BHP

Western Australian Iron Ore

Ghost Bat Research Plan

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1. Introduction

1.1 Background

BHP Iron Ore Pty Ltd (BHP) currently operates an iron ore mining operation at Mining Area C (Northern Flank) under Ministerial Statement (MS) 491, located approximately 100 kilometres (km) northwest of Newman township in the Pilbara region of Western Australia. BHP is seeking environmental approval under Part IV of the *Environmental Protection Act 1986* (EP Act) to develop and operate a satellite orebody at Southern Flank as part of its Mining Area C operations, and to expand the scope of disturbance currently approved at the Mining Area C hub under a single ministerial statement and development envelope (the Proposal).

The Proposal will involve conventional open-pit iron ore mining of the mineralised Marra Mamba and Brockman Iron Formation. The bulk of the orebody at Southern Flank lies above the water table but mine dewatering will be required in advance to facilitate dry mining conditions for where ore lies below the water table.

During baseline studies for the environmental approval, a number of caves were identified across Southern Flank that support daytime and maternity roosting for ghost bats (*Macroderma gigas*). The ghost bat has recently been listed as a Vulnerable species at a State (*Wildlife Conservation Act 1950*) and Federal (*Environment Protection and Biodiversity Conservation Act 1999*) level. Consequently, BHP has implemented the mitigation hierarchy to avoid, minimise and offset impacts to the ghost bat.

1.2 Offset Framework in Western Australia

Where an offset is required for a Proposal, the *WA Environmental Offsets Guidelines* (Government of Western Australia, 2014) identifies three types of offsets; acquisition, on ground management and research. With regards to research offsets the *WA Environmental Offsets Guidelines* (Government of Western Australia, 2014) states:

> *"Research projects can add significant value to the outcomes of on-ground management and the understanding of the environmental value being impacted. The research must be designed to result in positive conservation outcomes, and may be targeted at improving the management and protection of existing conservation estate. Research that may include field surveys should be designed to address priority knowledge gaps with the outcomes publicly available to improve management of the environment generally, and provide information that will improve environmental assessment of future projects. Research project should be focused on achieving an outcome, rather than expending a certain amount of money.*
>
> *Research projects are generally only appropriate as offsets where there is a high degree of uncertainty regarding impacts of a project and new science is required to develop better mitigation measures of predictive tools to avoid and minimise the particular type of impact. Where new information is gained through research this can lessen the need for a proponent to continue an existing offset, or avoid the need for an offset in future projects."*

Due to limited ecological information on the ghost bat in the Pilbara region, BHP proposes to undertake a research offset (this plan) to enable informed on ground management of the ghost bat in the Pilbara.

1.3 Purpose and Structure of this Document

This document provides a brief background on the current state of knowledge for the ghost bat in Australia, key threats to the species, and proposed outcomes and approach for the research plan.

2. The Ghost Bat

2.1 Current Knowledge on Ecology

Fossil evidence suggests ghost bats were widely spread across most of mainland Australia, including the arid zone, but their range has contracted northwards since the Holocene (Duncan et al., 1999; Hoyle et al., 2001). Their range is now restricted to the Pilbara, the Kimberley, the northern part of the Northern Territory (including Groote Eylandt), coastal and near coastal Queensland from Cape York to near Rockhampton (Churchill, 2008), and Western Queensland (TSSC, 2016).

In the Pilbara region, the species occurs in all four sub-regions, and was recorded in 21 of the 24 areas surveyed by the Department of Parks and Wildlife during the Pilbara Biological Survey (2002-2007; see McKenzie and Bullen, 2009).

The largest populations occur within the Chichester sub-region, where known populations are largely restricted to disused mines. Two of these artificial roosts appear to have disappeared, and the remaining four show evidence of collapse, flooding, human intrusion or nearby active mineral exploration (TSSC, 2016). The largest colonies occur around Bamboo Creek, Marble Bar and Nullagine, with the largest confirmed observations known from natural caves occurring in the Robe Valley near Pannawonica (15-35 individuals sighted in separate caves) (Bullen, pers. comm).

In the Hamersley sub-region, populations are more widespread but are much smaller in size. There are abandoned mines in this sub-region; a few have shown little evidence of ghost bat presence (e.g. Hashimoto [Specialised Zoological, 2009]), while others of suitable depth show continuous use, such as those along Rhodes Ridge and Bakers South (Bullen, pers. comm.).

The distribution of ghost bats in the Pilbara is determined by the presence of suitable roosting sites, either natural caves or man-made mines and adits. Natural roosts generally comprise deep, complex caves beneath bluffs or low rounded hills composed of Marra Mamba or Brockman Iron Formation, or in granite tors (Armstrong and Anstee, 2000); although Marra Mamba was considered the geology most predisposed to forming deep caves in the Pilbara suitable for use by the ghost bat. Armstrong and Anstee (2000) further noted that most caves used by ghost bats in bluffs have narrow entrances, generally less than 0.5 m^2, that opened into larger chambers.

Centralised breeding sites in the Pilbara are largely restricted to abandoned mines in the Chichester Ranges; however, there are a number of smaller maternity roosts in the Chichester and Hamersley Ranges (Armstrong and Anstee, 2000). There are few known maternity roosts in natural caves in the Pilbara. Based on available data, breeding has been documented in natural caves at Mining Area C (including Southern Flank), Mt Brockman and West Angeles in the Hamersley sub-region, and at Callawa and Tambrey Station in the Chichester sub-region (Armstrong and Anstee, 2000; Biologic 2013, 2015; M. O'Connell, pers. obs.).

Ghost bats move between a number of caves seasonally, or as dictated by weather conditions, and require a range of cave sites (Hutson et al., 2001). Outside the breeding season, male bats are known to disperse widely, most likely during the wet season when conditions would allow bats to use caves that would otherwise not be suitable. Genetic studies indicate that females are likely to stay close to preferred maternity roosts (Worthington-Wilmer et al., 1994).

There are currently no studies on the home range of ghost bats in the Hamersley Range. A study in the Northern Territory (Tidemann et al., 1985) may provide some information; however, there are likely to be differences in the ecology and foraging behaviour of ghost bats in the Pilbara compared to the tropics. Tidemann et al. (1985) recorded an average foraging area of 61 ha, with foraging areas centred around 1.9 km from the day roost. Ghost bats generally returned to the same foraging areas each night, and more than one bat may use a particular foraging area.

Ghost bats in the Pilbara are believed to mate in July and August, with the females giving birth approximately three months after in October (Richards et al., 2008) (Table 1). Young are weaned on prey captured by the mothers, and hunt with the mothers until they become completely independent.

Table 1: Approximate breeding cycle of ghost bats in the Pilbara

Month	Breeding Stage
July - August	Mating
August - October	Gestation
September - November	Birth

Ghost bats disperse widely when not breeding, but studies outside the Hamersley Ranges suggest that they concentrate in relatively few roost sites when breeding (TSSC, 2016). Few of these sites are known (Richards et al., 2008; Worthington Wilmer 2012) and most are not protected or managed.

Within the Hamersley Range, a number of roosts containing pregnant females have been documented and the concept of a centralised maternity roost is unlikely to be applicable in this region. Field observations within the Proposed Mining Area C Development Envelope and surrounds suggest that the maternity groups may use different maternity roosts across different seasons, as it is rare to encounter the maternity group despite visiting the most suitable caves in the area across a number of breeding seasons (Bat Call, 2010, Biologic, 2012; 2014).

After emerging from their roosts, ghost bats commence hunting approximately 1 to 1.5 hours after sunset and will hunt for about two hours (Boles, 1999). This is followed by periods of inactivity interspersed by periods of hunting. A resumption of feeding activity occurs just prior to sunrise. Ghost bats have a 'sit and inspect' foraging strategy; they hang on a perch where they visually inspect their surroundings for movement. Once their prey is detected it may be captured in the air, gleaned (taken from the surface of a substrate by a flying bat) from the ground or vegetation, or dropped on from a perch (Boles, 1999).

Ghost bats are carnivorous, with their diet comprising bats and other small mammals, birds, frogs and geckos. Studies in Central Queensland (Toop, 1985) suggest that the bats diet changes seasonally, with insects being the main food source during the warmer months while birds and mammals are the primary food source during the cooler months. Birds appear to be the primary food source outside of insects, with over 50 species of birds documented as prey items in the Northern Territory (Boles, 1999). Some of these species weigh almost as much as an average sized ghost bat (e.g. Pied Butcherbird which weighs 100-130 g). Studies in the Pilbara are consistent with these findings (Biologic, 2014).

The key difference between ghost bats in the Hamersley sub-region and those areas to the north (Chichester sub-region, Kimberleys and Northern Territory) is the use of a large centralised maternity roost, with in natural caves or abandoned mines. In the northern areas, roosts can support up to 1500 bats, which disperse widely outside the breeding season. Armstrong and Anstee (2000) suggested that within the Hamersleys, ghost bats occur in small groups that may move about in a local area, possibly in response to disturbance, microclimate or social factors. Studies undertaken for BHP have been consistent with this observation (M. O'Connell, pers. comm).

To date, there have been no published studies on ghost bat foraging habitat use in the Pilbara. Data on foraging by ghost bats are available from the Northern Territory, based on studies at Pine Creek (Tidemann et al 1985). The Pine Creek population appears to fluctuate, with population estimates ranging between 300 (July 1981) and 1500 (January 1990). The study undertaken by Tidemann et al (1985) was undertaken at the Kohinoor Mine, 1 km south of Pine Creek in May 1983. At this time the population at the mine was estimated to be 445 individuals (Tidemann et al 1985). The mean size of foraging areas was 61 ha, with bats on average foraging 1.9 km from the day roost, and most returning

to an individual foraging area over consecutive nights. There were however exceptions to this; one female foraged in the same area on two consecutive nights, but on the two subsequent nights it was located 10-15 km north-west of the day roost (Tidemann et al 1985). This is consistent with limited field observations near Mining Area C (M. O'Connell). There also appeared to be no apparent preference for different types of woodland or topographic features, with bats appearing to be randomly distributed with respect to these features (Tidemann et al 1985).

2.2 Key Threats

Key threats to the ghost bat as listed in the Federal conservation advice (TSSC, 2016) are:

- Habitat loss (destruction of, or disturbance to, roost sites and nearby areas) due to mining;
- Disturbance of (human visitation at) breeding sites;
- Modification to foraging habitat;
- Collision with fences, especially those with barbed wire;
- Collapse or reworking of old mine adits;
- Contamination by mining residue at roost sites;
- Disease; and
- Poisoning by cane toads (*Rhinella marina*).

2.3 Federal and State Government Research Objectives

Recommended conservation and management actions identified in the TSSC (2016) conservation advice are:

Survey and monitoring priorities

1. Survey to better define distribution
    a) Collate and review all information on Pilbara roost sites, and identify banded-ironstone areas in all parts of the region that are planned for future mining or may be quarantined from mining (high priority);
    b) Additional surveys, especially to locate breeding sites, are required in remote parts of the Pilbara, Kimberley and Northern Territory (high priority);
    c) Assess population size (and significance) of all known subpopulations (medium – high priority).
2. Establish or enhance monitoring program
    a) Monitor populations at key sites and where impacts from mining are occurring or likely (high priority);
    b) Develop cost-effective monitoring protocols (e.g. thermal tracking software) at a set of standardised sites that contain most of the known population (medium).

Information and research priorities

3. Assess impacts of disturbance of breeding sites, and identify appropriate buffer zones for specific activities around roost sites so mining and other activities do not lead to abandonment (high priority).
4. Assess options for establishment of new/artificial roost sites (as a last resort only), and mitigation options to reduce impacts of mining. Evaluate the success of such actions (medium priority).
5. Assess seasonal access to foraging areas in the Pilbara remote from major roosts (medium priority).

6. Assess proximity to roosts of foraging habitats used by lactating females compared to other adults (medium priority).

Research priorities identified by the Department of Biodiversity Conservation and Attractions are:

1. Survey within the conservation estate.
2. Further quantification of habitat (roost, including maternal roosts) requirements in the Pilbara.
3. Design and operationalise a monitoring program for known roosts (using remote technologies) so that trends in occupancy and abundance can be quantified over time and across space, especially in response to seasons, impacts to foraging habitats (i.e. fire) and disturbance (such as exploration drilling).
4. Basic ecological research which may inform species management in particular Population Viability Analysis models, e.g. births and deaths, demography, diet, foraging habitat preference.

3. Research Objectives and Approach

3.1 Research Objectives

The research objectives for this plan have been developed in consideration of the current state of knowledge for the ghost bat, key threats identified by the Federal Department of the Environment and Energy (see Section 2.3), consultation with the Department of Biodiversity Conservation and Attractions (DBCA) (see Section 2.3) and likely impacts to the ghost bat from implementation of the Southern Flank Proposal.

BHP is proposing to undertake a three-year study on the ecology of ghost bats in the Hamersley sub-region. The objective of this research plan is to provide key information on certain aspects of the ghost bat's ecology in the Pilbara that will inform on-ground management by BHP, the WA government and other proponents operating in the Pilbara. Information on spatial use of roosting habitat and areas of high value foraging habitat are the key gaps in species knowledge for the Pilbara, and therefore the specific objectives for this study are:

1. Determine the temporal and spatial use of roosting habitat by ghost bats in the eastern Hamersley sub-region.
2. Investigate the foraging strategy utilised by the ghost bat in the Pilbara.
3. Determine any key dispersal corridors for ghost bats in the eastern Hamersley sub-region.

3.2 Approach

Temporal and spatial use of roosting habitat

Scats will be collected every two months from 60-70 caves within the vicinity of BHP's operations at Mining Area C and Newman. In addition, scats will be collected six monthly from a population of ghost bats west of Karijini National Park (outside BHP tenure) in the vicinity of Mount Trochanos. This site has a similar cave density to Southern Flank and so may be suitable for use as a control programme in any future monitoring events.

Scats will be sub-sampled by the DBCA and then provided to the University of Queensland (UQ) for analysis of faecal hormones.

The genetic study will comprise the following:

1. Collation of ghost bat tissue and faecal samples;

2. Extraction of DNA from faecal and tissue samples and determine genetic profiles using existing microsatellite markers. Re-genotyping of a proportion of existing DNA extracts to ensure consistency and alignment amongst new and existing genotyping data.
3. Spatial temporal analysis: once unique individuals have been identified, statistical analyses will be used to estimate the movement of individuals within and between roost sites, and determine dispersal patterns as follows:
    - 3.1 genotype matching will be used to detect resident versus vagrant ghost bats over temporal samples;
    - 3.2 genotype matching will be used to detect incidences of individual ghost bats using multiple caves, and the temporal patterns of cave use;
    - 3.3 if sufficient sampling is available per cave, assignment tests will be used to assign individuals to a 'population of origin' based on their genetic profile to infer dispersal amongst caves;
    - 3.4 spatial autocorrelation analysis will be used to estimate the genetic neighbourhood-size and infer the spatial scale of dispersal.
4. Population genetic analyses: individual genotypes from Pilbara and Kimberley samples will be analysed to determine:
    - 4.1 If the Pilbara and Kimberley ghost bat populations are genetically distinct;
    - 4.2 The level of genetic differentiation amongst populations (FST) to infer gene flow amongst populations;
    - 4.3 The effective population size (Ne), and minimum number of bats genotyped; and
    - 4.4 Additional analyses to investigate population level questions, including identifying sites with high genetic diversity and whether any population(s) have been through genetic bottlenecks.

The hormone study will comprise:

1. Analysis of progesterone metabolite concentrations by enzyme immunoassay to determine the presence of pregnant females. Previous studies undertaken between 2014 and 2016 have determined likely progesterone metabolite levels (ng/g) for presumed pregnant and non-pregnant bats.
2. Analysis of testosterone and oestrodiol metabolite levels in male and female ghost bats, using wild and captive animals. Preliminary studies based on captive bats suggest that faecal testosterone levels may distinguish between the sexes.
3. Degradation analysis, to determine the collection frequency required to document the presence of pregnant bats.

The results from the genetic and hormone study will allow each bat to be allocated:

- a unique identification number (based on genotype);
- sex (based on field collections or hormone levels); and
- reproductive status.

Repeat collections from the same individual over multiple survey events will enable an understanding of temporal and spatial movement by the bats to be determined.

Foraging strategies

Location of preferred foraging habitats/ areas and home range will be undertaken using radio-telemetry and VHF transmitters. Up to ten bats will be fitted with trackers annually, where possible targeting a sex ratio of 50:50. Only adults will be fitted with trackers.

The Motus Wildlife Tracking System will be trialled to determine if it can be utilised in Australia. Motus is an international collaborative research network that uses an automated radio telemetry array to track the movement of organisms. Animals are fitted with digitally-encoded radio transmitters 'nano-tags' that broadcast signals several times each minute. Tags will be programmed to record over a 250 day period. During the first year of the trial, 20 automated stations will be established across Southern Flank, Mining

Area C and adjacent BHP tenure. Bats flying within 10 km of the directional towers will be recorded and the data will be triangulated to determine approximate location of the bat. The data will be used to determine key foraging areas over an extended period of time, and determine any temporal or seasonal changes in foraging areas.

Bats will also be fitted with VHF transmitters and manually tracked whilst foraging. This will provide fine-scale data to be obtained regarding use of habitats and preferred foraging areas, e.g. preferred vegetation and/or topographical features.

The infrastructure installed on BHP tenure can be used to track other target species (e.g. northern quoll, Pilbara olive python) and as it is open source, will be available for research projects undertaken by other government or non-government organisations.

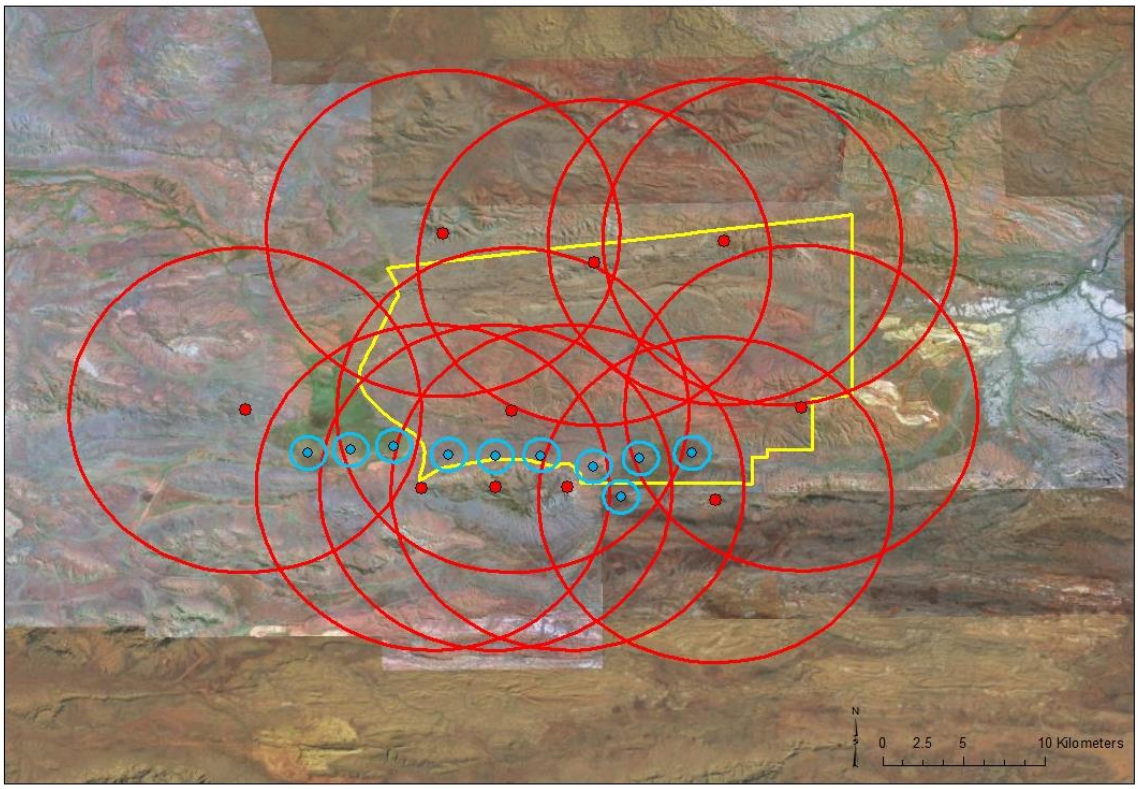

Figure 1: Indicative location of the Motus tracking stations relative to the Proposed Mining Area C Development Envelope, showing those with 10 km directional radius and 1 km non-directional radius.

3.3 Research Partners

Key research partners identified for this first year of this project are:

- Biologic Environmental Survey
- Bat Call WA
- Department of Biodiversity Conservation and Attractions (Science and Conservation, Perth Zoo)
- University of Queensland (UQ).

Based on the outcomes of the research, other partners may be included in the project. The intent is to transition the project to the WA Biodiversity Science Institute (WABSI).

3.4 Alignment with State and Federal Government Objectives

Table 2 summarises the State and Federal governments' research objectives for ghost bats (detailed in Section 2.3) with commentary on how this research plan aligns with these objectives.

4. Research Outcomes

The purpose of the research described in this plan to to enable effective on-ground management that will contribute to a long-term conservation outcome for the ghost bat. Understanding key aspects of the ghost bat's ecology in the Hamersley sub-region will enable BHP and other government and non-government organisations to target on-ground management to areas that will have the greatest benefit to the ghost bat. This on-ground management needs to focus on reducing the impacts of the key threats listed in Section 2.2 and also the following management actions detailed in the TSSC's (2016) Conservation Advice:

1. Protect land with significant colonies (high priority).
2. In barbed wire fences close to roost sites, replace the top strand with single-strand wire, and put a metal disc (around 10x10 cm) between the top and second strands (high priority).
3. Protect roost sites and surrounding foraging areas from disturbance, including the loss of habitat quality due to changes to fire and grazing regimes (medium priority).
4. Where appropriate, modify roost site areas to reduce risk of collapse, and ensure mine-adits that are known roost sites for ghost bats are maintained following the cessastion of mining activities (medium priority).
5. Educate people not to disturb roost sites (medium priority).
6. Where there are known roosts in proximity to mining or other activities, ensure disturbance is minimised by undertaking environmental assessment, considering alternative locations for works and impact mitigation measures.

This research plan will provide data that will enable operators in the Pilbara to address management actions 1 to 3 listed above.

The collection of spatial and temporal data over a large area in the Hamersley sub-region east and west of Karijini National Park will determine areas that are repeatedly used by ghost bats, and hormone analysis will show caves used by pregnant females. As it is possible (or likely) that these areas change from year to year, a research programme that extends over a number of years will be required to determine these areas. As the genetic work is being undertaken by the DBCA, other mining companies will be able to contribute specimens to the project to fill spatial data gaps. The DNA profile obtained for each individual bat will enable all participants to determine movement across tenure held by multiple parties (mining or government).

Similarly, use of the Motus system will enable third parties to track bats across BHP tenure, and if and when other parties utilise this approach, will enable landscape level movement of bats beyond the geographical extent of this study to be determined. These data should reveal key foraging areas and dispersal/ movement corridors.

This work will enable operators in the Pilbara to manage areas of high conservation value to the ghost bat (e.g. through fire management, removal of cattle or relocation of infrastructure) or potentially incorporate these areas into the conservation estate. It will also highlight areas that should be the focus of barbed wire fencing removal or replacement.

Table 2: Alignment of research plan with State and Federal government research objectives for the ghost bat

Resarch Priority	Addressed by this plan	Comment
Collate and review all information on Pilbara roost sites, and identify banded-ironstone areas in all parts of the region that are planned for future mining or may be quarantined from mining.	No	Addressed previously by Biologic and Bat Call WA (2014) and Biologic (2016).
Additional surveys, especially to locate breeding sites, are required in remote parts of the Pilbara, Kimberley and Northern Territory	Partly	Surveys will be undertaken in the Kimberleys to obtain reference material. Surveys of new areas within and outside of BHP tenure have previously been undertaken (see Biologic 2017).
Assess population size (and significance) of all known subpopulations	Partly	Population sizes will be determined for the Pilbara and a number of subpopulations within the Pilbara. Also previously undertaken by Biologic (2017).
Monitor populations at key sites and where impacts from mining are occurring or likely	Partly	Caves selected for study occur within the Proposed Mining Area C Development Envelope so conclusions will be made on impacts of current and future mining operations during the course of the study.
Develop cost-effective monitoring protocols (e.g. thermal tracking software) at a set of standardised sites that contain most of the known population	Partly	The Motus system will be trialled for efficacy in monitoring movement at a local and regional scale.
Assess impacts of disturbance of breeding sites, and identify appropriate buffer zones for specific activities around roost sites so mining and other activities do not lead to abandonment	Possibly	May be undertaken depending on scheduling of mining operations. If mining occurs within proximity of study caves then impacts will be assessed.
Assess options for establishment of new/artificial roost sites (as a last resort only), and mitigation options to reduce impacts of mining. Evaluate the success of such actions	No	Not addressed by this research plan; however BHP is monitoring the efficacy of two artificial roosts established on BHP tenure.

Resarch Priority	Addressed by this plan	Comment
Assess seasonal access to foraging areas in the Pilbara remote from major roosts	Partly	Foraging areas will be assessed across multiple seasons and years; however the roosts included in this study are not considered to by major roosts in the Pilbara.
Assess proximity to roosts of foraging habitats used by lactating females compared to other adults	Proposed	This will be dependent on ethics approval, the availability of nanotrackers that fall within specified weight requirements and the ability to capture a lactating bat.
Survey within the conservation estate.	Possibly	Will be dependent on the movement of tracked bats and access to Karijini National Park for installation of monitoring towers.
Further quantification of habitat (roost, including maternal roosts) requirements in the Pilbara.	Yes	
Design and operationalise a monitoring program for known roosts (using remote technologies) so that trends in occupancy and abundance can be quantified over time and across space, especially in response to seasons, impacts to foraging habitats (i.e. fire) and disturbance (such as exploration drilling).	Yes	
Basic ecological research which may inform species management in particular Population Viability Analysis models, e.g. births and deaths, demography, diet, foraging habitat preference.	Partly	Only within the geographical area covered by the study.

5. Program Review

BHP, in collaboration with its key research partners, will review annually this research plan. Following this review, the methods and approach may be modified based on the outcomes of the previous year's findings and in consideration of this research plan's objectives and those identified by the TSSC (2016) and DBCA.

6. Ongoing and Additional Consultation

BHP have undertaken ongoing consultation with the key research partners identified in Section 3.2 and the Office of the Environmental Protection Authority (OEPA) during the development of this plan.

7. Public Availability of Data

BHP commits to making all data collected during this study publicly available, including submission of genetic data to GenBank and publishing of studies in peer-reviewed scientific literature. Motus infrastructure installed on BHP tenure will be open source and available for use by third party government and non-government organisations.

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