

Sulphur Springs 2017 Targeted Fauna Assessment



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EXECUTIVE SUMMARY

Venturex Resources Ltd proposes to develop the Sulphur Springs Zinc-Copper Project located within the Pilbara region of Western Australia, approximately 144 km south-east of Port Hedland, and 57 km west of Marble Bar. As part of the Environmental Impact Assessment for the project, Kingfisher Environmental Consulting was commissioned by Venturex to conduct a targeted fauna assessment of the Sulphur Springs Project Area. The fauna assessment comprised a desktop review and targeted field survey which was conducted throughout the Sulphur Springs Project area during September 2017.

The Sulphur Springs targeted fauna assessment focused on species of conservation significance and their associated habitats, with consideration to recent taxonomic, legislative and ecological advances. As several conservation significant species had been previously recorded in the local area, the targeted fauna assessment aimed to determine the presence and likely occurrence of significant fauna across the current Sulphur Springs Zinc-Copper Project area. The survey focused on four species listed under the EPBC Act expected in the area - the Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python. Target searches were complimented by the use of motion-activated cameras and acoustic bat detectors. Key findings include:

- A total of 66 fauna species were recorded during the 2017 survey, including five species of conservation significance.
- The motion-activated cameras recorded a total of 17 fauna species and a further seven species were recorded on the bat detectors.
- Northern Quoll – not recorded during 2017, however was previously recorded within the project’s proposed footprint (during 2001). Likely to occur within the project area in low and fluctuating numbers during favourable conditions;
- Ghost Bat – a roosting cave recorded within the project area. A number of roost sites are likely to occur in adjacent areas and as such, the species is likely to forage widely throughout the area (as evidenced by feeding roosts).
- Pilbara Leaf-nosed Bat – likely to forage extensively throughout the project area, however, roosting sites appear limited. One Priority 4 (nocturnal refuge) was recorded within the project area. The species pattern of foraging (extensive along drainage lines within the project area) suggests additional refuge sites are likely to occur nearby.
- Pilbara Olive Python – likely to occur within the project area in low numbers and be associated with permanent pools in gorges and drainage lines.

Potential impacts associated with the project on federally listed fauna are not expected to be significant under the EPBC Significant Impact criteria, providing appropriate management measures are put in place.

Management strategies to reduce potential impacts of the development include:

- Avoid disturbance to important bat roosts and Northern Quoll denning sites where possible;

- Minimise the loss of high value foraging habitat: to minimise impacts on the Pilbara Leaf-nosed Bat, disturbances to Priority 1 foraging habitat should be minimised and avoided where possible;
- Maintain existing natural water pools to encourage long term persistence of significant fauna in the project area;
- Avoid direct illumination of bat roosts by artificial lights;
- Avoid the use of barbed-wire fences as they are known to entrap Ghost Bats;
- Restrict general access and entry to known or suspected roost sites; and
- Monitor important fauna populations if present.

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1. INTRODUCTION

1.1 Project Background

Venturex Resources Ltd (Venturex) proposes to develop the Sulphur Springs Zinc-Copper Project located within the Pilbara region of Western Australia, approximately 144 km south-east of Port Hedland, and 57 km west of Marble Bar (see Figures 1 and 2). Venturex owns the project and acquired the project tenements from CBH Sulphur Springs Pty Ltd in 2011.

In 2013 Venturex submitted a Mining Proposal for a 1.0 Mtpa underground mine, 1.0 Mtpa processing plant and dry stack tailings storage facility to the Department of Mines and Petroleum (now known as the Department of Mines Industry Regulation and Safety – DMIRS)). The proposal was granted approval by DMIRS in April 2014 (REG ID 40542). However, Venturex now proposes to expand on the original mining proposal to include both an open pit and underground operation with a conventional valley filled tailings storage facility (see Figure 2). While the site's fauna had been previously assessed (during 2001 and 2012), a targeted threatened fauna survey within the current project footprint to supplement previous surveys was required. Kingfisher Environmental Consulting (Kingfisher) was commissioned by Venturex to conduct a targeted fauna assessment of the Sulphur Springs Project Area. The fauna assessment included a desktop review, field survey and a detailed report (this report) outlining the results of the survey and providing advice on any potential fauna management measures.

Figure 1. The Sulphur Springs Zinc-Copper Project Location.

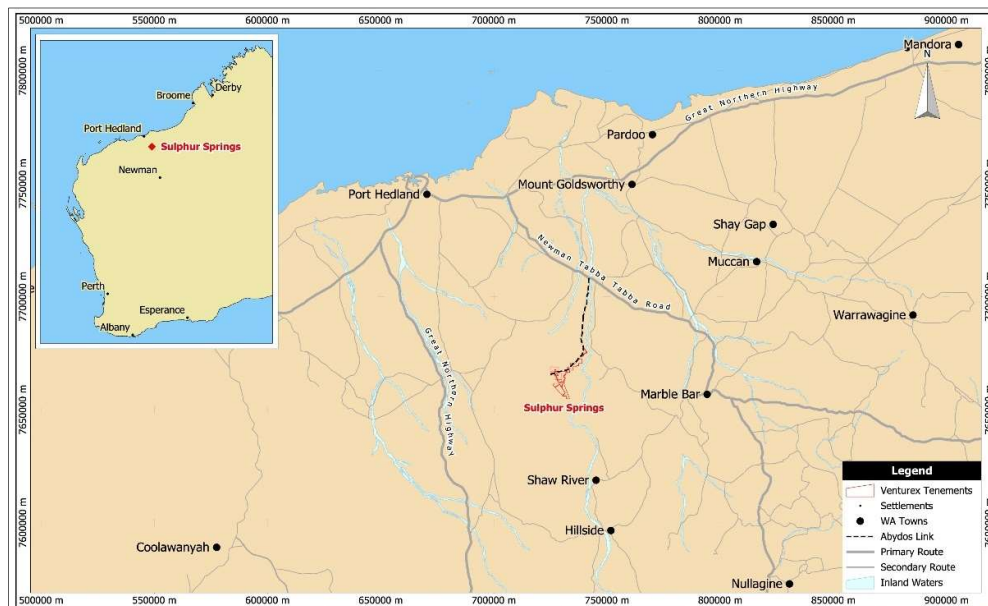
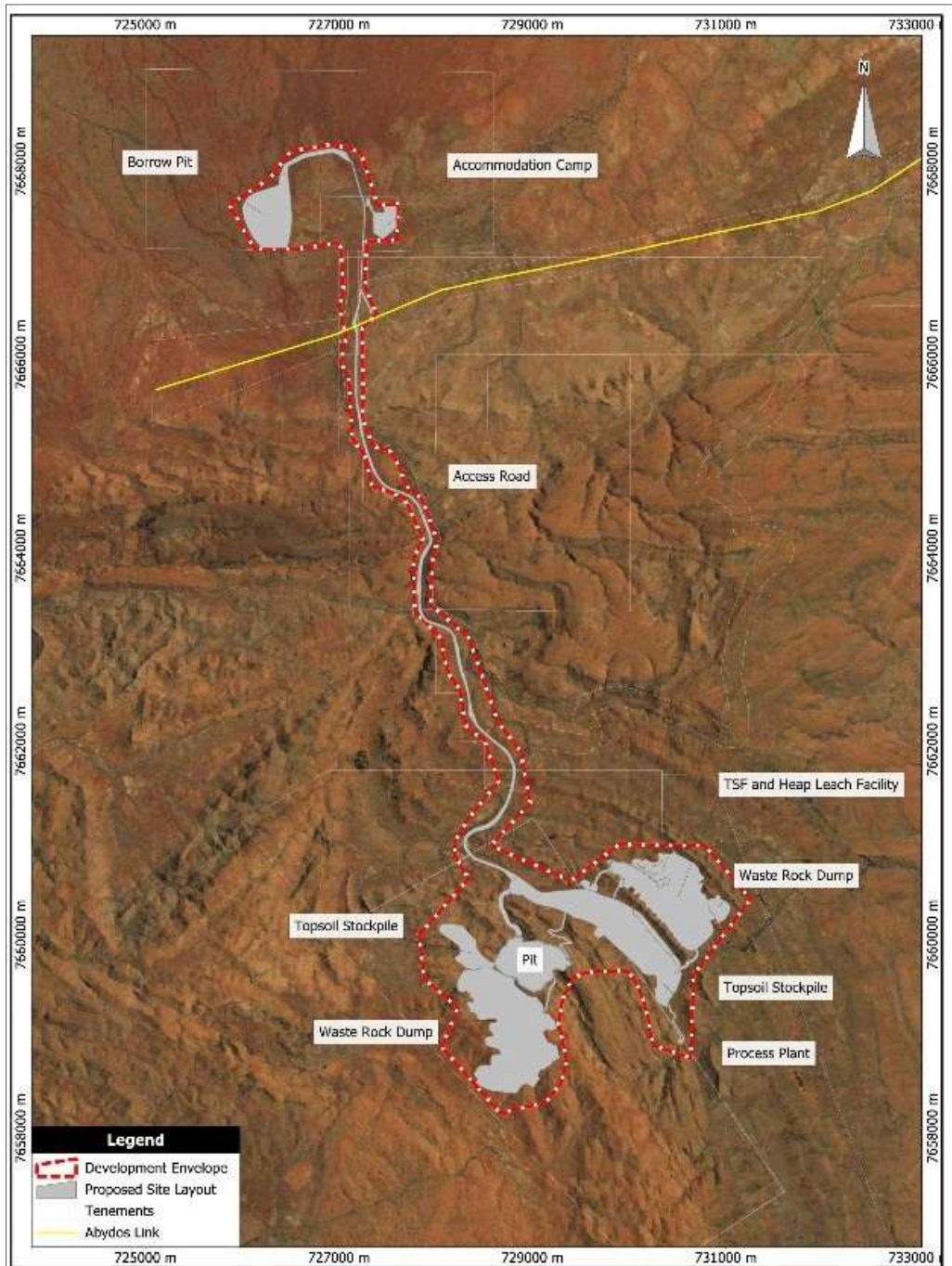


Figure 2. The Sulphur Springs Zinc-Copper Project Conceptual Site Layout Plan.



1.2 Targeted Fauna Assessment Objectives

The Sulphur Springs targeted fauna assessment focused on species of conservation significance and their associated habitats, with consideration to recent taxonomic, legislative and ecological advances. As several conservation significant species had been previously recorded in the local area (the vicinity of the Sulphur Springs project and its surrounds such as Atlas Iron's Abydos mine), the targeted fauna assessment aimed to determine the presence and/or likely occurrence of significant fauna across the current Sulphur Springs Zinc-Copper Project area.

Four fauna species listed under the EPBC Act were considered likely to occur at Sulphur Springs. The Northern Quoll and Ghost bat have been previously recorded at Sulphur Springs and suitable habitat for Pilbara Olive Python and Pilbara Leaf-nosed Bat has been noted (Bamford Consulting 2001, Outback Ecology 2012). Based on the referral guidelines for Northern Quoll (DSEWPaC 2011a and DoTE 2016); survey guidelines for reptiles, bats and mammals (DEWHA 2010a; DSEWPaC 2011b, c), and the Western Australian Environmental Protection Agency (EPA) Guidelines (EPA 2002; 2004; 2010 – revised 2016) targeted surveys were undertaken to determine the abundance and distribution of significant fauna within the project area.

The targeted fauna survey included the following objectives:

1. Conduct a desktop review of background information (a search of all sources for literature, data and map-based information);
2. Compile an inventory of vertebrate fauna present or expected to occur (regarding the fauna habitats present);
3. Identify species of conservation significance at an international, national, state, regional and local level;
4. Conduct a targeted Northern Quoll Assessment, including the identification and verification of important habitat areas (denning habitat);
5. Conduct roost and habitat assessments for conservation significant bats (Ghost Bat and Pilbara Leaf-nosed Bat);
6. Conduct opportunistic surveys to determine the status of additional fauna in the project area.
7. Identify significant fauna habitats or areas of particular importance for fauna;
8. Identify potential impacts to fauna and propose recommendations to minimise impacts.

1.3 Survey Area

The area covered by the fauna assessment (the "survey area") corresponds to the Sulphur Springs Zinc-Copper Project Area (approximately 320 hectares) and its immediate surrounds (see Figure 2). As the project has the potential to form a component of a species' foraging or breeding range, the survey area also included areas adjacent to the project's footprint where habitats were considered likely to support conservation significant fauna.

1.4 Scoping Requirements

This document has been developed in consideration of the following:

1. EPA Position Statement No 3, Terrestrial Biological Surveys as an element of Biodiversity Protection (EPA, 2002);
2. EPA Guidance Statement No 56, Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004; revised 2016);
3. EPA Technical guide, Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA, 2010; revised 2016);
4. Environmental Factor Guideline: Terrestrial Fauna (EPA, 2016);
5. Referral guidelines for the Northern Quoll, *Dasyurus hallucatus* (DSEWPaC 2011a);
6. EPBC Act referral guideline for the endangered Northern Quoll *Dasyurus hallucatus* (Department of the Environment, 2016);
7. Survey Guidelines for Australia's Threatened Reptiles, Birds, Bats and Mammals (Department of Environment, Water, Heritage and the Arts 2010a; 2010b; Department of Sustainability, Environment, Water, Population and Communities, 2011a; 2011b; 2011c);
8. Conservation Advice for species listed under the EPBC Act (e.g. Pilbara Leaf-nosed Bat, Ghost Bat and Northern Quoll, Threatened Species Scientific Committee 2016).

2. BACKGROUND

2.1 Regional Description

The Interim Biogeographic Regionalisation of Australia (IBRA) has identified 26 bioregions in Western Australia. Bioregions are classified on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell, 1995). IBRA Bioregions are affected by a range of different threatening processes and have varying levels of sensitivity to impact (EPA, 2004).

Pilbara Bioregion

The project is located within the Pilbara Bioregion and the Chichester Subregion (Pilbara 1, IBRA, 2008). The Pilbara Bioregion falls within the Bioregion Group 2 classification (EPA, 2004). Bioregions within Group 2 have “native vegetation that is largely contiguous but is used for commercial grazing.”

Kendrick and McKenzie (2001) describe the Chichester Subregion as:

“the northern section of the Pilbara Craton. Undulating Archaean granite and basalt plains include significant areas of basaltic ranges. Plains support a shrub steppe characterised by *Acacia* (spp.) shrublands over *Triodia* (spp.) hummock grasslands, while *Eucalyptus leucophloia* tree steppes occur on ranges. The climate is semi-desert-tropical and receives 300 mm of rainfall annually.”

Kendrick and McKenzie (2001) identify 14 significant fauna species occurring within the Chichester Subregion.

2.2 Previous Studies

Previous biological studies conducted in a local and regional context can serve to inform and direct field assessments. Kingfisher has conducted several fauna assessments in the local region including at Abydos (5 km north-west of Sulphur Springs); North Star (20 km south-west of Sulphur Springs); Wodgina (50 km west of Sulphur Springs); Yarrie (100 km north-east of Sulphur Springs); Port Hedland (144 km north-west of Sulphur Springs); and along the BHP Rail (40 km west of Sulphur Springs).

Two previous fauna surveys have been conducted in the Sulphur Springs project area. Bamford Consulting Ecologists conducted a Level 2 survey (two season) during June and September 2001 (Bamford, 2001). Outback Ecology conducted a Level 1 Fauna Survey (reconnaissance survey) to facilitate a habitat assessment of the project area (2012). An additional fauna survey (conducted by Biota during 2007) assessed the plains to the north of the Sulphur Springs operational area, however, sampled habitats that were significantly different to those found in the Sulphur Springs survey area. Furthermore, a survey for conservation significant bats was conducted to the north of Sulphur Springs, focusing on the disused Lalla Rookh Mine and Sulphur Springs Valley Road (Molhar 2007). Table 1 lists previous reports utilized during the desktop and field assessments. The results of these surveys are included in the current assessment and are detailed in Appendix 2.

Table 1: Relevant local and regional fauna surveys

Survey	Comments	Year
Panorama Baseline Fauna Study (Bamford Consulting 2001)	Level 2 survey (two phase) of the Panorama Project Area	2001
Pilbara Copper-Zinc Project Level 1 Survey (Outback Ecology 2012)	Level 1 survey of the Sulphur Springs Project. Limited fauna survey focussing on habitat mapping, no fauna records.	2012
Access Road Corridor Fauna Survey (Biota 2007)	Panorama Project Mine Site and Haul Road Corridor Targeted Fauna Survey – north of the Sulphur Springs mine	2007
Survey for conservation significant bats (Molhar 2007)	Survey for conservation significant bats near Sulphur Springs, focussing on Lalla Rookh mine and Sulphur Springs Valley Rd.	2007
Regional Surveys		
Fauna Assessment of Abydos DSO Project (Bamford Consulting 2009)	Level 2 survey conducted 5 – 10km west of Sulphur Springs	2008
Abydos DSO Project Fauna Baseline Survey (Outback Ecology 2011)	Level 2 survey conducted 5 – 10km west of Sulphur Springs	2010
North Star Level 2 Vertebrate Fauna Assessment (ecologia 2012)	Level 2 survey conducted 20km west of Sulphur Springs	2012
North Star Project Targeted Fauna Survey (ecologia 2011)	Targeted survey conducted 20km west of Sulphur Springs	2011

2.3 Conservation Significance

Biodiversity in Western Australia is protected, managed and assessed under international, national and state agreements, legislation and policy. For Environmental Impact Assessment, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Western Australian Wildlife Conservation Act 1950* (WC Act) are of particular relevance to Western Australian fauna.

EPBC Act

At the national level, fauna is protected under the EPBC Act. Schedule 1 of the Commonwealth EPBC Act contains a list of species that are considered Critically Endangered (CE), Endangered (E), Vulnerable (V), Extinct (Ex), Extinct in the wild (ExW) and Conservation Dependent (CD). These categories are described in Appendix 1. The significance levels for fauna used in the EPBC Act are those recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994).

Under the provisions of the Commonwealth EPBC Act proposed actions which have the potential to have a significant impact on a matter of national environmental significance must be referred to the Commonwealth Minister for the Environment for a decision as to whether an assessment is required under the provisions of that Act (EPA, 2004; EPA, 2016).

The EPBC Act also has lists of migratory species that are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA) and the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals).

Wildlife Conservation Act

At the state level, significant fauna is listed under the *Western Australian Wildlife Conservation Act 1950: Wildlife Conservation (Specially Protected Fauna) Notice 2016*. There are seven levels of conservation significance provided for fauna. Scheduled species are prioritised and listed as:

- Schedule 1 (S1): Fauna that is rare or likely to become extinct – Critically Endangered;
- Schedule 2 (S2): Fauna that is rare or likely to become extinct – Endangered;
- Schedule 3 (S3): Fauna that is rare or likely to become extinct – Vulnerable;
- Schedule 4 (S4): Fauna that is rare or likely to become extinct – Extinct;
- Schedule 5 (S5): Birds subject to international agreements – the protection of migratory species;
- Schedule 6 (S6): Fauna that are of special conservation need - species dependent on ongoing conservation intervention; and
- Schedule 7 (S7): Fauna that is in need of special protection.

Further details regarding these schedules are provided in Appendix 1.

Priority Fauna

In Western Australia, the Department of Biodiversity, Conservation and Attractions (DBCA) has produced a supplementary list of Priority Fauna for species that do not meet the criteria for listing as threatened under Schedule 1 (of the WC Act). These species are often poorly known and/or of conservation dependence. Some Priority species, however, are also assigned to the IUCN Conservation Dependant Category. Levels of Priority are described in Appendix 1 (Priority 1 – 4).

Conservation Significant Fauna

Fauna species included under conservation acts and/or agreements are formally recognised as of conservation significance under state or federal legislation. Species listed as Priority by DBCA, or that are included in biodiversity publications (such as the Action Plan for Australian Birds 2010), are also of recognised conservation significance. In addition, species that are at the limit of their distribution, those that have a very restricted range and those that occur in breeding colonies, such as some waterbirds, can be considered of conservation significance, although this level of significance has no legislative or published recognition and is based on interpretation of distribution information.

Locally significant fauna are species not listed under Acts or in publications but considered of at least local significance because of their pattern of distribution. This level may have links to preserving biodiversity at the genetic level (EPA, 2002). For example, if a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as locally significant.

3. SURVEY METHODS

3.1 Approach

Kingfisher has conducted numerous fauna surveys within the vicinity of project area (see Section 2.2) and holds an extensive fauna database for the area. There have also been several fauna surveys conducted over the project area within the last 18 years. These provided the background information on which the study was based. This fauna assessment was conducted with reference to guidance and position statements published by the WA Environmental Protection Authority (EPA) on fauna surveys and environmental protection and commonwealth biodiversity legislation and survey guidelines for the EPBC listed fauna (e.g. EPA, 2002, 2004, 2016; EPA and DEC, 2010; 2016; DSEWPaC 2011a; DoTE, 2016). Particular reference was given to survey and referral guidelines for the Northern Quoll (DoTE, 2016).

3.2 Personnel and Survey Timing

The Sulphur Springs Fauna Assessment was undertaken from 27th September 2017 to the 3rd October 2017 by the following personnel:

- Ray Lloyd (Senior Zoologist, B.Sc. Hons Zoology);
- Carly Watson (Field Assistant, BSc. Conservation Biology);

Field work was conducted under a Regulation 17 licence (08-001185-1). Reporting and data analysis was conducted by Jeff Turpin (Supervising Zoologist, B.Sc. Zoology) and Ray Lloyd.

3.3 Desktop Survey

As per the recommendations of EPA and DEC (2010), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's Checklist of the Vertebrates of Western Australia (Western Australian Museum, 2017). Information for this fauna assessment was drawn primarily from the DBCA threatened species database and "NatureMap" (DBCA, 2017), the BirdLife Australia Atlas Database (BirdLife Australia, 2017), EPBC Protected Matters Search Tool (DEE, 2017) and the results of fauna surveys conducted in the region (J. Turpin records – see section 2.2; particularly Bamford Consulting Ecologists 2001, Outback Ecology 2012). All databases were interrogated in September 2017 (Table 2). This information was supplemented with species expected in the area based on general patterns of distribution and presence of suitable habitat.

Table 2: Fauna databases

Title	Comments	Area Searched / Year
NatureMap	Records of specimens held in the WA Museum and DBCA database records. Includes historical data.	Survey area with a 20 km Buffer.
Birds Australia Atlas Database	Records of bird observations in Australia, 1998-2017.	Species list for the 1-degree grid cell containing the survey area.
EPBC Protected Matters Search Tool	Records on matters protected under the EPBC Act, including threatened species and conservation estate.	Survey area (plus ~100 km buffer).
DBCA Threatened and Priority Fauna database	Records of significant fauna within DBCA databases.	Survey area with 30 km buffer, 2017.

3.4 Field Survey

The Sulphur Springs field survey was undertaken with consideration to the previous surveys conducted in the local area. During the fauna survey, the project area was visually inspected and extensively traversed on foot. All major fauna habitats (major vegetation types) present were sampled and assessed for the likelihood of supporting conservation significant fauna. Those habitats deemed suitable to support significant fauna were subject to further intensive targeted surveying, including motion sensor camera monitoring. While surveying focused on locating evidence of significant fauna, all species observed were recorded. Surveying included:

- Identification of major fauna habitats;
- Targeted fauna searches, particularly for the Northern Quoll - intensive searches of proposed disturbance areas conducted on foot (all significant fauna recorded and mapped);
- Roost searches for conservation significant bats (all significant roosts recorded and mapped);
- Use of motion sensitive cameras – deployed during the initial survey and collected over one month later – used to enhance species detection and collect ecological information;
- Analysis of bat detectors deployed (SM2BAT Detectors); and
- Opportunistic searches.

Species of Conservation Significance

The presence of many conservation significant fauna species can be confirmed by searching for evidence of their activities (e.g. scats, tracks, diggings, burrows, nests). Searching for significant fauna was therefore undertaken by walking through habitat considered suitable for such species. Surveying focused on searching for:

- Northern Quoll (distinctive tracks and scats): including the identification and verification of important habitat areas (denning habitat) via:
 - scat searches along survey transects;
 - deployment of motion sensitive cameras throughout the project area;
 - assessment of denning habitat throughout the project area.
- Ghost Bat (distinctive scats, specific roosting requirements): including the identification and verification of important habitat areas (roost sites) conducted by:
 - Roost searches along survey transects;
 - Deployment of bat detectors throughout the project area;
 - Assessment of roosting habitat throughout the project area.

- Pilbara Leaf-nosed Bat (distinctive echolocation calls, specific roosting requirements): including the identification and verification of important habitat areas (roost sites) conducted by:
 - Roost searches along survey transects;
 - Deployment of bat detectors throughout the project area;
 - Assessment of roosting habitat throughout the project area.
- Pilbara Olive Python (distinctive sloughs, scats): including the identification and verification of important habitat areas (den sites) conducted by:
 - Scat / slough searches along survey transects;
 - deployment of motion sensitive cameras throughout the project area;
 - assessment of denning habitat throughout the project area.
- Priority fauna species; and,
- Opportunistic observations to determine the status of additional fauna in the project area. This includes all fauna observed and recorded on motion sensitive cameras.

The project area was extensively traversed on foot and where significant habitat was encountered (such as rocky outcrops, crevices and caves), searches were conducted for Northern Quoll, Ghost Bat and Pilbara Olive Python scats (and other signs). The Northern Quoll and Pilbara Olive Python inhabit rock crevices and scat latrines can often be found amongst rocky habitat near den sites. All rocky areas within the project area with the potential to support significant fauna were searched for the presence of the species' distinctive scats.

The project area was extensively searched for the presence of caves. Where encountered, caves were inspected for the potential to support conservation significant bats (Ghost Bat and Pilbara Leaf-nosed Bat). Caves and overhangs were searched for the presence of the Ghost Bat's distinctive scats and noted for their depth and humidity as both species (Ghost Bat and Pilbara Leaf-nosed Bat) roost in deep, dark, humid caves.

Motion-activated Cameras

Motion-activated cameras (Bushnell Trophy Cam) were placed at a total of 23 locations within the survey area to sample for conservation significant fauna (e.g., particularly the Northern Quoll, Figure 3). Cameras were situated within the habitats and sites deemed the most suitable to contain Northern Quoll den sites (caves, rocky outcrops, boulder piles and drainage lines) and were placed within shelter, foraging and dispersal habitat (DoTE, 2016). Cameras were baited with universal bait (a mixture of sardines, rolled oats and peanut butter) and operated over several consecutive nights (Table 3). To maximise the probability of detection, 10 Motion Cameras were left established within the survey area for over a month. Cameras were established for a total of 536 camera nights. The use of motion cameras was supplemented by latrine searches.

Table 3: Camera locations

Camera	Easting	Northing	Habitat / Comments	Date Set	Date Collected	Survey Nights
fc9	728528	7659897	Rocky outcrop	27/9	14/11	48
fa1	728945	7659597	Fig Grove	27/9	14/11	48
fa2	729098	7659641	Waterhole in Sulphur springs gorge	27/9	2/10	5
fa4	728801	7660115	NE cliff face of Sulphur Springs creek	27/9	2/10	5
fb2	729443	7659351	Creek line south of Sulphur Springs	27/9	14/11	48
fb9	727835	7663437	Drainage line with large trees	27/9	14/11	48
fc4	728255	7659922	Rocky overhang	27/9	2/10	5
fc10	728462	7659624	Overhang, Ghost Bat scats present	27/9	14/11	48
fb1	729066	7659082	Rocky gully with figs and water	27/9	14/11	48
fc6	728764	7658339	Permanent spring / pool in rocky gully	27/9	14/11	48
fa7	727184	7660185	Puku Gorge (treed line, rocky gorge)	27/9	14/11	48
fa3	730810	7658816	Overhang in ironstone hills	27/9	2/10	5
fc3	730216	7660187	Rocky overhang	27/9	2/10	5
fa9	728596	7661569	Waterhole in rocky gully	27/9	2/10	5
fa8	727836	7663807	Drainage in gorge with waterholes	28/9	2/10	4
fa6	727922	7664016	Rocky gorge	28/9	2/10	4
fa10	730503	7660723	Boulder pile in ridgeline	28/9	14/11	47
fa5	729279	7659768	Cliff on side of hillslope	28/9	2/10	4
fa3_1	731254	7659907	Large boulder pile next to waterhole	28/9	14/11	47
fb2_1	729132	7659660	Overhang, rocky outcrop	28/9	2/10	4
FA1_2	728999	7659635	Overhang, rocky outcrop	28/9	2/10	4
fa4_1	727135	7666670	Creek line near Haul Road	28/9	2/10	4
fb1_1	727108	7665324	Basalt ridge / creek line	28/9	2/10	4

Bat Detectors

Five bat detectors (Wildlife Acoustics SM2BAT Units) were used to survey for bats and to assess bat activity within or adjacent to a select number of caves. The units surveyed over a total of 18 nights at 17 locations (Table 4, Figure 4). Appendix 3 provides a detailed description of the bat call analysis (Specialised Zoological, 2018).

Table 4: SM2BAT locations

Unit	Easting	Northing	Comments / Habitat	Date Set	Date Retrieved	Survey Nights
8060a	728898	7659570	Unit placed at gorge at Sulphur Spring	29/9	30/9/17	1
8060b	729085	7659660	Unit placed at pool in gorge	30/9	1/10/17	1
8060c	728991	7659751	Unit placed at pool in Sulphur Spring	1/10	2/10/17	1
8060d	727129	7666672	Unit placed in creek near Haul Rd	2/10	3/10/17	1
8072a	728764	7658339	Unit placed at permanent pool in gorge	29/9	30/9/17	1
8072b	727855	7663818	Rocky gorge with outcrops, large trees	30/9	1/10/17	1
8072c	730349	7658472	Rocky Gorge	1/10	2/10/17	1
8072d	727110	7665333	Creek line with large Eucalypts	2/10	3/10/17	1
FTSM2a	730647	7658848	Creek line in gully	29/9	30/9/17	1
FTSM2b	730677	7659567	Large overhang on gully/hillside	30/9	1/10/17	1
FTSM2c	728230	7660979	Outcrop next to waterhole in creek	1/10	2/10/17	1
10980a	729011	7659615	Cave at Sulphur Spring, Ghost Bat scats	28/0	30/9/17	2
10980b	731209	7659883	Permanent pool in wooded creek	30/9	1/10/17	1
10980c	727388	7663875	Cave with 2 x Ghost Bats observed	1/10	2/10/17	1
8066a	727184	7660185	Creek line in Puku Gorge	29/9	30/9/17	1
8066b	728492	7662662	Creek between cliff and range	30/9	1/10/17	1

8066c	728772	7659808	Gully / gorge, many rock crevices	1/10	2/10/17	1
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At all times, observations of fauna were noted when they contributed to the accumulation of information on the local fauna assemblage. These included such casual observations as birds or reptiles seen while travelling through the site.

Figure 3. The locations of motion-activated cameras deployed during the Sulphur Springs field survey located in key habitat locations

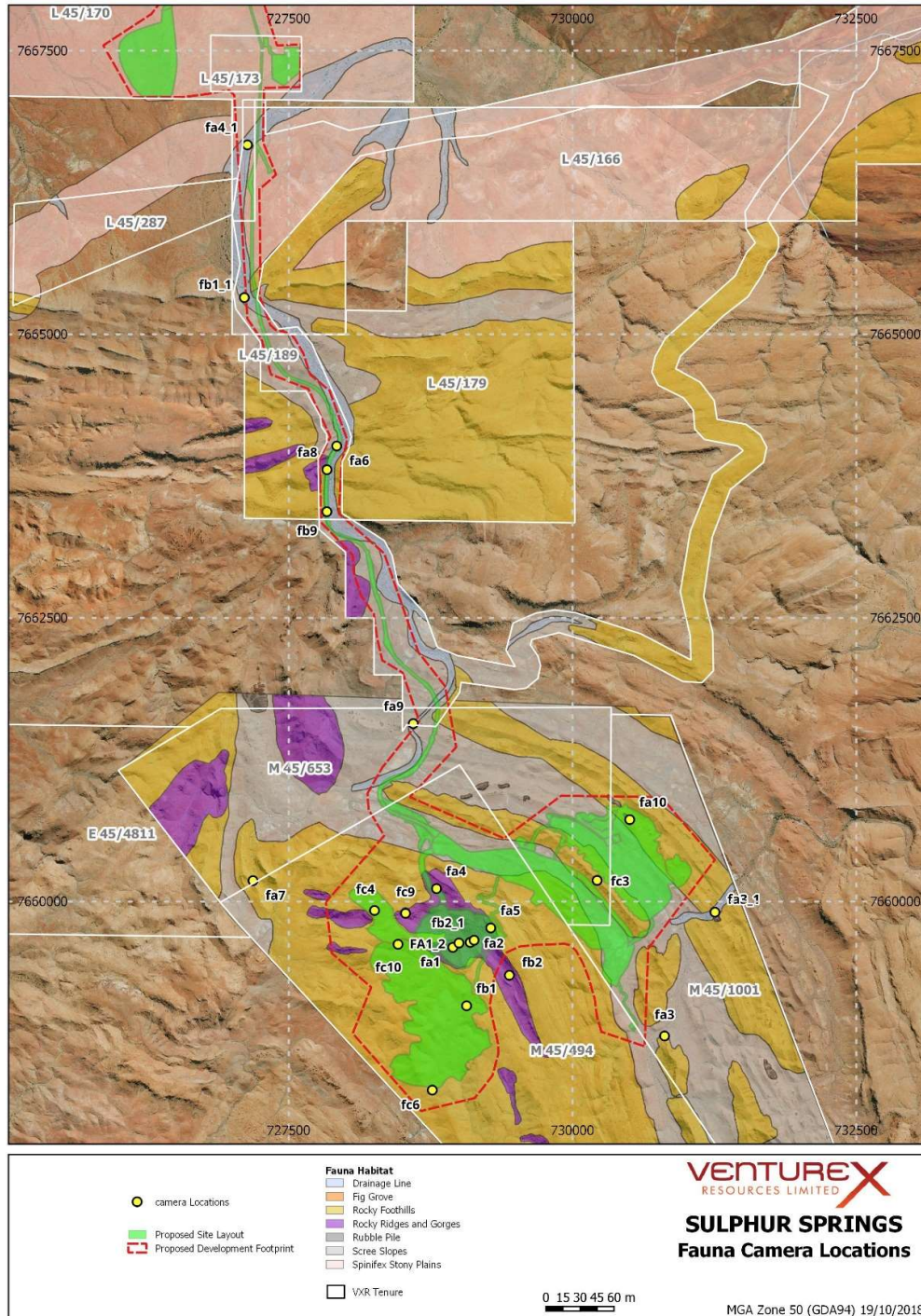
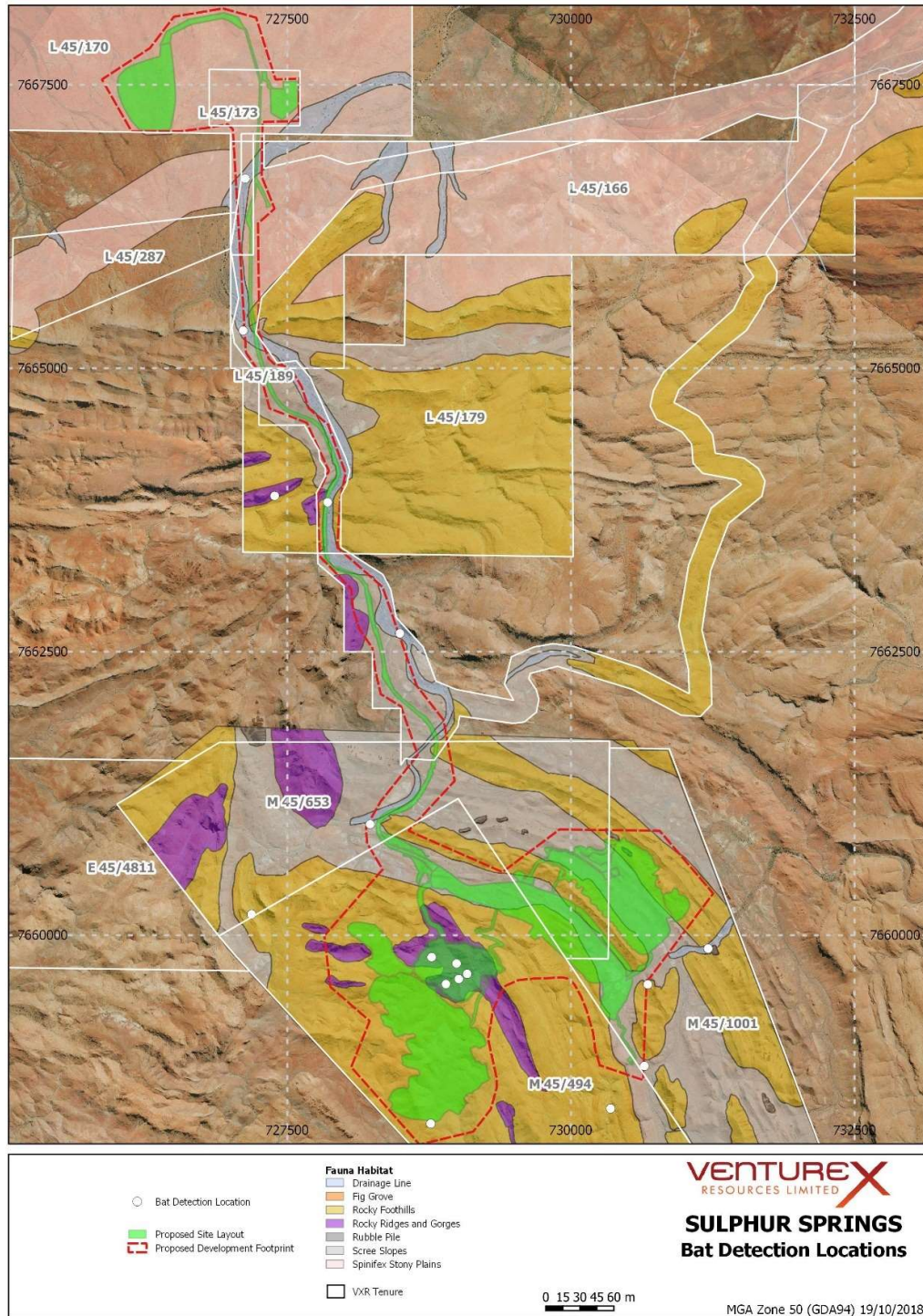


Figure 4. The locations of bat detectors deployed during the Sulphur Springs field survey.



3.5 Limitations

EPA Guidance Statement 56 (EPA 2004; EPA 2016) outlines limitations that may arise during surveying. These survey limitations are addressed below (Table 5).

Table 5: Potential fauna survey limitations

Limitation	Comment
Level of survey.	Targeted Survey (desktop review and targeted surveying for conservation significant fauna). Survey effort was deemed sufficient to detect conservation significant fauna. Motion cameras were used to detect the Northern Quoll and supplemented by latrine searches (DoTE, 2016). While sampling was conducted across all habitats, to maximise detection efforts were concentrated in areas deemed most likely to support targeted fauna (DoTE, 2016).
Competency/experience of the consultant(s) carrying out the survey.	The field personnel/authors have had extensive experience in conducting desktop reviews and fauna surveys. This includes several Northern Quoll, Ghost Bat and Pilbara Leaf-nosed Bat surveys across the region. Bat call analysis conducted by bat expert Dr Kyle Armstrong.
Scope (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?)	Due to the nature of the survey, opportunistic survey was conducted for most reptiles, amphibians, birds and mammals. Intensive surveying was conducted for the Northern Quoll (den searches, scat searches, motion cameras), Ghost Bat (roost searches, scat searches, bat detectors), Pilbara Leaf-nosed Bat (roost searches, bat detectors) and Olive Python (den searches, scat searches).
Proportion of fauna identified, recorded and/or collected.	All fauna observed were identified. Urate from a large python scat was collected and due to its location was considered a likely Olive Python scat, however there is the potential for the Black-headed Python to occur in the area. No fauna collected.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Sources include previous reports on the fauna of the region (Outback Ecology 2012; BCE 2001, 2009; ecologia 2012; Biota 2007 and Molhar 2007); databases (BirdLife Australia, DBCA, EPBC, J. Turpin) and local fauna records obtained by J. Turpin.
The proportion of the task achieved and further work which might be needed.	Targeted Survey complete. Further study on diurnal bat roosts located in and around the project area could be undertaken. .
Timing/weather/season/cycle.	Field survey conducted during September - October 2017. A similar time of year to the Bamford Consulting surveys in 2001.
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey.	No disturbances affected the survey results.
Intensity (in retrospect, was the intensity adequate?)	Survey intensity was moderate (desktop review and targeted surveying for conservation significant fauna) and was adequate to satisfy EPA guidelines. Sufficient effort was employed to sample for the Pilbara Leaf-nosed Bat, Ghost Bat, Northern Quoll and Pilbara Olive Python.
Completeness (e.g. was relevant area fully surveyed).	The entire survey area was visually inspected significant portions traversed on foot. All major fauna habitats sampled. All areas likely to support Northern Quoll were inspected for the species scats and the most suitable habitats were further sampled with the use of motion activated cameras. All potential roosting sites for bats (caves) were inspected and sampled with SM2 Units. Rocky gorges and gullies were also searched for python scats.
Resources.	All species identified to taxon level.
Remoteness and/or access problems.	Not Applicable.
Availability of contextual information on the region.	Regional information was available and was consulted. See Section 2.2 "Previous Studies".

4. SURVEY RESULTS

4.1 Literature Review and Database Results

Vertebrate Fauna Assemblage

The desktop survey identified 268 vertebrate fauna species potentially occurring in the survey area (Appendix 2). A list of conservation significant species with the potential to occur within the Sulphur Springs Project Area generated by reviewing existing fauna survey reports in and around the project area and fauna database searches is provided in Table 6.

Table 6: Conservation Significant Fauna Recorded or Expected in the Sulphur Springs Project Area.

Common Name	Conservation Status			Local Records	Suitable Habitat within Sulphur Springs Project Area	Likely to occur in Project Area
	EPBC	WC	Priority			
REPTILES						
Woma	-	-	P1	Regional records	Minimal	No
Pin-striped Ctenotus	-	-	P1	Regional records	Minimal	No
Pilbara Olive Python	VU	S3	-	Abydos	Yes – rocky hills, outcrops, drainage lines	Yes
BIRDS						
Peregrine Falcon	-	S7	-	Regional records	Yes, minimal breeding habitat	Visitor
Grey Falcon	-	S3	-	Regional records	Yes, minimal breeding habitat	Vagrant
Rainbow Bee-eater	MG	S5	-	Sulphur Springs	Yes - Recorded within the study area	Migrant
Night Parrot	EN	S1	-	None	Expected as Vagrant only	Vagrant
MAMMALS						
Brush-tailed Mulgara	-	-	P4	Sulphur Springs	Yes - Recorded on northern plains	Yes
Northern Quoll	EN	S2	-	Sulphur Springs	Yes – rocky hills, outcrops, drainage lines	Previously Recorded
Spectacled Hare-Wallaby	-	-	P3	Sulphur Springs	Minimal, recorded on northern plains	Potential Visitor
Lakeland Downs Mouse	-	-	P4	Regional records	Minimal, patchy distribution across Pilbara	No
Bilby	VU	S3	-	Greater Area	Minimal, recent records from region	No
Ghost Bat	VU	S3	P4	Sulphur Springs	Yes – rocky hills, outcrops, drainage lines	Recorded
Pilbara Leaf-nosed Bat	VU	S3	-	Sulphur Springs	Yes – rocky hills, outcrops, drainage lines	Recorded
Pebble-mound Mouse	-	-	P4	Sulphur Springs	Recorded within the study area	Recorded
Long-tailed Dunnart	-	-	P4	Sulphur Springs	Recorded within the greater area	Yes

Status Codes:

- EPBC Act listed species: End = Endangered, Vul = Vulnerable, Mig = Migratory, CrE = Critically Endangered;
- WC Act listed species: S1 -7 = Schedule 1 – 7; DBCA Priority Species: P1 - 4 = Priority 1 - 4;
- Locally Significant species: L = Locally Significant.

Four threatened species listed under the EPBC Act occur, or are considered likely to occur, within the Sulphur Springs Project Area. These are the Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and Pilbara Olive Python and are discussed below.

Northern Quoll

The Northern Quoll (EPBC Endangered) has previously been recorded at Sulphur Springs, where the species was recorded from four locations, and tracks were observed to be abundant around pools along the “Creek Access Track” (Bamford Consulting Ecologists 2001). The series of rocky uplands which extend well beyond the Sulphur Springs Project area supports an intact and extensive Northern Quoll Population. The species has been extensively recorded at Abydos, North Star and Wodgina (Bamford Consulting Ecologists 2009; Outback Ecology 2012; ecologia 2012). However, as the species favours rocky areas, the extensive plains in the northern part of the project area are likely to support much lower numbers.

Northern Quolls are generally considered to be solitary, with females having mutually exclusive denning areas, although foraging areas can be overlapping, with territoriality likely to be related to the abundance, dispersion and availability of food (Oakwood 2002). Similar to other Dasyurids, male and female home ranges are of similar size outside of the breeding season; however, during the breeding season male home ranges expand significantly and can overlap extensively with several female ranges and numerous other male territories (Oakwood 2008). Female home ranges are up to 35 ha, preferring rocky habitat. Males can occupy territories of over 100 ha (Oakwood 2008). In the Pilbara, breeding has been recorded in September and October (at Abydos, J. Turpin records). However, females have been recorded with pouch young as late as February (How *et al.* 1991).

In the Pilbara, the Northern Quoll population appears intact as it has not yet experienced the invasion of the cane toad seen elsewhere in Australia. However, populations in the arid interior (>200 km from the coast) are few and poorly known (Turpin and Bamford, 2015). The Northern Quoll is regularly recorded from rocky areas within 200 km of the coastline, from Pannawonica east to Shay Gap and particularly north of the Fortescue Marsh (DBCA, 2017). Outside this area, records are few and scattered but occur from near Newman, from south of Nullagine and from the Little Sandy Desert (Turpin and Bamford, 2015).

Ghost Bat

The Ghost Bat has recently been upgraded to Vulnerable under the EPBC Act. It occurs in the series of rocky uplands extending well beyond the Sulphur Springs area, with adjacent areas known to support a significant Ghost Bat population. The species has been recorded at Abydos, Wodgina and North Star (5 – 50 km west of Sulphur Springs, J. Turpin observations; Outback Ecology 2012, Bamford Consulting 2009), from North Pole (20 km north-east of Sulphur Springs, Armstrong and Anstee, 2000) and a large Maternity Roost supporting hundreds of individuals is known from Lalla Rookh Mine (15 km north of Sulphur Springs, J. Turpin pers. obs., Armstrong and Anstee, 2000). During target searches of the Abydos and Wodgina areas, the Ghost Bat was recorded in deep, complex caves (10 – 20m deep with numerous caverns and chambers) within ironstone ridges (J. Turpin pers. obs.). Several significant roosts (maternity roosts, roosts supporting 20 - 40 individuals) were recorded from the deepest caves.

The Ghost Bat was recorded from the Project area during the 2001 survey conducted by Bamford Consulting. Individuals were observed flying at night and also found roosting in two caves to the south of the mine area (Bamford Consulting 2001).

The Ghost Bat formerly occurred over a wide area of central and northern Australia, however, it has declined significantly in the southern and arid parts of its range in the last 200 years (Armstrong and Anstee 2001). It now occurs in only a few highly disjunct sites across northern Australia and in Western Australia is confined to the Kimberley and Pilbara. Due to the species ongoing decline, the Ghost Bat has been upgraded to Vulnerable under the EPBC Act.

The distribution of Ghost Bats is influenced by the availability of suitable caves and mines for roost sites (Armstrong and Anstee 2001). The species' persistence in the arid Pilbara depends on the physiologically benign day-roosts found deep underground in humid, temperature-stable caves (Leitner & Nelson, 1967; Hall et al., 1997; Armstrong & Anstee 2000; McKenzie & Bullen, 2009). The preferred roosting habitats of Ghost Bats in the Pilbara are deep, complex caves beneath bluffs of low rounded hills composed of Marra Mamba geology, Brockman Iron Formations, granite rockpiles and abandoned mines (Armstrong and Anstee, 2000). Elsewhere, Ghost Bats have been known to roost in large colonies in sandstone caves, under boulder piles and in abandoned mines (Churchill, 1998).

The structure of a roost site is largely indicative of its use. Transient day roosts or feeding sites of the Ghost Bat are often shallow overhangs and crevices with microclimates similar to ambient conditions. Roosts for breeding activity often have a relative humidity of above 80 % (Armstrong and Anstee 2000). Domed ceilings which create humid microclimates are often present in, but not exclusive to maternity caves. Deep, humid and complex mine shafts and deep humid caves with several chambers and dome ceilings are associated with permanent Ghost Bat occupancy and maternity roosts (Hall *et al.* 1997).

Ghost Bats move between a number of caves seasonally, or as dictated by weather conditions, and require a range of cave sites to survive (Hutson *et al.*, 2001). Ghost Bats disperse widely when not breeding, but concentrate in a relatively few maternity roost sites when breeding. Outside of the breeding season, individuals often display low roost site fidelity, and utilise a number of caves throughout their home range (J. Turpin pers. obs.). This can confound search efforts as Ghost Bats can switch roosts on a regular basis. However, their distinctive scats are a reliable indicator of regular roost use (J. Turpin, pers. obs.).

Pilbara Leaf-nosed Bat

The Pilbara Leaf-nosed Bat (PLNB) has been recorded in the rocky uplands that extend well beyond the Sulphur Springs Project area. The species has been recorded at Abydos (Bamford Consulting Ecologists 2009; Outback Ecology 2012) and significant diurnal roosts have been recorded at Lalla Rookh Mine and at North Star (J. Turpin, pers. obs.). Bamford Consulting Ecologists describe a potential sighting of an individual Pilbara leaf-nosed bat from the Sulphur Springs area in 2001.

The Pilbara Leaf-nosed Bat is classified as Vulnerable under the EPBC Act. The relictual Pilbara population is known from a select few locations in the Pilbara region and from the Barlee Range Nature Reserve in the adjacent Gascoyne region (DBCA, 2017). Due to its physiological constraints, the Pilbara Leaf-nosed Bat roosts in deep, humid caves and abandoned, deep mines as it requires very hot (28 – 32 °C) and very humid (96 – 100 %) sites for roosting (Armstrong 2001; Churchill 2008; McKenzie and Bullen 2009). Cave roost sites occur typically within areas of high relief, within gorges, watercourses and in areas of permanent surface water. Although caves are common throughout the Pilbara, most are essentially shallow overhangs, or are not sufficiently deep to support warm, humid microclimates. Consequently, the roosting opportunity and area of occupancy of the Pilbara Leaf-nosed Bat is restricted to a very small area.

The DEE has categorised Pilbara Leaf-nosed Bat roosts according to how the species uses them (TSSC, 2016). A standardised nomenclature for these different types is provided in the Conservation Advice for the Pilbara Leaf-nosed Bat (PLNB; TSSC, 2016):

- permanent diurnal roosts (Priority 1)—occupied year-round and likely the focus for some part of the 9-month breeding cycle; considered as critical habitat that is essential for the daily survival of the PLNB.
- non-permanent breeding roosts (Priority 2)—evidence of usage during some part of the 9-month breeding cycle (July–March), but not occupied year-round; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB.
- transitory diurnal roosts (Priority 3)—occupied for part of the year only, outside the breeding season (i.e. April–June), and which could facilitate long distance dispersal in the region; considered as critical habitat that is essential for both the daily and long-term survival of the PLNB.
- nocturnal refuge (Priority 4)—occupied or entered at night for resting, feeding or other purposes, with perching not a requirement. Excludes overhangs. Not considered critical habitat but are important for persistence in a local area.

The type and quality of foraging habitat surrounding known or suspected roost sites can be critical to the survival of the Pilbara Leaf-nosed Bat. A colony requires access to suitable foraging habitat within its nightly flight range, and larger colonies require access to a greater proportion of the landscape (TSSC, 2016). The Pilbara Leaf-nosed Bat has been recorded foraging in a variety of habitats including watercourses, around rocky outcrops, gullies, gorges and over pools (Armstrong 2001; TSSC, 2016). The foraging habitats used by the Pilbara Leaf-nosed bat area classified by the TSSC (2016) as follows:

- Gorges with pools (Priority 1)—watercourses through upland areas bounded by sheer rock walls for parts of their length, often containing pools that remain for weeks or months, sites of relatively large biomass production, sometimes containing caves;
- Gullies (Priority 2)—primary drainage with limited riparian development in upland rocky habitats, sometimes containing small pools that may last for weeks, with less biomass production than Priority 1 gorge habitat;

- Rocky outcrop (Priority 3)—areas of exposed rock at the top of rocky outcrop and mesa hills that contain caves and overhangs, and boulder piles in the granite terrains;
- Major watercourses (Priority 4)—riparian vegetation on flat land plus the main gravelly or sandy channel of the river bed, sometimes containing pools that persist for weeks or months, and generally supporting higher productivity of biomass than the surrounding habitats;
- Open grassland and woodland (Priority 5)—dominated by *Triodia*, on lowland plains, colluvial slopes and hilltops.

Pilbara Olive Python

The Pilbara Olive Python is listed as Vulnerable under the EPBC Act. This subspecies is restricted to ranges within the Pilbara region, occurring in rocky areas (such as gorges, caves, and rock crevices) and also along major drainage lines. It is often associated with water (DEE, 2017) and permanent and semi-permanent pools are considered critical habitat to the species survival.

The Pilbara Olive Python has been previously recorded at Abydos and North Star (Bamford Consulting 2009, ecologia 2012). At Abydos, several individuals were recorded foraging and basking in rocky gorges within close proximity to waterholes (J. Turpin, pers. obs.). The species can be elusive and overlooked during fauna surveys and was not recorded in the Sulphur Springs area during the previous fauna assessments.

4.2 Field Survey Results

A total of 66 fauna species were recorded during the 2017 Sulphur Springs survey. This comprised 38 birds, 9 reptiles and 19 mammals (15 native and four introduced species, see Appendix 2). The motion-activated cameras recorded a total of 17 fauna species (11 birds, 2 reptiles, 4 Mammals – see Table 7). The Northern Quoll was not recorded despite the cameras installed for over a month in the field.

Table 7: Fauna Species recorded on motion sensitive cameras.

Species	FA1	FA3	FA7	FA10	FB1A	FB1B	FB2A	FB2B	FB9	FC6	FC9	FC10
<i>Varanus giganteus</i> (Perentie)	X		X									
<i>Varanus pilbarensis</i> (Pilbara Monitor)	X	X			X			X				
Common Bronzewing								X			X	
Spinifex Pigeon								X				
Yellow-throated Miner												X
Magpielark	X						X	X	X	X		
Willie Wagtail	X								X			
Grey Shrike-thrush	X							X		X	X	
Western Bowerbird	X									X		
Pied Butcherbird	X							X			X	X
Torresian Crow										X		
Pheasant Coucal			X									
Painted Finch									X			
<i>Pseudantechinus wooleyae</i>				X		X						
<i>Petrogale rothschildi</i> (Rock-wallaby)	X			X				X			X	X
<i>Zyomys argurus</i> (Rock Rat)	X			X		X					X	
<i>Felis catus</i> (Feral Cat)			X									

The bat detectors recorded seven bat species including several locations where the Pilbara Leaf-nosed Bat was detected (Appendix 3). The species detected included:

1. Pilbara Leaf-nosed Bat (*Rhinioncteris aurantia*);
2. Yellow-bellied Sheath-tailed Bat (*Saccolaimus flaviventris*);
3. Common Sheath-tailed Bat (*Taphozous georgianus*);
4. Gould's Wattled Bat (*Chalinolobus gouldii*);
5. Little Broad-nosed Bat (*Scotorepens greyii*);
6. Finlayson's Cave Bat (*Vespadelus finlaysoni*); and
7. Greater Northern Free-tailed Bat (*Chaerephon jobensis*).

4.2 Fauna Habitats

The major fauna habitats present within the Sulphur Springs Project Area are described in the Sulphur Springs Pilbara Copper-Zinc 2012 Assessment (Outback Ecology 2012). The eight major fauna habitats inspected for conservation significant fauna were:

1. Drainage Lines;
2. Fig Groves;
3. Rocky Foothills;
4. Rocky Ridges and Gorges;
5. Boulder Piles;
6. Scree Slopes; and,
7. Spinifex Stony Plains.

Figures 3 and 4 outline the fauna habitats present within the project area. The targeted survey focused on sampling within the project's footprint and particularly within habitats deemed suitable to support conservation significant fauna. This included the drainage lines, fig groves, boulder piles and rocky ridges and gorges.

5. CONSERVATION SIGNIFICANT FAUNA

5.1 Conservation Significant Fauna Recorded or Expected to Occur

Five species of conservation significance were recorded during the 2017 field survey:

- Ghost Bat (*Macroderma gigas*): - two individuals observed, two diurnal roosts recorded and seven feeding roosts recorded;
- Pilbara Leaf-nosed Bat (*Rhinonictis aurantia*): echolocation calls recorded from 12 locations including from within one cave;
- Pilbara Olive Python (*Liasis olivaceus barroni*): potential scat recorded;
- Western Pebble-mound Mouse (*Pseudomys chapmani*): mounds recorded;
- Rainbow Bee-eater (*Merops ornatus*): several individuals seen throughout the project area.

The conservation significant fauna recorded from the Sulphur Springs Project area are summarised in Table 8.

Table 8: Significant fauna recorded from the Sulphur Springs area.

Common Name	Species Name	Status	Easting	Northing	Comments
Ghost Bat	<i>Macroderma gigas</i>	VUL	727388	7663875	2 individuals in cave
Ghost Bat	<i>Macroderma gigas</i>	VUL	729012	7659618	Large scat pile in cave
Ghost Bat	<i>Macroderma gigas</i>	VUL	728988	7659655	Scat pile in overhang
Ghost Bat	<i>Macroderma gigas</i>	VUL	728928	7660109	Scat pile in overhang
Ghost Bat	<i>Macroderma gigas</i>	VUL	729333	7659530	Scat pile in overhang
Ghost Bat	<i>Macroderma gigas</i>	VUL	728462	7659623	Scat pile in overhang
Ghost Bat	<i>Macroderma gigas</i>	VUL	730677	7659567	Feeding remains
Ghost Bat	<i>Macroderma gigas</i>	VUL	728048	7662340	Scat pile in overhang
Ghost Bat	<i>Macroderma gigas</i>	VUL	728025	7662331	Scat pile in overhang
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	729011	7659615	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	731208	7659882	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	728898	7659570	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	729084	7659659	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	728991	7659750	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	727184	7660185	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	728492	7662661	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	728772	7659807	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	728764	7658338	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	727854	7663818	Echolocation call
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	727109	7665333	Echolocation call
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>	P4	726337	7667546	Pebble Mound
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>	P4	727440	7667399	Pebble Mound
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>	P4	726984	7668073	Pebble Mound
Pilbara Olive Python	<i>Liasis olivaceus barroni</i>	VUL	727804	7663496	Likely urate

Status Codes: EPBC Act listed species: Vul = Vulnerable, DBCA Priority Species: P1 - 4 = Priority 1 – 4.

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5.2 Northern Quoll

The rocky gorges, gullies and drainage lines present throughout the project area were searched extensively during the field survey for the presence of the Northern Quoll. However, the Northern Quoll was not recorded. Several areas of potential denning habitat (within rocky gorges, gullies and boulder piles) were noted and the project area is likely to support the species during favourable conditions (see Plates 1 – 4). Motion cameras situated within the habitat most likely to support the species did not detect the Northern Quoll despite over 500 camera nights of survey effort. As a result, the Northern Quoll population in the Sulphur Springs area is likely to be dynamic, with its occurrence in the area reflecting changes in seasonal conditions. Previous records from the project area during the 2001 survey are shown in Figure 5.

Plate 1: Rocky boulder piles within the project area – potential Northern Quoll denning habitat.



Plate 2: Rocky drainages within the project area – potential Northern Quoll denning habitat.



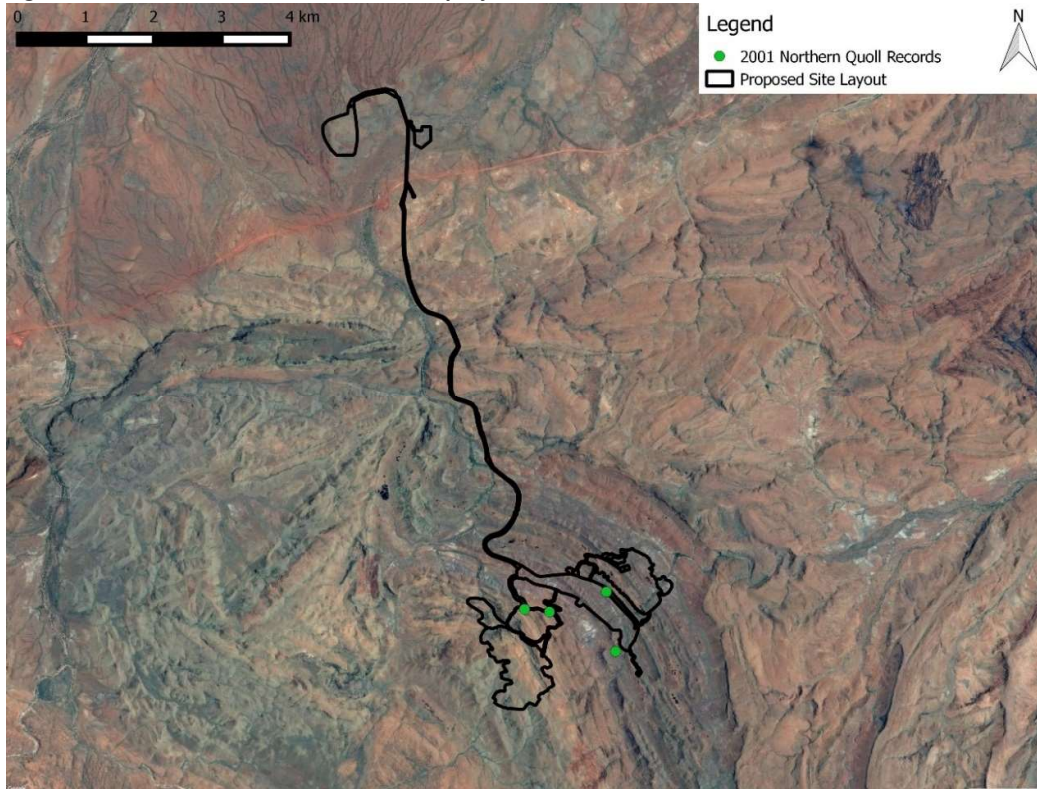
Plate 3: Rocky drainages in the vicinity of the project area – potential Northern Quoll denning habitat.



Plate 4: Rocky gorges within the project area – potential Northern Quoll denning habitat.



Figure 5. Northern Quoll records from the project area and its surrounds.



5.3 Ghost Bat

The Ghost Bat was recorded throughout the project area (Figure 6). The species' distinctive scats were recorded at seven locations, below rocky overhangs and in shallow caves – the indicative presence of feeding roosts (Plate 6). As such, the species is likely to forage throughout the project area.

Two diurnal roosts were recorded (Plate 7). A cave located within the project area (Cave 1; 729011E, 7659615N) contained a large pile of Ghost Bat scats on the cave floor. The large extent of scat material (combined with a sighting in 2001) is indicative the roost is regularly used by the species. A second cave with two Ghost Bats present (Plate 5) was recorded from just outside of the project area.

Plate 5: Ghost Bats recorded during the 2017 survey.



Figure 6. Ghost Bat records from the project area and its surrounds.

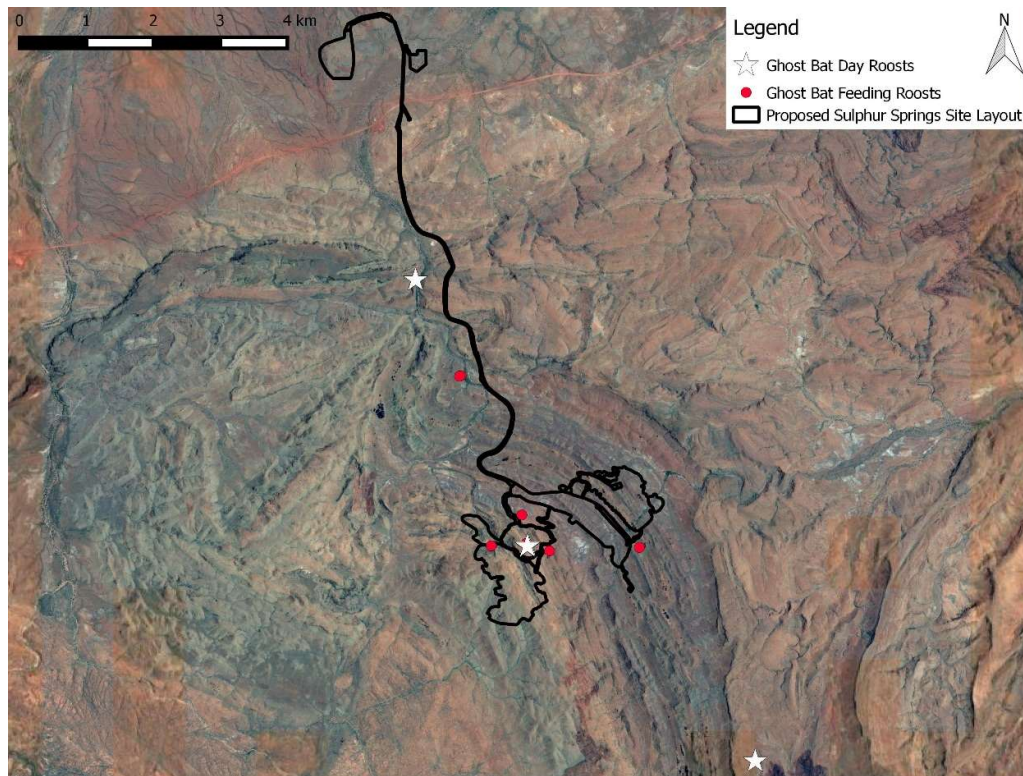


Plate 6: Evidence of a Ghost Bat feeding roost (the remains of several species, birds and the Kaluta).



Plate 7: Significant Ghost Bat caves recorded during the survey.



5.4 Pilbara Leaf-nosed Bat

The Pilbara Leaf-nosed Bat was recorded extensively during the 2017 survey. The species was recorded via bat detectors, from 11 locations, which included along drainage lines, gullies and within one cave. A summary of the call analysis is present within Appendix 3. The highest number of calls were from drainage lines in the Sulphur Springs area where the species is likely to forage widely along creek lines (both within and outside of the Project Area).

The Pilbara Leaf-nosed Bat was recorded from within one cave within the Sulphur Springs Project Area (Cave 1; 729011E, 7659615N, bat detector placed inside the cave, Figures 7 - 9). An analysis of the calls recorded within the cave over two nights revealed an activity pattern outside of the twilight period (calls recorded between 2330 and 0330) suggesting that while the cave may be important during nocturnal foraging it was not used as a day roost during the survey period. This assigns the cave to Priority 4 roost as classified by the Threatened Species Scientific Committee (TSSC, 2016).

While no Pilbara Leaf-nosed Bat roosts were recorded within the Sulphur Springs project area, due to the high volume of calls recorded, coupled with the timing of the first calls recorded at several sites (numbers of calls recorded within 30 minutes of civil twilight, Figure 10, Appendix 3), roosts are considered likely to occur nearby in the rocky uplands adjacent to the project area.

Figure 7. Pilbara Leaf-nosed Bat records from the project area and its surrounds.

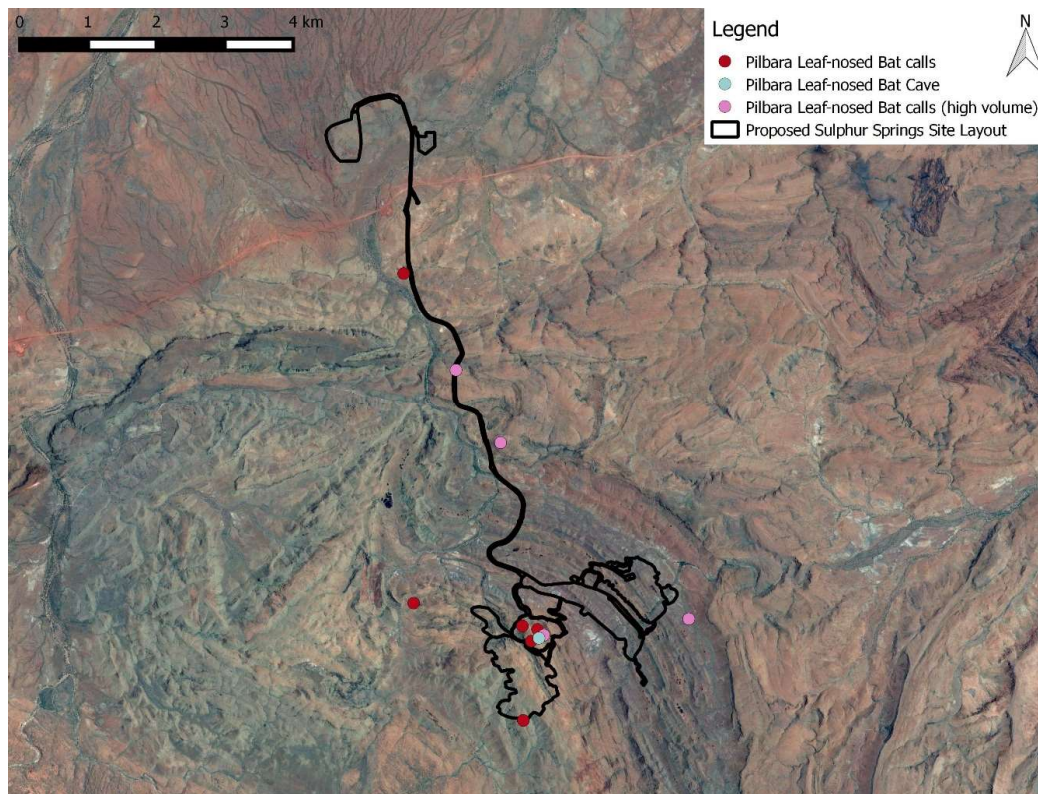


Figure 8. Pilbara Leaf-nosed Bat calls recorded from Cave 1 within the project area (28/09/17).

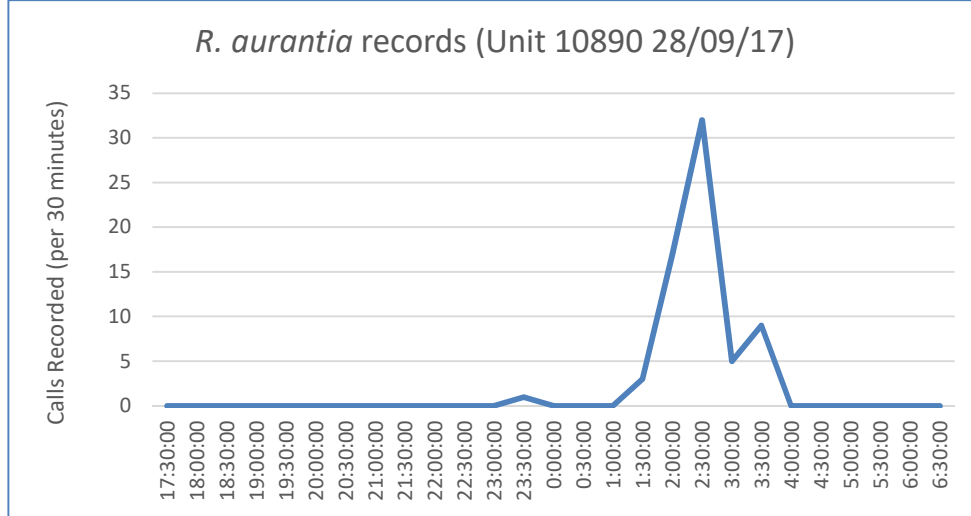


Figure 9. Pilbara Leaf-nosed Bat calls recorded from Cave 1 within the project area (29/09/17).

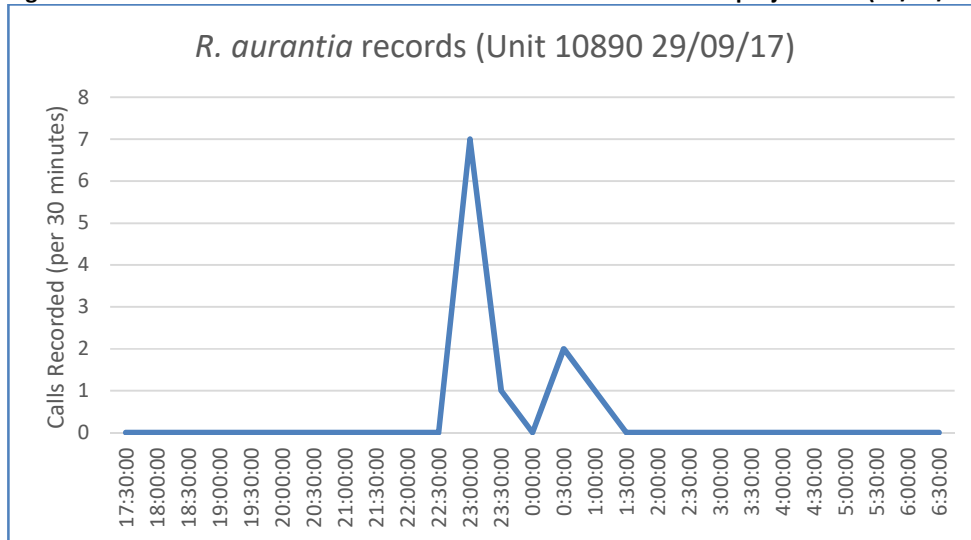
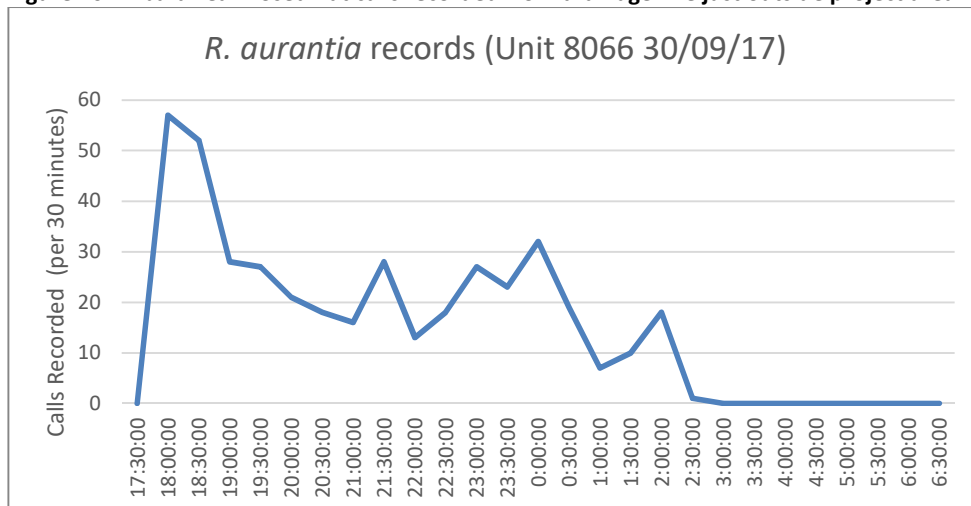


Figure 10. Pilbara Leaf-nosed Bat calls recorded from drainage line just outside project area.



5.5 Pilbara Olive Python

The rocky gorges, gullies and drainage lines present throughout the project area were searched for the presence of the Pilbara Olive Python. Rock crevices and caves were inspected for scats and waterholes were opportunistically searched. While the species was not observed, one large scat (urate) considered likely to be attributable to the species was recorded from a rocky area at 727804E, 7663496N.

The Pilbara Olive Python has been previously recorded at Abydos and North Star (Bamford Consulting 2009, ecologia 2012). At Abydos, several individuals were recorded foraging and basking in rocky gorges within close proximity to waterholes (J. Turpin, pers. obs.). The species can be elusive and overlooked during fauna surveys and was not recorded in the Sulphur Springs area during the previous fauna assessments.

5.4 Other Conservation Significant Fauna Expected in the Survey Area

Additional conservation significant fauna species occur or have the potential to occur within the Sulphur Springs Project Area. However, several are likely to occur as visitors or vagrants (e.g., Peregrine Falcon, Rainbow Bee-eater). The project area and surrounds are likely to be important for an additional six significant species which are expected to occur there in resident populations, or may utilise the project area during foraging or breeding. These are:

- Western Pebble-mound Mouse – mounds recorded during the 2017 survey;
- Long-tailed Dunnart – resident population likely to occur in the project area;
- Peregrine Falcon – likely to be a regular visitor;
- Rainbow Bee-eater – likely to be a regular migrant – recorded during the 2017 survey;
- Brush-tailed Mulgara – occurs on the plains to the north, potential for small numbers of individuals to occur on plains in the northern section of the project area; and,
- Spectacled Hare-Wallaby - occurs on the plains to the north, potential for small numbers of individuals to visit the northern project area.

6. DISCUSSION

Northern Quoll

The Northern Quoll, is expected to occur within the survey area, at least periodically, during favourable conditions. Habitat critical to the survival of the Northern Quoll is considered by DEE to include:

- Rocky habitats such as ranges, escarpments, mesas, gorges, breakaways, boulder fields, major drainage lines or treed creek lines;
- Structurally diverse woodland or forest areas containing large diameter trees, termite mounds or hollow logs;
- Off shore islands where the northern quoll is known to exist.

Rocky habitat suitable for the Northern Quoll occurs throughout the Sulphur Springs Project Area, however it appears to be only periodically utilised as no individuals were recorded despite the survey conducted over more than 500 camera nights. The detectability of the Northern Quoll can vary depending on habitat, the duration of sampling, the time of year and proximity to core populations. At sites where the species occurs in low densities, the Northern Quoll has been detected at a rate of one animal per 82 camera nights (Turpin and Bamford 2014). Where quolls occur in high densities, rates of one individual every 1.8 camera nights has been recorded (Turpin 2015). Due to the previous presence of the Northern Quoll at Sulphur Springs and at similar time of year (September 2001, Bamford *et al.* 2001) the camera effort employed here to detect the Northern Quoll was deemed to be sufficient. As such, the Northern Quoll is considered to occur currently in the Sulphur Springs area in low and fluctuating numbers.

During optimal conditions, the species is likely to occur in a higher abundance (and therefore readily detectable, e.g., Bamford *et al.* 2001). However, the Northern Quoll responds to resource pulses, and populations can fluctuate dramatically. The project area is unlikely to be a significant population refuge as the species was not recorded during the current survey, despite motion cameras positioned in locations deemed to be the most suitable habitat present. As such habitat is extensive outside of the project area and throughout the surrounding rocky uplands, the Northern Quoll population (which is known to be extensive in the greater area – J. Turpin, pers. obs.) is unlikely to be dependent on refuge within the Sulphur Springs area.

Pilbara Leaf-nosed Bat

The Pilbara Leaf-nosed Bat is likely to forage extensively throughout the project area however roosting sites appear limited. One Priority 4 nocturnal refuge was recorded within the project area. The species pattern of foraging (extensive along drainage lines within the project area) suggests additional refuge sites are likely to occur nearby. The conservation advice for the Pilbara Leaf-nosed Bat (TSSC, 2016) details habitat critical to the species survival and provides guidance for impact assessment. Significant habitat includes:

- Underground diurnal roosting sites (Priority 1, 2 and 3 refuge sites): an underground diurnal roost is critical to the survival of the Pilbara Leaf-nosed Bat, given the species reliance on warm, humid roost microclimates (TSSC, 2016).
- Nocturnal refuge sites (Priority 4 refuge sites): considered important for the species persistence in the local area (alternative roost sites and for facilitating longer distance dispersal in the region, TSSC, 2016).
- Foraging habitat: the type and quality of potential foraging habitat surrounding known or suspected roost sites can also be critical to the survival of the Pilbara Leaf-nosed Bat. A colony requires access to suitable foraging habitat within its nightly flight range, and larger colonies might require access to a greater proportion of the landscape (TSSC, 2016).

The development of the project is unlikely to result in a significant impact to the local population (using the EPBC Significant Impacts Guidelines) if appropriate management measures are in place.

Ghost Bat

Evidence of the Ghost Bat was recorded throughout the Sulphur Springs Project area. Seven feeding roosts were located and one diurnal roost (significant cave with evidence of Ghost Bat) was recorded. A further two diurnal roosts were located within caves adjacent to the project area.

Ghost Bats utilise a variety of different caves at different times of the year and for different purposes. These include:

1. Maternity Roosts: select, deep, complex and humid sites where Ghost Bats concentrate during breeding;
1. Diurnal roosts: deep caves or mines used as a day roost by one or several bats;
2. Transient day roosts or feeding roosts: shallow overhangs / caves (with microclimates similar to ambient conditions) facilitating feeding, dispersal or a temporary refuge.

Therefore, all roosting caves are considered import to the species. Ghost Bats move between a number of caves seasonally, or as dictated by weather conditions, and require a range of cave sites to survive (Hutson et al., 2001).

The Ghost Bat occurs throughout the rocky uplands surrounding the Sulphur Springs project. Significant roosts (maternity roosts and caves supporting over 20 individuals) have been recorded at North Star and Abydos and a large, regionally significant

population occurs at Lalla Rookh Mine. However, much of the proposed Sulphur Springs disturbance footprint is comprised of low, undulating hills and lacks the ironstone geology suitable for cave development. The diurnal roost located within the project area was found within the reduced area of rocky gorge habitat present. The extensive ironstone ridges flanking the Sulphur Springs Project Area are likely to contain a number of Ghost Bat roosts as the species has been extensively recorded in similar geology to the west (at Abydos, J. Turpin, pers. obs.).

The development of the project is unlikely to result in a significant impact to the local population (using the EPBC Significant Impacts Guidelines) if appropriate management measures are in place.

Management

Management strategies are recommended below to reduce the potential impacts of the project on the Northern Quoll, Ghost Bat, Pilbara Leaf-nosed Bat and other significant fauna species:

- Avoid disturbance to important bat roosts and Northern Quoll denning sites where possible;
- Minimise the loss of high value foraging habitat: to minimise impacts on the Pilbara Leaf-nosed Bat, disturbances to Priority 1 foraging habitat should be minimised and avoided where possible;
- Maintain existing natural water pools to encourage long term persistence of significant fauna in the project area;
- Avoid direct illumination of bat roosts by artificial lights;
- Restrict general access and entry to known or suspected roost sites;
- Avoid use of barbed wire fences to prevent Ghost Bat entrapment; and
- Monitor important fauna populations if present.

6. Conclusions

The 2017 Sulphur Springs Targeted Fauna Survey was conducted during September and October 2017 and comprehensively assessed the project's proposed disturbance footprint and opportunistically surveyed the adjacent area. Key findings of the survey include:

- Northern Quoll – not recorded during 2017, however, previously recorded within the project's proposed footprint (during 2001). Likely to occur within the project area in low and fluctuating numbers during favourable conditions;
- Ghost Bat – one important roosting cave recorded within the project area. A number of roost sites are likely to occur in adjacent areas and as such, the species forages widely throughout the area (as evidenced by feeding roosts);
- Pilbara Leaf-nosed Bat – likely to forage extensively throughout the project area, however, roosting sites appear limited. One Priority 4 (nocturnal refuge) was recorded within the project area. The species pattern of foraging (extensive along drainage lines within the project area) suggests additional refuge sites are likely to occur nearby;
- Pilbara Olive Python – likely to occur within the project area in low numbers and be associated with permanent pools in drainage lines;
- Much of the proposed Sulphur Springs disturbance footprint is comprised of low, undulating hills and lacks the ironstone geology suitable for cave or den development;
- Foraging habitat for significant fauna includes the drainage lines and associated riparian vegetation with significant areas containing permanent water; and
- The monitoring of important fauna populations should be undertaken if present.

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Appendix 1. Categories used in the assessment of conservation status.

IUCN categories (based on review by Mace and Stuart 1994) as used for the *Environment Protection and Biodiversity Conservation Act 1999* and the *Western Australian Wildlife Conservation Act 1950*.

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (Ex)	Taxa known to survive only in captivity.
Critically Endangered (CR)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (E)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (V)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Near Threatened	Taxa that risk becoming Vulnerable in the wild.
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
Data Deficient (Insufficiently Known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
Least Concern.	Taxa that are not Threatened.

Schedules used in the *WA Wildlife Conservation Act 1950*

Schedule 1 (S1)	Critically Endangered fauna.
Schedule 2 (S2)	Endangered fauna
Schedule 3 (S3)	Vulnerable Migratory species listed under international treaties.
Schedule 4 (S4)	Presumed extinct fauna
Schedule 5 (S5)	Migratory birds under international agreement
Schedule 6 (S6)	Conservation dependant fauna
Schedule 7 (S7)	Other specially protected fauna

WA Department of Environment and Conservation Priority species (species not listed under the *Wildlife Conservation Act 1950*, but for which there is some concern).

Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4. (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.
Priority 5 (P5)	Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years (IUCN Conservation Dependent).

Appendix 2. Fauna expected in the Sulphur Springs survey area (Table 2.1 to Table 2.4).

These lists are derived from the results of the field surveys conducted in the Sulphur Springs area and its surrounds and from database and literature searches. These include:

- Species recorded at Sulphur Springs:
 - Species recorded during the current fauna assessment (Kingfisher 2017);
 - Species recorded during the 2012 Level 1 Fauna Assessment (Outback Ecology 2012);
 - Species recorded during the 2001 survey (Bamford Consulting 2001);
- Species recorded during surveys conducted in areas adjacent to Sulphur Springs including at:
 - Abydos Mine (Outback Ecology 2011, Bamford Consulting 2009);
 - North Star (ecologia 2012);
 - Wodgina (outback Ecology 2012, Bamford Consulting 2008);
- Species listed under fauna databases – DCBA Threatened Species Database and NatureMap records (DCBA, 2017), Birddata (BirdLife Australia, 2017), Atlas of Living Australia (ALA, 2017) or EPBC Protected Matters Search (DEE, 2017), or from the literature.

Table 2.1. Frog species expected to occur in the survey area.

FROGS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
HYLIDAE							
Giant Frog	<i>Cyclorana australis</i>		X	X			
Main's Frog	<i>Cyclorana maini</i>		X	X			
Desert Tree Frog	<i>Litoria rubella</i>		X	X	X		X
LIMNODYNASTIDAE							
Northern Burrowing Frog	<i>Neobatrachus aquilonius</i>						
Shoemaker Frog	<i>Neobatrachus sutor</i>			X			
Desert Spadefoot	<i>Notaden nicholli</i>			X			
Spencer's Burrowing Frog	<i>Platyplectrum spenceri</i>			X			
MYOBATRACHIDAE							
Glandular Toadlet	<i>Uperoleia glandulosa</i>			X			
Pilbara Toadlet	<i>Uperoleia saxatilis</i>		X	X	X		
Total Number of Species: 9		0	4	8	2	0	1

Table 2.2. Reptile species recorded or expected to occur in the survey area.

REPTILES		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
Cheluidae							
<i>Chelodina steindachneri</i>	Steindachner's Turtle			X			
Agamidae							
<i>Gowidon longirostris</i>	Long-nosed Dragon		X	X	X		X
<i>Ctenophorus caudicinctus</i>	Ring-tailed Dragon		X	X	X		X
<i>Ctenophorus isolepis</i>	Central Military Dragon			X			
<i>Ctenophorus nuchalis</i>	Central Netted Dragon			X			
<i>Ctenophorus reticulatus</i>	Western Netted Dragon						
<i>Diporiphora valens</i>	Southern Pilbara Tree Dragon			X			
<i>Diporiphora vescus</i>	Northern Pilbara tree dragon						
<i>Pogona minor</i>	Western Bearded Dragon		X	X			
Diplodactylidae							
<i>Crenadactylus ocellatus</i>	Clawless Gecko		X	X	X		
<i>Diplodactylus conspicillatus</i>	Fat-tailed Gecko		X	X			
<i>Diplodactylus galaxias</i>	Pilbara Beak-Faced Gecko		X	X			
<i>Diplodactylus savagei</i>	Pilbara Beak-Faced Gecko		X	X	X		
<i>Lucasium stenodactylum</i>	Sand-plain Gecko		X	X			
<i>Lucasium wombeyi</i>	Pilbara ground gecko		X	X			
<i>Oedura marmorata</i>	Marbled Velvet Gecko		X	X			
<i>Rhynchoedura ornata</i>	Beaked Gecko			X			
<i>Strophurus elderi</i>	Jewelled Gecko		X	X	X		
<i>Strophurus jeanae</i>	Southern phasmid gecko			X			
Carphodactylidae							
<i>Nephrurus levis</i>	Three-lined Knob-tail			X			
<i>Nephrurus wheeleri</i>	Banded Knob-tailed Gecko			X			
Gekkonidae							
<i>Gehyra pilbara</i>	Pilbara Dtella			X			
<i>Gehyra punctata</i>	Spotted Dtella		X	X	X		
<i>Gehyra variegata</i>	Variegated Dtella		X	X	X		
<i>Hemidactylus frenatus</i>	Asian House Gecko						
<i>Heteronotia binoei</i>	Bynoe's Gecko		X	X	X		
<i>Heteronotia spelea</i>	Desert Cave Gecko		X	X			
Pygopodidae							
<i>Delma butleri</i>	Unbanded delma		X				
<i>Delma elegans</i>	Pilbara delma		X	X	X		
<i>Delma haroldi</i>	Neck-barred delma		X				
<i>Delma nasuta</i>	Sharp-snouted delma		X	X	X		
<i>Delma pax</i>	Peace delma		X	X	X		
<i>Delma tincta</i>	Excitable delma		X	X			
<i>Lialis burtonis</i>	Burton's Legless Lizard			X	X		

REPTILES		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
<i>Pygopus nigriceps</i>	Western Hooded Scaly-foot			X			
Scincidae							
<i>Carlia munda</i>	Shaded-litter Rainbow Skink		X	X	X		
<i>Carlia triacantha</i>	Desert rainbow-skink		X	X			
<i>Cryptoblepharus buchananii</i>	Buchanan's Snake-eyed Skink		X	X			
<i>Cryptoblepharus ustulatus</i>	Russet snake-eyed skink		X	X	X		X
<i>Ctenotus ariadnae</i>	Ariadna's Ctenotus			X			
<i>Ctenotus duricola</i>	Pilbara Ctenotus		X	X			
<i>Ctenotus grandis</i>	Grand Ctenotus		X	X			
<i>Ctenotus helenae</i>	Clay-soil Ctenotus			X			
<i>Ctenotus nigrilineatus</i>	Pin-striped Finesnout Ctenotus	P1					
<i>Ctenotus pantherinus</i>	Leopard Ctenotus		X	X			
<i>Ctenotus piankai</i>	Coarse Sands Ctenotus			X			
<i>Ctenotus rubicundus</i>	Ruddy ctenotus		X	X	X		
<i>Ctenotus saxatilis</i>	Rock Ctenotus		X	X	X		X
<i>Ctenotus schomburgkii</i>	Barred Wedgesnout ctenotus		X	X			
<i>Cyclodomorphus melanops</i>	Spinifex Slender Blue-Tongue		X	X	X		
<i>Egernia cygnitos</i>	Pygmy Spiny-tailed Skink						
<i>Egernia epcisolus</i>	Eastern Pilbara spiny-tailed skink			X			
<i>Egernia formosa</i>	Goldfields Crevice-skink		X	X	X		X
<i>Egernia pilbarensis</i>	Pilbara Crevice-skink						
<i>Eremiascincus richardsonii</i>	Broad-banded Sand-swimmer		X				
<i>Lerista bipes</i>	North-western Sandslider		X	X			
<i>Lerista jacksoni</i>	Jackson's Three-toed Slider		X	X			
<i>Lerista muelleri</i>	Wood mulch-slider			X	X		
<i>Lerista timida</i>	Timid Slider						
<i>Lerista verhmens</i>	Powerful three-toed slider		X	X			
<i>Menetia greyii</i>	Common Dwarf Skink		X	X			
<i>Menetia surda</i>	Western dwarf skink		X	X	X		
<i>Morethia ruficauda</i>	Lined fire-tailed skink		X	X	X		X
<i>Notoscincus ornatus</i>	Ornate soil-crevice skink		X	X	X		
<i>Proablepharus reginae</i>	Western soil-crevice skink		X	X	X		
<i>Tiliqua multifasciata</i>	Centralian Blue-tongue		X	X			
Varanidae							
<i>Varanus acanthurus</i>	Spiny-tailed Monitor		X	X	X		
<i>Varanus brevicauda</i>	Short-tailed Pygmy Monitor		X	X			
<i>Varanus eremius</i>	Pygmy Desert Monitor		X	X			
<i>Varanus giganteus</i>	Perentie		X	X	X		X
<i>Varanus gouldii</i>	Sand Goanna		X	X			
<i>Varanus panoptes</i>	Yellow-spotted Monitor		X	X			
<i>Varanus pilbarensis</i>	Pilbara Rock Monitor		X	X			X

REPTILES		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
<i>Varanus tristis</i>	Black-headed Monitor		X	x			
Typhlopidae							
<i>Anilius ammodytes</i>	Pilbara Blind Snake			X			
<i>Anilius grypus</i>	Beaked Blind Snake			X			
<i>Anilius pilbarensis</i>	Pilbara Blind Snake						
<i>Anilius waitii</i>	Beaked Blind Snake						
Pythonidae							
<i>Antaresia perthensis</i>	Pygmy Python		X	X	X		
<i>Antaresia stimsoni</i>	Stimson's Python		X	X			
<i>Aspidites melanocephalus</i>	Black-headed Python		X				
<i>Liasis olivaceus barroni</i>	Pilbara Olive Python	VUL	X	X			Scat?
Elapidae							
<i>Acanthophis wellsi</i>	Pilbara Death Adder		X	X			
<i>Brachyuropsis approximans</i>	Northwestern Shovel-nosed Snake		X	X			
<i>Demansia psammophis</i>	Yellow-faced Whipsnake		X	X			
<i>Demansia rufescens</i>	Rufous Whipsnake		X	X	X		
<i>Furina ornata</i>	Moon Snake		X	X			
<i>Parasuta monachus</i>	Monk Snake		X	X			
<i>Pseudechis australis</i>	Mulga Snake		X	X			
<i>Pseudonaja modesta</i>	Ringed Brown Snake			X			
<i>Pseudonaja mengdeni</i>	Gwardar			X			
<i>Suta fasciata</i>	Rosen's Snake		X	X			
<i>Suta punctata</i>	Spotted Snake			X			
<i>Vermicella snelli</i>	Pilbara bandy-bandy		X	X			
Total Number of Species: 94		2	64	81	27	0	9

Table 2.3. Bird species recorded or expected to occur in the survey area.

BIRDS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
Casuariidae							
<i>Dromaius novaehollandiae</i>	Emu						
Phasianidae							
<i>Coturnix pectoralis</i>	Stubble Quail						
<i>Coturnix ypsilophora</i>	Brown Quail		X	X	X		X
Anatidae							
<i>Dendrocygna eytoni</i>	Plumed Whistling-Duck			X			
<i>Cygnus atratus</i>	Black Swan		X	X			
<i>Chenonetta jubata</i>	Australian Wood Duck						
<i>Malacorhynchus membranaceus</i>	Pink-eared Duck						
<i>Anas gracilis</i>	Grey Teal		X	X			
<i>Anas superciliosa</i>	Pacific Black Duck		X	X	X		
Podicipedidae							
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe		X				
<i>Poliiocephalus poliocephalus</i>	Hoary-headed Grebe						
Columbidae							
<i>Phaps chalcoptera</i>	Common Bronzewing		X	X	X		X
<i>Ocyphaps lophotes</i>	Crested Pigeon		X	X	X		
<i>Geophaps plumifera</i>	Spinifex Pigeon		X	X	X		X
<i>Geopelia cuneata</i>	Diamond Dove		X	X	X		
<i>Geopelia striata</i>	Peaceful Dove			X	X		X
Podargidae							
<i>Podargus strigoides</i>	Tawny Frogmouth		X	X	X		
Eurostopodidae							
<i>Eurostopodus argus</i>	Spotted Nightjar		X	X	X		
Aegothelidae							
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar		X	X	X		X
Apodidae							
<i>Apus pacificus</i>	Fork-tailed Swift			X			
Phalacrocoracidae							
<i>Microcarbo melanoleucos</i>	Little Pied Cormorant			X	X		
<i>Phalacrocorax carbo</i>	Great Cormorant						
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant			X	X		
<i>Phalacrocorax varia</i>	Pied Cormorant						
Ciconiidae							
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork			X	X		
Pelicanidae							
<i>Pelecanus conspicillatus</i>	Australian Pelican		X	X	X		
Ardeidae							
<i>Ardea pacifica</i>	White-necked Heron		X	X	X		
<i>Ardea modesta</i>	Eastern Great Egret		X	X	X		
<i>Ardea ibis</i>	Cattle Egret						
<i>Egretta novaehollandiae</i>	White-faced Heron		X	X	X		
<i>Nycticorax caledonicus</i>	Nankeen Night Heron			X	X		

BIRDS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
Threskiornithidae							
<i>Threskiornis spinicollis</i>	Straw-necked Ibis				X		
<i>Threskionis molucca</i>	Australian White Ibis						
<i>Platelea regia</i>	Royal Spoonbill						
<i>Platalea flavipes</i>	Yellow-billed Spoonbill						
Accipitridae							
<i>Elanus axillaris</i>	Black-shouldered Kite		X	X	X		
<i>Lophoictinia isura</i>	Square-tailed Kite			X			
<i>Hamirostra melanosternon</i>	Black-breasted			X			
<i>Haliastur sphenurus</i>	Whistling Kite		X	X	X		X
<i>Milvus migrans</i>	Black Kite		X	X			
<i>Accipiter fasciatus</i>	Brown Goshawk			X			
<i>Accipiter cirrocephalus</i>	Collared Sparrowhawk			X	X		
<i>Circus assimilis</i>	Spotted Harrier			X	X		
<i>Circus approximans</i>	Swamp Harrier						
<i>Aquila audax</i>	Wedge-tailed Eagle		X	X	X		
<i>Hieraaetus morphnoides</i>	Little Eagle			X	X		
Falconidae							
<i>Falco cenchroides</i>	Nankeen Kestrel		X	X	X		
<i>Falco berigora</i>	Brown Falcon		X	X	X		X
<i>Falco longipennis</i>	Australian Hobby						
<i>Falco hypoleucos</i>	Grey Falcon	VUL		X			
<i>Falco subniger</i>	Black Falcon						
<i>Falco peregrinus</i>	Peregrine Falcon	S7					
Rallidae							
<i>Gallirallus philippensis</i>	Buff-banded Rail			X			
<i>Tribonyx ventralis</i>	Black-tailed Native-hen						
<i>Fulica atra</i>	Eurasian Coot						
Otididae							
<i>Ardeotis australis</i>	Australian Bustard		X	X			X
Burhinidae							
<i>Burhinus grallarius</i>	Bush Stone-curlew			X	X		
Recurvirostridae							
<i>Himantopus himantopus</i>	Black-winged Stilt						X
<i>Recurvirostra novaehollandiae</i>	Red-necked Avocet						
<i>Cladorhynchus leucocephalus</i>	Banded Stilt						
Charadriidae							
<i>Charadrius ruficapillus</i>	Red-capped Plover						
<i>Eiseyornis melanops</i>	Black-fronted Dotterel			X	X		
<i>Peltohyas australis</i>	Inland Dotterel						
<i>Erythronyx cinctus</i>	Red-kneed Dotterel						
Scolopacidae							
<i>Tringa glareola</i>	Wood Sandpiper	MIG					
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	MIG					
<i>Calidris ruficollis</i>	Red-necked Stint	MIG					
Turnicidae							

BIRDS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
<i>Turnix velox</i>	Little Button-quail		X	X	X		X
Glareolidae (Pratincoles)							
<i>Stiltia isabella</i>	Australian Pratincole						
Laridae							
<i>Chlidonias leucopterus</i>	White-winged Black Tern						
<i>Chlidonia hybrida</i>	Whiskered Tern			X			
<i>Sterna nilotica</i>	Gull-billed Tern						
Cacatuidae (Cockatoos)							
<i>Eolophus roseicapillus</i>	Galah		X	X	X		X
<i>Cacatua sanguinea</i>	Little Corella		X	X	X		X
<i>Nymphicus hollandicus</i>	Cockatiel		X	X	X		
Psittacidae							
<i>Barnardius zonarius</i>	Australian Ringneck		X	X	X		
<i>Melopsittacus undulatus</i>	Budgerigar		X	X	X		
<i>Neopsephotus bourkii</i>	Bourke's Parrot		X				
<i>Neophema elegans</i>	Elegant Parrot						
<i>Pezoporus occidentalis</i>	Night Parrot	CrE					
Cuculidae							
<i>Centropus phasianinus</i>	Pheasant Coucal		X	X	X		X
<i>Chalcites basalus</i>	Horsfield's Bronze-Cuckoo		X	X	X		
<i>Chalcites osculans</i>	Black-eared Cuckoo						
<i>Cacomantis pallidus</i>	Pallid Cuckoo		X	X	X		
Strigidae							
<i>Ninox connivens</i>	Barking Owl			X			
<i>Ninox novaeseelandiae</i>	Southern Boobook		X	X	X		
Tytonidae							
<i>Tyto javanica</i>	Eastern Barn Owl						
Halcyonidae							
<i>Dacelo leachii</i>	Blue-winged Kookaburra		X	X	X		
<i>Todiramphus pyrropygius</i>	Red-backed Kingfisher		X	X	X		
<i>Todiramphus sanctus</i>	Sacred Kingfisher		X	X	X		X
Meropidae			X				
<i>Merops ornatus</i>	Rainbow Bee-eater		X	X	X		X
Ptilonorhynchidae							
<i>Ptilonorhynchus guttatus</i>	Western Bowerbird		X	X	X		X
Maluridae							
<i>Malurus leucopterus</i>	White-winged Fairy-wren		X	X			
<i>Malurus lamberti</i>	Variegated Fairy-wren		X	X	X		X
<i>Stipiturus ruficeps</i>	Rufous-crowned Emu-wren			X	X		
<i>Amytornis striatus</i>	Striated Grasswren		X	X	X		X
Acanthizidae							
<i>Smicronis brevirostris</i>	Weebill		X	X	X		
<i>Gerygone fusca</i>	Western Gerygone			X	X		
<i>Acanthiza uropygialis</i>	Chestnut-rumped Thornbill						
Pardalotidae							
<i>Pardalotus rubricatus</i>	Red-browed Pardalote		X	X	X		

BIRDS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
<i>Pardalotus striatus</i>	Striated Pardalote		X	X	X		X
Meliphagidae							
<i>Certhionyx variegatus</i>	Pied Honeyeater			X	X		
<i>Lichenostomus virescens</i>	Singing Honeyeater			X	X		X
<i>Lichenostomus keartlandi</i>	Grey-headed Honeyeater		X	X	X		X
<i>Lichenostomus plumulus</i>	Grey-fronted Honeyeater			X			
<i>Lichenostomus penicillatus</i>	White-plumed Honeyeater			X	X		X
<i>Manorina flavigula</i>	Yellow-throated Miner		X	X	X		X
<i>Acanthagenys rufogularis</i>	Spiny-cheeked Honeyeater			X			
<i>Conopophila whitei</i>	Grey Honeyeater		X	X			
<i>Epthianura tricolor</i>	Crimson Chat		X	X			
<i>Sugomel niger</i>	Black Honeyeater						
<i>Lichmera indistincta</i>	Brown Honeyeater		X	X	X		X
<i>Melithreptus gularis</i>	Black-chinned Honeyeater			X	X		
Pomatostomidae							
<i>Pomatostomus temporalis</i>	Grey-crowned Babbler		X	X			X
<i>Pomatostomus superciliosus</i>	White-browed Babbler						
Eupetidae							
<i>Cinclosoma castaneothorax</i>	Chestnut-breasted Quail		X				
Neosittidae							
<i>Daphoenositta chrysoptera</i>	Varied Sittella						
Campephagidae							
<i>Coracina maxima</i>	Ground Cuckoo-shrike						
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike		X	X	X		X
<i>Lalage sueurii</i>	White-winged Triller		X	X	X		X
Pachycephalidae			X				
<i>Pachycephala rufiventris</i>	Rufous Whistler		X	X	X		
<i>Colluricincla harmonica</i>	Grey Shrike-thrush		X	X	X		X
<i>Oreoica gutturalis</i>	Crested Bellbird		X	X	X		
Climacteridae			X				
<i>Climacteris melaneura</i>	Black-tailed Treecreeper						
Artamidae							
<i>Artamus personatus</i>	Masked Woodswallow			X			X
<i>Artamus cinereus</i>	Black-faced Woodswallow		X	X	X		X
<i>Artamus minor</i>	Little Woodswallow			X	X		X
<i>Cracticus torquatus</i>	Grey Butcherbird			X			
<i>Cracticus nigrogularis</i>	Pied Butcherbird		X	X	X		X
<i>Cracticus tibicen</i>	Australian Magpie		X	X	X		
Rhipiduridae							
<i>Rhipidura albiscapa</i>	Grey Fantail						
<i>Rhipidura leucophrys</i>	Willie Wagtail		X	X	X		X
Corvidae							
<i>Corvus bennetti</i>	Little Crow						
<i>Corvus orru</i>	Torresian Crow		X	X	X		X
Monarchidae							

BIRDS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
<i>Grallina cyanoleuca</i>	Magpie-lark		X	X	X		X
Petroicidae							
<i>Petroica goodenovii</i>	Red-capped Robin						
<i>Melanodryas cucullata</i>	Hooded Robin						
Alaudidae							
<i>Mirafrja javanica</i>	Horsfield's Bushlark		X	X			
Megaluridae							
<i>Cincloramphus mathewsi</i>	Rufous Songlark			X	X		
<i>Cincloramphus cruralis</i>	Brown Songlark			X			
<i>Eremiornis carteri</i>	Spinifexbird		X	X	X		X
Hirundinidae							
<i>Cheramoeca leucosterna</i>	White-backed Swallow						
<i>Hirundo neoxena</i>	Welcome Swallow		X				
<i>Petrochelidon nigricans</i>	Tree Martin		X	X			
<i>Petrochelidon ariel</i>	Fairy Martin		X	X	X		
Nectariniidae							
<i>Dicaeum hirundinaceum</i>	Mistletoebird		X	X	X		
Estrildidae							
<i>Taeniopygia guttata</i>	Zebra Finch			X	X		X
<i>Neochmia ruficauda</i>	Star Finch		X	X			
<i>Emblema pictum</i>	Painted Finch			X	X		X
Motacillidae							
<i>Anthus novaeseelandiae</i>	Australasian Pipit			X			
TOTAL: 125		6	73	101	76	0	38

Table 2.4. Mammal species recorded or expected to occur in the survey area.

MAMMALS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
Tachyglossidae							
Echidna	<i>Tachyglossus aculeatus</i>		X	X	X		X
Dasyuridae							
Northern Quoll	<i>Dasyurus hallucatus</i>	END	X	X	X		
Brush-tailed Mulgara	<i>Dasyercus blythi</i>	P4		X			
Little Red Kaluta	<i>Dasykaluta rosamondae</i>		X	X			X
Pilbara Ningau	<i>Ningau timealeyi</i>		X	X	X		
Planigale	<i>Planigale sp. 1</i>			X			
Planigale	<i>Planigale sp. 2</i>						
Rory's Pseudantechinus	<i>Pseudantechinus roryi</i>		X	X			
Woolley's Pseudantechinus	<i>Pseudantechinus woolleyae</i>		X	X			X
Long-tailed Dunnart	<i>Sminthopsis longicaudata</i>	P4	X	X			
Stripe-faced Dunnart	<i>Sminthopsis macroura</i>			X			
Lesser Hairy-footed Dunnart	<i>Sminthopsis youngsoni</i>			X			
Macropodidae							
Spectacled Hare-Wallaby	<i>Lagorchestes conspicillatus</i>	P3	X	X			
Euro	<i>Macropus robustus</i>		X	X	X		X
Red Kangaroo	<i>Macropus rufus</i>		X	X			
Rothschild's Rock-Wallaby	<i>Petrogale rothschildi</i>		X	X	X		X
Megadermatidae							
Ghost Bat	<i>Macroderma gigas</i>	VUL	X	X	X		X
Hipposideridae							
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	VUL	X	X			X
Emballonuridae							
Yellow-bellied Sheath-tail-bat	<i>Saccolaimus flaviventris</i>			X			X
Common Sheath-tail-bat	<i>Taphozous georgianus</i>		X	X	X		X
Vespertilionidae							
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>		X	X			X
Northwestern Long-eared Bat	<i>Nyctophilus bifax</i>						
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>		X	X			
Inland Broad-nosed Bat	<i>Scotorepens greyii</i>		X	X			X
Finlayson's Cave Bat	<i>Vespadelus finlaysoni</i>		X	X	X		X
Molossidae							
Northern Freetail-bat	<i>Chaerephon jobensis</i>			X			X
Beccari's Freetail-bat	<i>Mormopterus beccarii</i>			X			
White-striped Freetail-bat	<i>Austronomus australis</i>			X	X		
Muridae							
Short-tailed Mouse	<i>Leggadina lakedownensis</i>			X			

MAMMALS		Conservation Status	Database Records	Surrounding Surveys	Bamford Consulting 2001	Outback Ecology 2012	Kingfisher 2017
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>	P4	X	X	X		X
Delicate Mouse	<i>Pseudomys delicatulus</i>		X	X	X		
Desert Mouse	<i>Pseudomys desertor</i>		X	X	X		
Sandy Inland Mouse	<i>Pseudomys hermannsburgensis</i>		X	X			
Common Rock-rat	<i>Zyzomys argurus</i>		X	X	X		X
Introduced Mammals							
House Mouse	<i>Mus musculus</i>		X	X	X		
Dog/Dingo	<i>Canis lupus</i>		X	X	X		X
Cat	<i>Felis catus</i>		X	X	X		X
Donkey	<i>Equus asinus</i>			X			
Horse	<i>Equus caballus</i>			X			
Dromedary Camel	<i>Camelus dromedarius</i>			X	X		X
European Cattle	<i>Bos taurus</i>		X	X			X
Total Number of Species: 40		7	27	39	17	0	19

Appendix 3. Bat Call Identification from Sulphur Springs, Western Australia.



Bat call identification from Sulphur Springs, Western Australia

Type: Acoustic analysis

Prepared for: Kingfisher Environmental Consulting

Date: 3 January 2018

Job No.: SZ435

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This report should be included amongst the technical appendices of the main report, and cited as:

Specialised Zoological (2018). Bat call identification from Sulphur Springs, Western Australia. Acoustic analysis. Unpublished report by Specialised Zoological for Kingfisher Environmental Consulting, 3 January 2018, Job number SZ435.

SUMMARY

Bat identifications from acoustic recordings are provided from Sulphur Springs, in the Pilbara region of Western Australia. Seven species of bat were identified as being present (**Tables 1 and 2**). Representative echolocation calls for each identification are illustrated (**Figure 1**), as recommended by the Australasian Bat Society (ABS 2006). Further data are available should verification be required.

COMMENTS ON IDENTIFICATIONS

The identification of bat species from full spectrum WAV-format recordings of their echolocation calls was based on measurements of characteristic frequency, observation of pulse shape, and the pattern of harmonics. All call types could be attributed unambiguously to species. The most significant identification was that of the Pilbara Leaf-nosed Bat *Rhinonictis aurantia*. A summary of nightly activity is provided with this report, which can be plotted for interpretation of the likelihood of roosting if the recording site was at a cave entrance (**Tables 3 and 4**). No echolocation or social calls of the Ghost Bat *Macroderma gigas* were observed.

METHODS

Data recorded in full spectrum lossless WAC0 format with Wildlife Acoustics SM2BAT bat detectors (sampling rate 384 kHz, trigger 6 dB above background; 48 dB gain; set to turn on automatically at sunset and off at sunrise) was converted to high quality bitstream WAV format using Kaleidoscope 3.0.0 software.

A multi-step acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats (Armstrong and Aplin 2014; Armstrong et al. 2016) was then applied to the recordings made on the survey. Firstly, the WAV files were scanned for bat echolocation calls using several parameter sets in the software SCAN'R version 1.7.7 (Binary Acoustic Technology), which also provides measurements (in "SonoBat™ compatible output") from each putative bat pulse. The output was then used to determine if putative bat pulses measured in SCAN'R could be identified to species. This was done using a custom [R] language script that performed three tasks: 1. undertook a Discriminant Function Analysis on training data from representative calls from the Pilbara; 2. from the measurements of each putative bat pulse from SCAN'R, calculated values for the first two Discriminant Functions that could separate the echolocation call types derived from the analysis of training data, and plotted these resulting coordinates over confidence regions for the defined call types; and 3. facilitated an inspection in a spectrogram of multiple examples of each call type for each recording night by opening the original WAV files

SZ435: Bat call identification from Sulphur Springs, Western Australia

containing pulses of interest in Adobe Audition CS6 version 5.0.2. Species were identified based on information in McKenzie and Bullen (2009), and nomenclature follows Jackson and Groves (2015) and Reardon et al. (2015). Activity data of the Pilbara Leaf-nosed Bat was compiled with a separate R language script, and all files with putative calls of this species were inspected to weed out false positive identifications

LIMITATIONS

The identifications presented in this report have been made within the following context:

1. The identifications made herein were based on the ultrasonic acoustic data recorded and provided by a 'third party' (the client named on the front of this report).
2. The scope of this report extended to providing information on the identification of bat species in bulk ultrasonic recordings, and summarising activity data of the Pilbara Leaf-nosed Bat. Further comment on these species and the possible impacts of a planned project on bat species were not part of the scope.
3. In the case of the present report, the recording equipment was set up and supplied by Specialised Zoological. The equipment was operated by the third party during the survey.
4. Other than the general locality of the study area, Specialised Zoological has not been provided with detailed information of the survey area, has not made a site visit to observe the habitats available for bats, nor have we visited the specific project areas on a previous occasion.
5. Specialised Zoological has had no input into the overall design of this bat survey, and no input into the survey timing, recording site placement, nor degree of recording site replication on this survey.
6. While Specialised Zoological has made identifications to the best of our ability given the available materials, and reserves the right to re-examine the data and revise any identification following a query, it is the client's and / or proponent's responsibility to provide supporting evidence for any identification, which might require follow-up trapping effort or non-invasive methods such as video recordings. Specialised Zoological bears no liability for any follow-up work that may be required to support an identification based initially on the analysis of acoustic recordings undertaken and reported on here.
7. There are a variety of factors that affect the 'detectability' of each bat species, given the frequency, power and shape characteristics of their calls. Further information on the analysis and the various factors that can impinge on the reliability of identifications can be provided upon request.

SZ435: Bat call identification from Sulphur Springs, Western Australia

REFERENCES

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TABLE 1. Species identified in the present survey from all sites combined.

RHINONYCTERIDAE Pilbara Leaf-nosed Bat	<i>Rhinonycteris aurantia</i>
EMBALLONURIDAE Yellow-bellied Sheath-tailed Bat Common Sheath-tailed Bat	<i>Saccolaimus flaviventris</i> <i>Taphozous georgianus</i>
VESPERTILIONIDAE Gould's Wattled Bat Little Broad-nosed Bat Finlayson's Cave Bat	<i>Chalinolobus gouldii</i> <i>Scotorepens greyii</i> <i>Vespadelus finlaysoni</i>
MOLOSSIDAE Greater Northern Free-tailed Bat	<i>Chaerephon jobensis</i>

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TABLE 2. Species identifications, with the degree of confidence indicated by a code. Date and serial/unit number correlates with recording site; see **Table 1** for full species names.

	<i>C. gouldii</i>	<i>C. jobensis</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
SM2BAT 10890							
28/09/2017	—	—	◆	—	—	◆	◆
29/09/2017	—	—	◆	—	—	◆	◆
30/09/2017	◆	—	◆	—	—	◆	◆
SM2BAT 8060							
29/09/2017	—	◆	◆	—	◆	◆	◆
30/09/2017	◆	—	◆	—	◆	◆	◆
1/10/2017	◆	—	◆	—	◆	◆	◆
SM2BAT 8066							
29/09/2017	—	◆	◆	◆	◆	◆	◆
30/09/2017	—	—	◆	◆	◆	◆	◆
1/10/2017	◆	—	◆	—	◆	◆	◆
SM2BAT 8072							
29/09/2017	—	◆	◆	◆	◆	◆	◆
30/09/2017	◆	—	◆	◆	◆	◆	◆
1/10/2017	—	—	—	—	◆	◆	—
2/10/2017	◆	—	◆	◆	◆	◆	◆
SM2BAT (Lloyd)							
29/09/2017	—	◆	—	—	—	◆	◆
30/09/2017	—	—	—	—	—	◆	◆

Definition of confidence level codes:

— Not detected.

◆ Unambiguous identification of the species at the site based on measured call characteristics and comparison with available reference material. Greater confidence in this ID would come only after capture and supported by morphological measurements or a DNA sequence.

NC Needs Confirmation. Either call quality was poor, or the species cannot be distinguished reliably from another that makes similar calls. Alternative identifications are indicated in the *Comments on identifications* section of this report. If this is a species of conservation significance, further survey work might be required to confirm the record.

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TABLE 3. Comma-delimited summary of activity of the Pilbara Leaf-nosed Bat by recording unit and night (can be copied and pasted elsewhere for plotting).

start	time	29/09/2017	30/09/2017	1/10/2017	29/09/2017	30/09/2017	1/10/2017	29/09/2017	30/09/2017
17:30:00	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0								
18:00:00	0,19,0,0,57,0,0,13,0,0,0,15								
18:30:00	0,35,0,0,52,0,0,28,0,0,0,13								
19:00:00	1,16,1,0,28,0,1,12,0,0,0,13								
19:30:00	1,21,2,0,27,0,0,15,1,0,0,4								
20:00:00	3,12,0,0,21,0,3,16,1,0,0,2								
20:30:00	0,18,1,0,18,0,0,58,0,0,0,6								
21:00:00	0,4,0,0,16,0,2,25,1,0,0,6								
21:30:00	0,11,0,0,28,0,0,64,0,0,0,7								
22:00:00	0,17,0,3,13,0,0,42,1,0,0,13								
22:30:00	0,13,0,0,18,0,0,48,0,0,0,28								
23:00:00	1,7,0,1,27,0,0,46,0,0,7,6								
23:30:00	1,5,0,0,23,0,0,18,0,1,1,30								
0:00:00	2,7,0,0,32,0,0,15,0,0,0,46								
0:30:00	1,0,0,0,19,0,0,7,0,0,2,39								
1:00:00	0,6,0,0,7,0,0,4,0,0,1,23								
1:30:00	0,51,0,0,10,0,0,8,1,3,0,18								
2:00:00	0,30,0,0,18,0,0,5,0,17,0,15								
2:30:00	0,2,0,0,1,0,0,0,0,32,0,2								
3:00:00	0,0,0,0,0,0,0,0,0,3,5,0,0								
3:30:00	0,0,0,0,0,0,1,0,0,4,9,0,0								
4:00:00	0,0,0,0,0,0,0,0,0,3,0,0,0								
4:30:00	0,0,0,0,0,0,0,0,0,0,0,0,0								
5:00:00	0,0,0,0,0,0,0,0,0,0,0,0,0								
5:30:00	0,0,0,0,0,0,0,0,0,0,0,0,0								
6:00:00	0,0,0,0,0,0,0,0,0,0,0,0,0								
6:30:00	0,0,0,0,0,0,0,0,0,0,0,0,0								

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TABLE 4. Summary of first and last detection times of the Pilbara Leaf-nosed Bat, with reference to sunrise and sunset times and the beginning and end of civil twilight (#: HH:MM:SS; *: HH:MM; a 'pass' is defined as at least one pulse in a WAV file of length 5 seconds or less; Trend: Microsoft Excel 'sparklines' providing a miniature plot of nightly activity from sunset to sunrise).

Unit	Date	Total passes	First time of detection #	Last time of detection #	Sunset *	Civil twilight end *	Civil twilight begin *	Sunrise *	Detection after sunset *	Detection before sunrise *	Trend
8060	29/09/2017	10	19:00:52	0:56:36	18:02	18:25	5:25	5:47	0:59	4:50	
8060	30/09/2017	274	19:00:52	4:01:49	18:03	18:25	5:24	5:46	0:58	1:44	
8060	1/10/2017	4	19:04:02	20:42:30	18:03	18:25	5:23	5:45	1:01	9:02	
8066	29/09/2017	4	22:12:21	23:24:21	18:02	18:25	5:25	5:47	4:10	6:22	
8066	30/09/2017	415	18:45:23	4:00:15	18:03	18:25	5:24	5:46	0:42	1:45	
8066	1/10/2017	1	3:50:44	—	18:03	18:25	5:23	5:45	9:47	—	
8072	29/09/2017	6	19:10:45	21:21:15	18:02	18:25	5:25	5:47	1:09	8:25	
8072	30/09/2017	424	18:51:17	3:54:16	18:03	18:25	5:24	5:46	0:48	1:51	
8072	2/10/2017	15	19:38:59	4:10:31	18:03	18:26	5:22	5:45	1:36	1:34	
10890	28/09/2017	67	23:39:50	3:32:09	18:02	18:25	5:25	5:47	5:38	2:14	
10890	29/09/2017	11	23:21:36	1:12:54	18:03	18:25	5:24	5:46	5:19	4:33	
10890	30/09/2017	286	18:41:03	4:01:22	18:03	18:25	5:23	5:45	0:38	1:43	

FIGURE 1. Representative call sequence portions of the species identified (A: *Chaerephon jobensis*; B: *Saccolaimus flaviventris*; C: *Taphozous georgianus*; D: *Chalinolobus gouldii*; E: *Scotorepens greyii*; F: *Vespadelus finlaysoni*; G: *Rhinonicteris aurantia*; time between pulses has been compressed).

