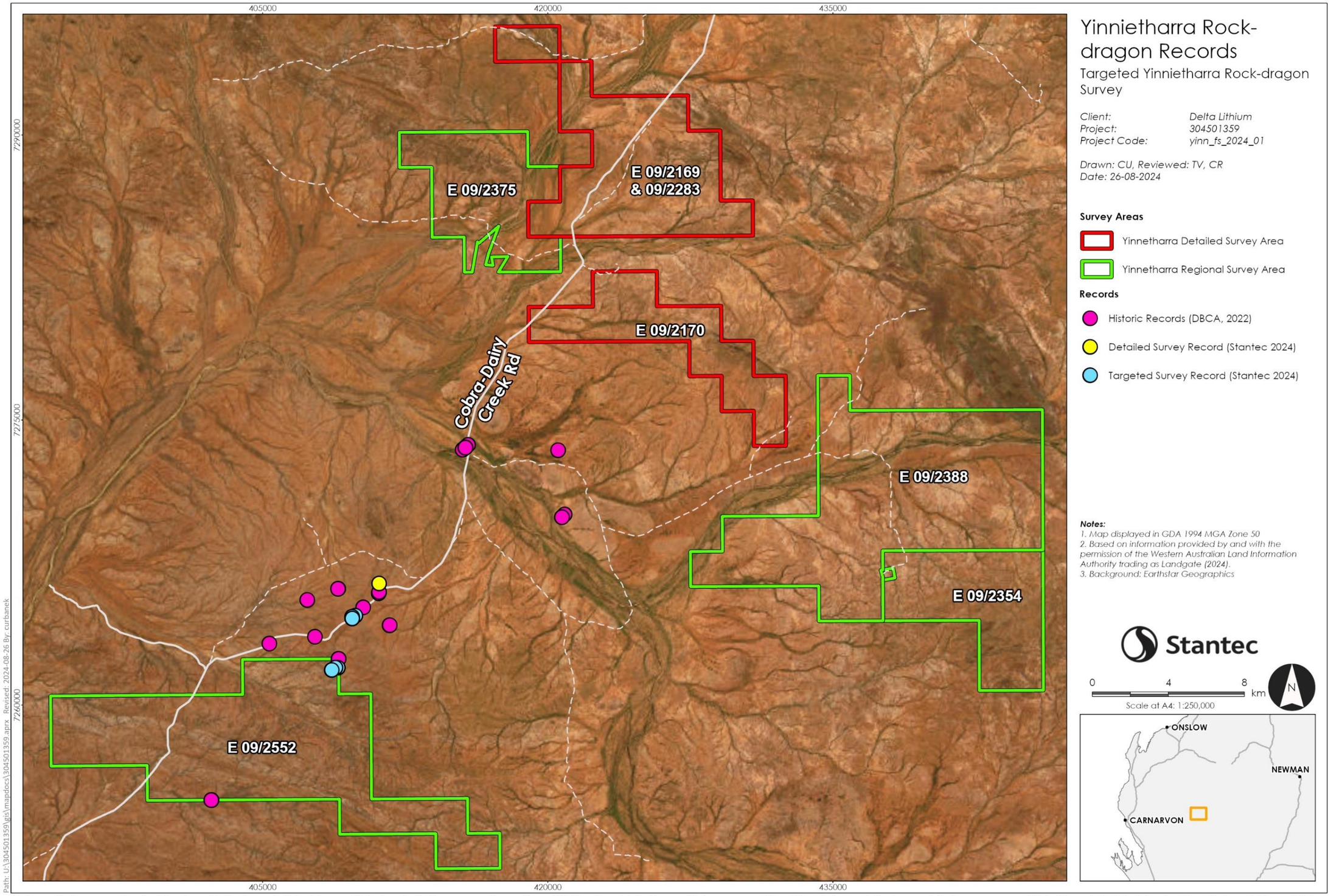


Figure 3-2: Yinnietharra Rock-dragon records from the Targeted Survey, in comparison to previous records from the Detailed Survey and DBCA.

3.2.2 Habitat Assessments

A total of 17 fauna habitat assessments were undertaken during the Targeted Survey (Appendix A). Of these, four were conducted at locations where the Yinnietharra Rock-dragon was confirmed to occur. Based on these assessments, a definition of suitable Yinnietharra Rock-dragon habitat was established in collaboration with Steve Wilson. The definition of suitable habitat is as follows:

- Suitable Yinnietharra Rock-dragon habitat comprises very low, weathered granite outcrops that typically rise to heights of only 0.5 -1.0 m. Outcrops are typically less than 1 m^2 in area; however, some larger outcrops can also be present (>1 m^2, <3 m^2). These low outcrops occur on plains and low rises where they are widely spaced, separated by open, sparsely vegetated expanses spanning about 50-100 m, and are not found in association with larger and more extensive granite outcropping which occurs in the region. Ground cover is predominantly sparse quartz/granite gravel (1-4 cm) and sandy clay soil; however, may contain patches of pebbles (5-10 cm) which are more densely spaced. Overall, ground cover is much less dense than the quartz plain which commonly occurs in the surrounding region. Critical elements within this habitat are the woody shrubs (*Acacia* spp. and *Eremophila* spp.) that offer shade and additional elevated perching sites for the species (Plate 3-2).

Based on this description, criteria were developed to assess suitable Yinnietharra Rock-dragon habitat. For a habitat to be considered suitable it must have the following four characteristics:

1. Substrate – Primarily gravel (1-4 cm) but may be pebble sized (5-10 cm) quartz and granite on sandy clay soils. Rock cover is sparse compared to dense quartz plain habitat that commonly occurs in the surrounding region.

2. Presence of granite outcrops – Species requires low weathered granite outcrops.

3. Size of granite outcrops – Majority (>90%) of outcrops present are only 0.5 to 1 m in height and less than 2 m in length.

4. Density of granite outcrops – Outcrops are sparsely distributed, often separated by distances of 50 to 100 m.

Using these criteria, suitable Yinnietharra Rock-dragon habitat was determined to be present at six habitat assessment sites (Table 3-2). These sites were all within the Regional Survey Area, and no suitable habitat was found within the Detailed Survey Area. While there were areas of granite outcropping within the Detailed Survey Area these sites had much larger and more closely spaced granite outcrops compared to known Yinnietharra Rock-dragon habitat. Even where lower weathered outcrops did occur, ground cover consisted of larger quartz rocks that were densely packed (Plate 3-3). Therefore, based on the criteria developed, there is no suitable Yinnietharra Rock-dragon habitat within the Detailed Survey Area, which aligned with the species modelling results.

Plate 3-2: Examples of suitable Yinnietharra Rock-dragon habitat recorded during the Targeted Survey. Suitability was assessed using the four criteria presented in Section 3.2.2. (A) and (B) site HA-35, (C) site HA-49, and (D) site HA-47.

Plate 3-3: Examples of unsuitable Yinnietharra Rock-dragon habitat recorded in the Detailed Survey Area during the Targeted Survey. Suitability was assessed using the four criteria presented in Section 3.2.2. (A) site HA-34, (B) site HA-37, (C) site HA-42, and (D) site HA-50.

Table 3-2: Habitat assessment sites and suitability to support Yinnietharra Rock-dragons (YRD). Suitability was assessed using the four criteria presented in Section 3.2.2. A check (✓) denotes that a site met that suitability criterion while a cross (×) denotes that it did not meet that suitability criterion. A site must meet all four criteria to be considered suitable.

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Detailed Survey Area	H-34	✓	×	×	×	No	No	
	H-37	✓	×	×	×	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Detailed Survey Area	H-42	✓	×	×	×	No	No	
	H-50	✓	×	×	✓	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-35	✓	✓	✓	✓	Yes	Yes	
	H-36	✓	✓	✓	✓	Yes	Yes*	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-38	✓	×	×	✓	No	No	
	H-39	✓	×	×	✓	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-40	✓	✓	×	×	No	No	
	H-41	✓	✓	×	×	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-43	✓	✓	✓	✓	No	Yes	
	H-44	✓	×	×	✓	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-45	✓	✓	×	×	No	No	
	H-46	✓	×	×	×	No	No	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-47	✓	✓	✓	✓	Yes	Yes	
	H-48	✓	✓	✓	✓	No	Yes	

Survey Area	Site ID	Suitability Criteria				YRD Detected	Suitable YRD habitat?	Photo
		Outcrops Present	Outcrop Size	Outcrop Density	Ground Cover			
Regional Survey Area	H-49	✓	✓	✓	✓	Yes	Yes	

4. Discussion

A total of 15 targeted searches were conducted at 13 locations across the Survey Areas, however Yinnietharra Rock-dragons were only recorded at one search location within the Regional Survey Area (E09/2552) and opportunistically at one location along Cobra-Dairy Creek Road (outside of the Survey Areas). These results are consistent with the Detailed Survey, in which 17 targeted searches and 16 targeted motion cameras were employed and did not detect the species. Published records of the species are also extremely limited, with distribution and ecological preferences considered key knowledge gaps (DBCA 2022; DEWHA 2008).

During the Targeted Survey, weather conditions were warm (>30°C) and clear, and were considered suitable for detecting the Yinnietharra Rock-dragon, which is a surface-active diurnal reptile (DEWHA 2011). The final ensemble SDM also indicated that climate and specifically ADM (mean annual aridity), had the highest importance of all environmental variables tested. This factor represents the ratio of rainfall to evaporation and is a numerical indicator of the degree of dryness at a given location, which had an inverse relationship to the distribution of the species. Reptile diversity was also of high importance, with a positive relationship, suggesting that the Yinnietharra Rock-dragon is more likely to occur and persist in areas that support a diverse reptile fauna assemblage.

The final ensemble SDM indicated that habitat classified as highly suitable for the Yinnietharra Rock-dragon habitat does not occur in the Detailed Survey Area, which was also consistent with the Targeted Survey. The model suggested that some moderately suitable habitat may occur in the southern portion of the Detailed Survey Area, however, the Targeted Survey did not support this finding. These areas of granite outcropping were observed to be larger and more widely distributed compared to known Yinnietharra Rock-dragon habitat. The SDM indicated that the most suitable habitat occurs in the vicinity of the historic and Targeted Survey Yinnietharra Rock-dragon records, located ~15 km southwest of the Detailed Survey Area and typically comprises low weathered granite outcrops (<2 m high), which are sparsely distributed.

The Targeted Survey expanded on the limited published information on suitable Yinnietharra Rock-dragon habitat and the known ecological preferences for the species (Cogger *et al.* 1993; G. Shea and M. Peterson pers obs in DEWHA 2011). While it was previously noted that the species favoured lower granite outcrops, this is only one aspect of likely suitable habitat features. In addition to the presence of low weathered granite outcrops, spacing of outcrops (sparse) and substrate (predominantly a limited cover of gravel) were also important environmental variables that influence the presence of the species. Suitable habitat where the species was recorded only occurred at four habitat assessment sites within the Regional Survey Area.

The results of the Targeted Survey support the theory that Yinnietharra Rock-dragons do not co-occur with Ring-tailed Dragons (G. Shea and M. Peterson pers obs in DEWHA 2011). During the Targeted Survey, Ring-tailed Dragons were frequently observed on larger granite outcrops within the Detailed Survey Area, however, were not found where Yinnietharra Rock-dragons occurred. While the reason for this is currently unknown, the presence of Ring-tailed Dragons may serve as a useful indicator that Yinnietharra Rock-dragons are absent from an area. In contrast, the Yinnietharra Rock-dragon was observed coexisting with the Western Netted Dragon (*Ctenophorus reticulatus*), which unlike the Ring-tailed Dragon and Yinnietharra Rock-dragon is not a rock sheltering specialist (Melville *et al.* 2001).

The results of the Targeted Survey, including the species distribution modelling, provide a substantial contribution to understanding the most suitable habitat for the Yinnietharra Rock-dragon in the region. Within the SDM Study Area, only 5.93% of the area was identified as highly suitable for the species, and of this only 0.43% was found in the Regional Survey Area, with none (0%) occurring in the Detailed Survey Area. Together with the Targeted Survey results, this supports the finding that the Detailed Survey Area is unsuitable habitat for the Yinnietharra Rock-dragon. This is likely attributed to drier conditions supporting less reptile diversity and the absence of suitable habitat for the species (low weathered granite outcrops, with adequate spacing and substrate type).

Yours sincerely,

Stantec Australia Pty Ltd

Caitlin Roberts
Zoologist

Chris Urbanek
Senior GIS Analyst

Reviewed by:

Paul Bolton

Terrestrial Fauna Team Lead

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Appendix A Habitat Assessments

Site	Name	H-34
	Habitat Type	Stony plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20°)
	Aspect	N/A
	Woody Debris	0
	Tree Hollows (>50 cm)	None
Condition	Condition	Very Good
	Disturbance Type	Cattle grazing, Mining exploration
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Acacia curryana, *Eremophila exilifolia* and *Senna artemisioides* subsp. *helmsii* open shrubland over *Aristida contorta* very open tussock grassland.

Site	Name	H-35
	Habitat Type	Stony plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20°)
	Aspect	N/A
	Woody Debris	None
	Tree Hollows (>50 cm)	None
Condition	Condition	Very Good
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila cuneifolia and *Acacia tetragonophylla* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-36
	Habitat Type	Stony Plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Very Good
	Disturbance Type	Cattle grazing, Weed invasion
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila cuneifolia and Eremophila fraseri open shrubland over *Aristida contorta* open tussock grassland.

Site	Name	H-37
	Habitat Type	Stony Plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	None
	Tree Hollows (>50 cm)	None
Condition	Condition	Very Good
	Disturbance Type	Cattle grazing, Road/Access tracks
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Acacia tetragonophylla and *Senna artemisioides* subsp. *Helmsii* open shrubland over *Aristida contorta* open tussock grassland.

Site	Name	H-38
	Habitat Type	Granite outcrop
	Landform	Granite outcrops domes
Habitat Features	Slope	Steep (46-75º)
	Aspect	N/A
	Woody Debris	None
	Tree Hollows (>50 cm)	None
Condition	Condition	Excellent
	Disturbance Type	Weed invasion
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Many large patches
	Leaf Litter	Scarce
Rocks	Type	Granite
	Size	Boulders (>61cm)
	Outcropping	Extensive outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila exilifolia and *Acacia tetragonophylla* open shrubland over **Cenchrus ciliaris* and *Aristida contorta* scattered tussock grassland.

Site	Name	H-39
	Habitat Type	Stony Plain
	Landform	Stony plain
Habitat Features	Slope	Flat (0º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	None
Condition	Condition	Very Good
	Disturbance Type	Weed invasion, Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila cuneifolia and *Acacia xiphophylla* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-40
	Habitat Type	Outcropping/stony rise
	Landform	Undulating low hills
Habitat Features	Slope	Low (1-20º)
	Aspect	East
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	None discernible
	Soil	Many small patches
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Acacia aneura and *Senna artemisioides* subsp. oligophylla over *Aristida contorta* scattered tussock grassland.

Site	Name	H-41
	Habitat Type	Stony plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	None
Condition	Condition	Excellent
	Disturbance Type	Road/Access tracks, Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Limited outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila phyllopoda subsp. *phyllopoda* open shrubland over *Aristida contorta* very open shrubland.

Site	Name	H-42
	Habitat Type	Outcropping/stony rise
	Landform	Undulating low hills
Habitat Features	Slope	Low (1-20º)
	Aspect	North
	Woody Debris	Moderate
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Very Good
	Disturbance Type	Road/Access tracks, Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Acacia xiphophylla over *Acacia synchronicia, Senna sp. Meekatharra* (E. Bailey 1-26) and *Eremophila cuneifolia* open shrubland over *Sclerolaena densiflora* scattered herbs.

Site	Name	H-43
	Habitat Type	Stony Plain
	Landform	Sandy stony plain
Habitat Features	Slope	Flat (0º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	None
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing, Road/Access tracks
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila fraseri, *Senna artemisioides* subsp. *helmsii*, and *Acacia tetragonophylla* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-44
	Habitat Type	Stony Plain
	Landform	Sandy stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	None
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing, Road/Access tracks
	Fire Age	No Evidence
Ground Cover	Rock	Many large patches
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila forrestii open shrubland over very open *Aristida contorta* tussock grassland.

Site	Name	H-45
	Habitat Type	Outcropping/stony rise
	Landform	Undulating low hills
Habitat Features	Slope	Low (1-20º)
	Aspect	West
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Many large patches
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Pebbles (5-10cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila phyllopoda subsp. *phyllopoda* and *Acacia aneura* open shrubland over very open *Aristida contorta* tussock grassland.

Site	Name	H-46
	Habitat Type	Stony Plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	None
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Granite
	Size	Gravel (1-4cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Clay Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila cuneifolia and *Senna artemisioides* subsp. *helmsii open shrubland* over very open *Aristida contorta* tussock grassland.

Site	Name	H-47
	Habitat Type	Stony plain
	Landform	Sandy stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing, Road/Access tracks
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Limited outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila exilifolia, *Senna artemisioides* subsp. *Helmsii*, and *Acacia tetragonophylla* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-48
	Habitat Type	Stony plain
	Landform	Sandy stony plain
Habitat Features	Slope	Low (1-20°)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing, Road/Access tracks
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila cuneifolia and *Acacia aneura* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-49
	Habitat Type	Stony plain
	Landform	Sandy stony plain
Habitat Features	Slope	Low (1-20°)
	Aspect	N/A
	Woody Debris	Rare
	Tree Hollows (>50 cm)	Rare
Condition	Condition	Excellent
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Moderate outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila fraseri, *Senna artemisioides* subsp. *Helmsii*, and *Acacia tetragonophylla* open shrubland over *Aristida contorta* scattered tussock grassland.

Site	Name	H-50
	Habitat Type	Stony plain
	Landform	Stony plain
Habitat Features	Slope	Low (1-20º)
	Aspect	N/A
	Woody Debris	None
	Tree Hollows (>50 cm)	None
Condition	Condition	Very Good
	Disturbance Type	Cattle grazing
	Fire Age	No Evidence
Ground Cover	Rock	Evenly spread
	Soil	Evenly spread
	Leaf Litter	Scarce
Rocks	Type	Quartz
	Size	Gravel (1-4cm)
	Outcropping	Minor outcropping
Soil	Type	Sandy Loam
	Colour	Red/brown

Site Photograph

Vegetation description

Eremophila exilifolia, *Acacia tetragonophylla*, *Senna artemisioides* subsp. *helmsii* open shrubland over *Aristida contorta* very open tussock grassland.

Appendix B SDM Correlation Testing

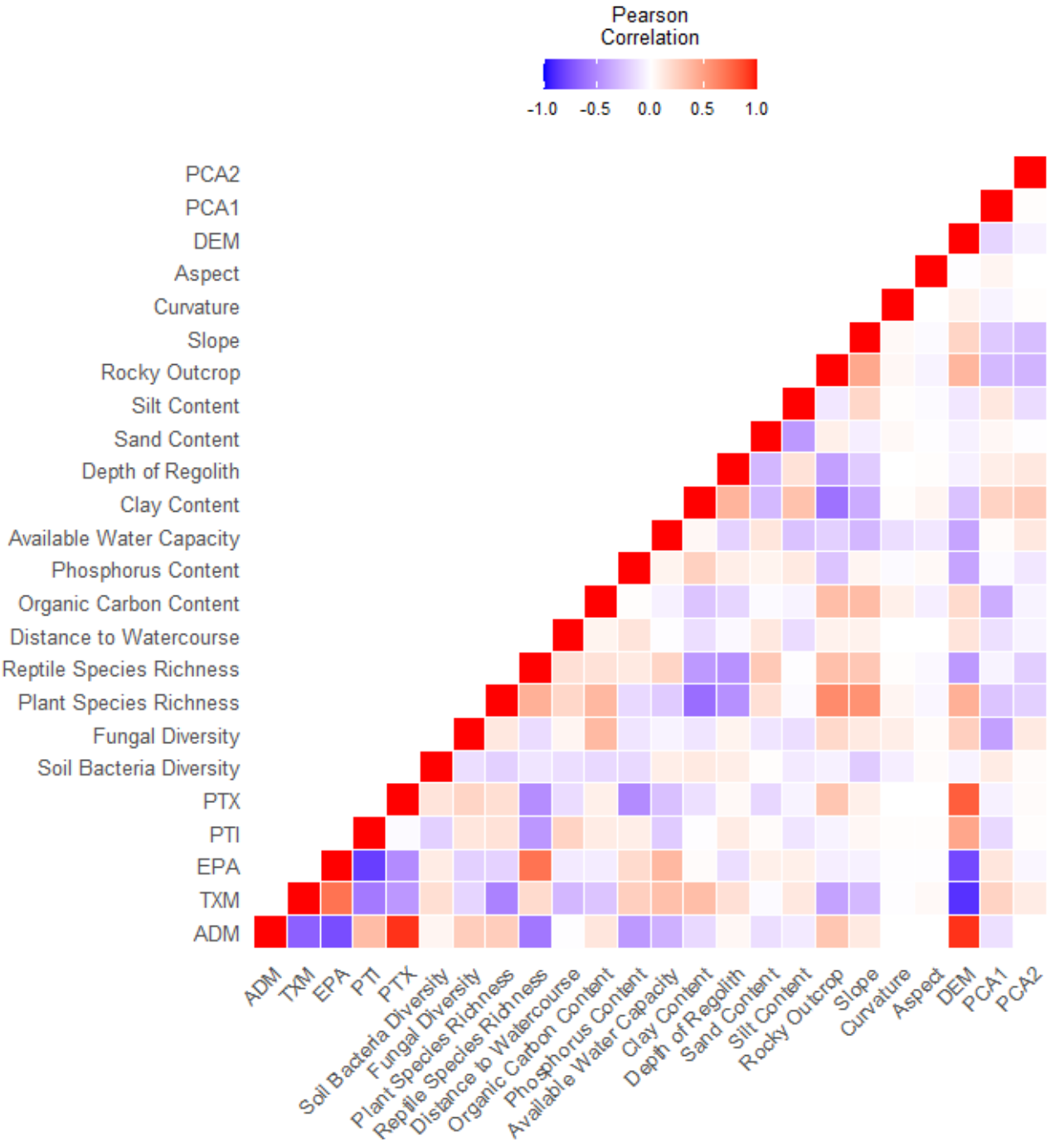

Figure B 1: Correlation heat map (based on Pearson's correlation coefficient) for tested environmental variables for the SDM (red symbolises a high positive correlation and blue symbolises a strong negative correlation).

Appendix C Ensemble Species Distribution Models

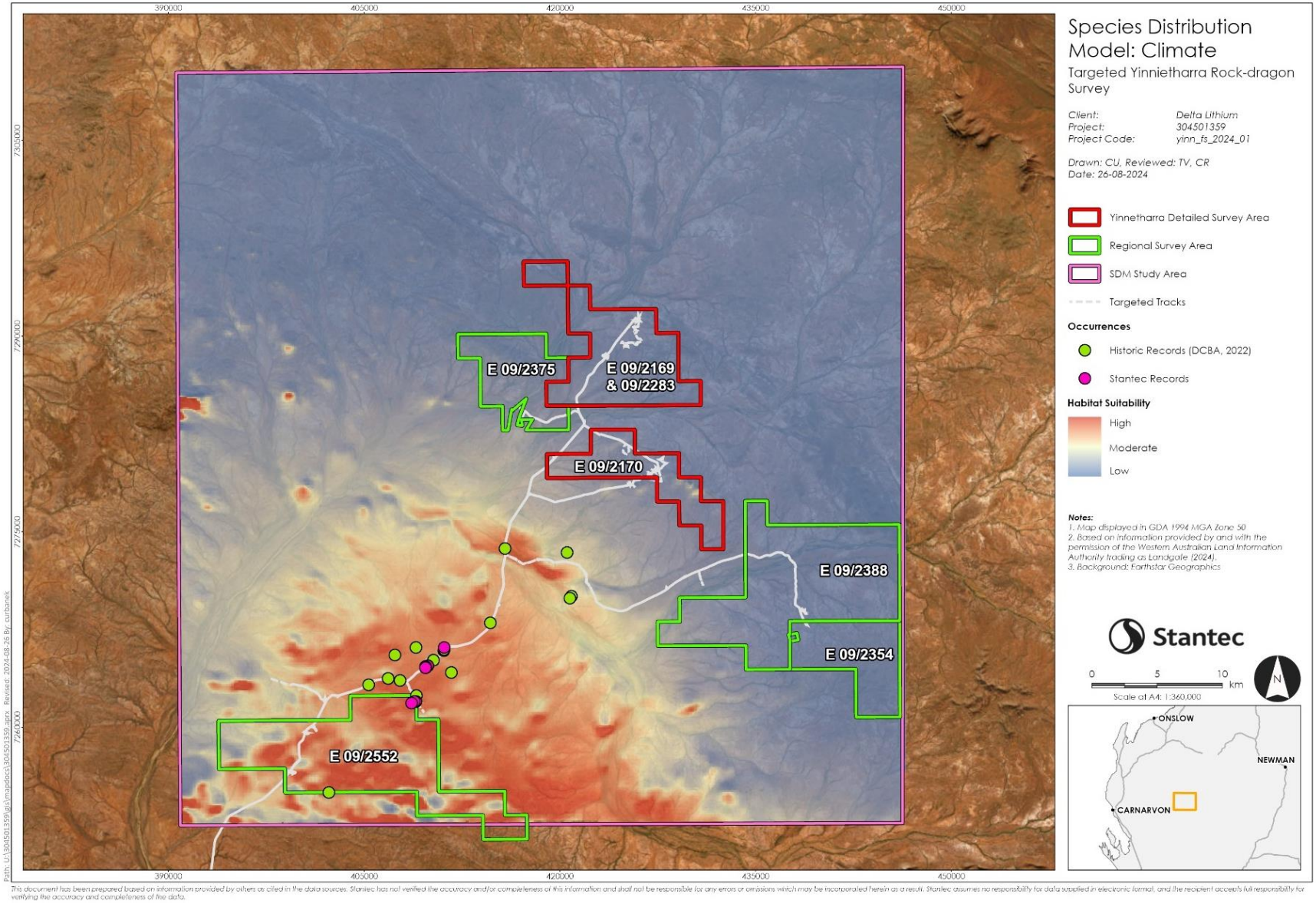

Figure C 1: Post-field species distribution model for climate, showing the habitat suitability of the Yinnietharra Rock-dragon (red shows high suitability and blue shows low suitability habitat).

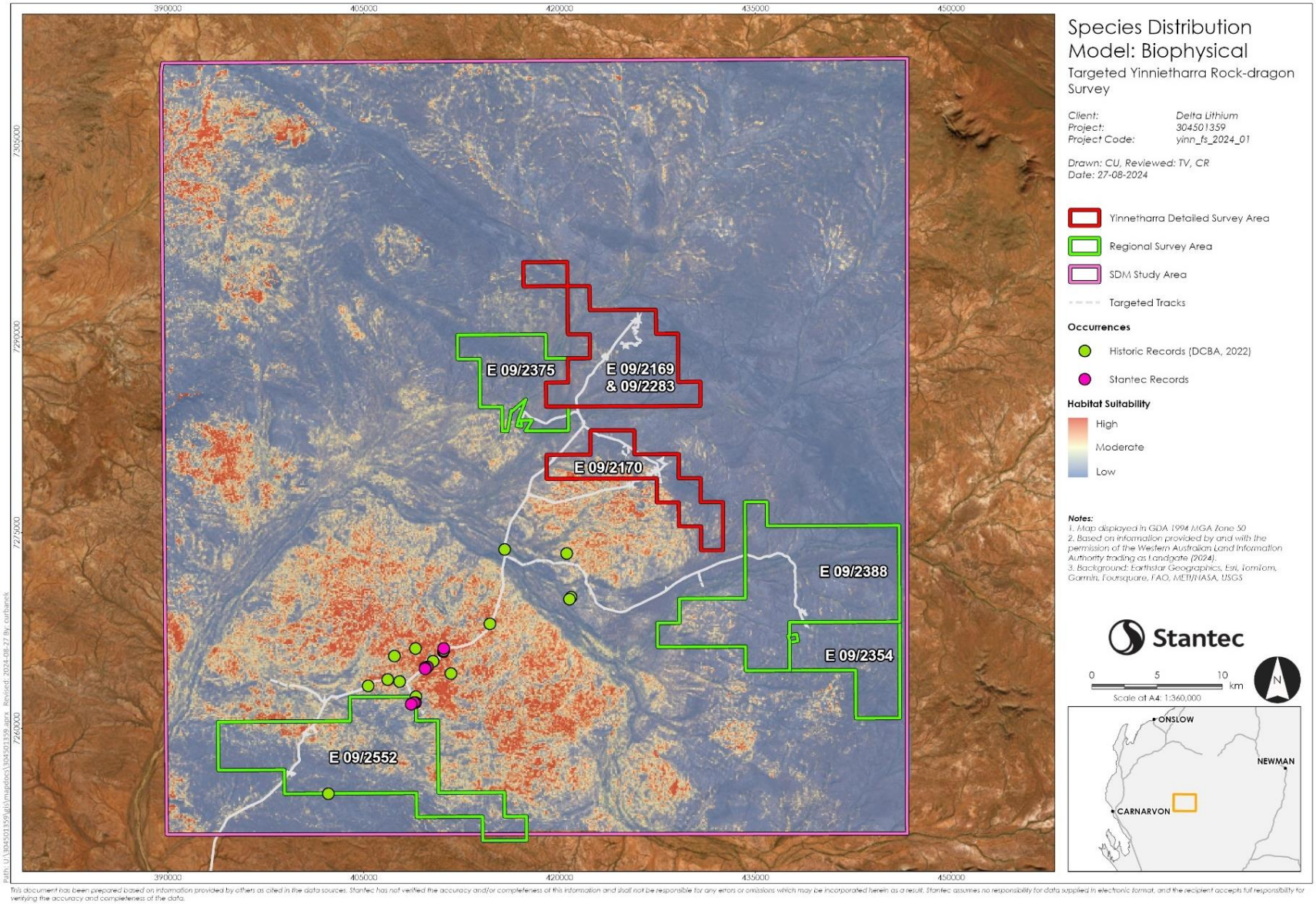

Figure C 2: Post-field species distribution model for biophysical parameters showing the habitat suitability of the Yinnietharra Rock-dragon (red shows high suitability and blue shows low suitability habitat).