Mining Area C - Southern Flank

Environmental Impact Assessment for Ghost Bat (*Macroderma gigas*)

BHP Billiton Iron Ore Pty Ltd

November 2016
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EXECUTIVE SUMMARY

Mining Area C is a BHP Billiton Iron Ore operated mine located approximately 100 km north west of Newman in the Pilbara region of Western Australia (Figure 1.1). BHP Billiton Iron Ore is currently preparing a Public Environmental Review document to develop satellite orebodies at Southern Flank, located approximately 8 km south of the existing Mining Area C operations (the Proposal). The Proposal will require additional ground disturbance within the existing approved Mining Area C development envelope and the development of the proposed new satellite deposits at Southern Flank within an Additional Development Envelope. For the purposes of impact assessment, areas proposed to be disturbed are referred to as the Indicative Additional Impact Assessment Area.

The Environmental Scoping Document for the Proposal (EPA, 2016) considered the ghost bat (Macroderma gigas) to be a key factor for the Proposal, and hence Biologic Environmental Survey Pty Ltd (Biologic) was commissioned to undertake a formal review of the species’ ecology and an assessment of potential impacts to the species. The ghost bat has recently been listed as Vulnerable under the Western Australian Wildlife Conservation Act 1950 (WC Act) and the Federal Environment Protection and Biodiversity Act 1999 (EPBC Act).

This report aims to provide a detailed summary of survey work specific to the ghost bat completed for BHP Billiton Iron Ore to date, and to use these data along with available published literature to assess the potential impacts to the ghost bat from implementation of the Proposal. The impacts are based on areas considered likely to be impacted prior to and following mitigation measures and also consider cumulative impacts within the Proposed Mining Area C Development Envelope and within the region. This report is intended to support environmental approvals sought by BHP Billiton Iron Ore under Part IV of the Western Australian Environmental Protection Act 1986 (EP Act).

In total, 63 caves have been recorded to date within the Proposed Mining Area C Development Envelope. Thirty three caves (12 high value and 21 low value) have been recorded within the Indicative Additional Impact Assessment Area. Eighteen caves have been recorded within the Current Approved Impact Assessment Area (areas already approved for disturbance). The 12 caves set to remain are widely spaced (generally 10 km apart) and may not provide the necessary spatial organisation to allow ghost bats to persist in the area. Given this uncertainty, it was determined that the planned disturbance boundary should be modified to ensure that additional high value caves would be retained.

With implementation of the Modified Indicative Additional Impact Assessment Area the number of high value caves within impact areas is reduced from 12 to 5 caves and the number of low value caves is reduced from 21 to 12. The number of caves retained in the Proposed Mining Area C Development Envelope will be increased from 12 to 27 (11 high value; 16 low value). It is considered likely that with mitigation ghost bats will persist in the
Proposed Mining Area C Development Envelope following closure and rehabilitation. Due to limited ecological data on the species’ response to disturbance it is uncertain in what capacity ghost bats will persist within the Proposed Mining Area C Development Envelope during the 30 year period of mining, even with mitigation.

The EPA’s objective for terrestrial fauna is ‘To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.’ Considering this project in isolation and at a species level, the impacts to the ghost bat are considered low, however as more projects are developed in the northern Australia the pressure on the species will increase.

Population estimates for the Hamersley Range Population are between 300 and 400 individuals and any loss of individuals in a regional context is considered significant. It is considered likely that with mitigation the ghost bat will persist in the Proposed Mining Area C Development Envelope, although this will likely be at lower numbers (it is difficult to quantify this potential reduction). It is therefore considered likely that, with mitigation, the Proposal meets the EPA objectives for terrestrial fauna with respect to ghost bat at the species, population and assemblage level.
1. INTRODUCTION

1.1 Proposed Project Description

Mining Area C is located approximately 100 km north west of Newman in the Pilbara region of Western Australia (Figure 1.1). BHP Billiton Iron Ore is planning to develop a new satellite ore body at Southern Flank (the Proposal), which is located approximately 8 km to the south of the existing Mining Area C operations (Figure 1.2). The Proposal will require additional ground disturbance (including areas within the existing approved Mining Area C Development Envelope) and the development of the proposed new satellite deposits at Southern Flank. Conventional open pit mining methods will continue to extract ore from the existing approved Mining Area C deposits and the proposed Southern Flank deposits. Overland conveyors will transport ore from the Southern Flank deposits to existing processing facilities at Mining Area C. Incremental mining activity will be supported by the construction of new infrastructure such as primary crushing, ore handling plants and supporting non process infrastructure.

1.2 Rationale for this document

The ghost bat (Macroderma gigas) has recently (2015 and 2016 respectively) been listed as Vulnerable under the Wildlife Conservation Act 1950 (WC Act) and the Environment Protection and Biodiversity Act 1999 (EPBC Act). The reasons for the conservation status as listed in the 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).

Preliminary impact assessments undertaken for the Proposal identified potentially significant impacts to a number of factors, including the ghost bat, and consequently BHP Billiton Iron Ore modified the proposed disturbance footprint to avoid and minimise impacts to the species.

This report aims to provide a detailed summary of the survey work specific to the ghost bat completed for BHP Billiton Iron Ore to date, and to use these data along with available published literature to assess the potential additional impacts to the ghost bat from implementation of the Proposal. The impacts are based on areas considered likely to be
impacted prior to and following modification of the Indicative Additional Impact Assessment Area. This report is intended to support environmental approvals sought by BHP Billiton Iron Ore under Part IV of the Western Australian *Environmental Protection Act 1986* (EP Act).

### 1.3 Mining Area C Approved Operations

An environmental impact assessment (EIA) for Mining Area C was conducted in 1997 via the Public Environmental Review (PER) process. The PER presented BHP Billiton Iron Ore’s proposal to mine 14 iron ore deposits in the Northern Flank Valley at Mining Area C (i.e. deposits A, B, C, D, E, F, R, P1, P2, P3, P4, P5, P6, and the Brockman Detrital Deposit). This is referred to herein as the Current Approved Development Envelope (Figure 1.2). A Ministerial Statement of Approval (MS 491) was issued by the Minister for the Environment in December 1998 under Part IV of the EP Act. Expansion of mining activities beyond the two originally approved deposits has been undertaken via a revision of the Environmental Management Plan (EMP). In 2015, all deposits within the Current Approved Development Envelope (Figure 1.2) were assessed under a Life of Asset revision of the EMP (Revision (Rev) 6).

Revision 6 of the EMP considered the ghost bat (at the time listed by the Department of Parks and Wildlife (DPaW) as a Priority 4 species) to be a key receptor species with the greatest exposure to potential impacts from the proposed development (Biota, 2015). It was noted that 12 feeding and day roost sites would be directly affected by areas considered under the Revision 6 EMP proposal, of which the majority were considered nocturnal feeding roosts. A number of direct and indirect impacts were also detailed but most were considered data deficient due to knowledge limitations. No confirmed maternity roosts were regarded as being affected by the proposed development.

Prior revisions of the EMP had identified impacts to six caves within the Packsaddle Range.

### 1.4 Terminology used in this report

Terminology and definitions of areas referred to in this document are shown in Table 1.1 and Figure 1.2.

**Table 1.1: Terminology and Definitions of areas referred to in this document**

<table>
<thead>
<tr>
<th>Area</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Mining Area C Development Envelope</td>
<td>This spatial area is the proposed Development Envelope for the Mining Area C hub. It consists of the addition of the Approved Mining Area C (Northern Flank) Development Envelope and the Additional Development Envelope and will constitute the boundary of the new Ministerial Statement if approved</td>
</tr>
<tr>
<td>Approved Mining Area C (Northern Flank) Development Envelope</td>
<td>This spatial area is the boundary current approved as the Development Envelope under MS 491</td>
</tr>
<tr>
<td>Area</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Approved Impact Assessment Area</td>
<td>This is the spatial area that was impact assessed and approved in line with Condition 7 of MS 491 via Environmental Management Plan (EMP) Revision 6 in January 2016.</td>
</tr>
<tr>
<td>Additional Development Envelope</td>
<td>This spatial area is the additional development envelope proposed and assessed for impacts and is proposed to be added to the approved Mining Area C (Northern Flank) Development Envelope to form the Mining Area C Development Envelope</td>
</tr>
<tr>
<td>Indicative Additional Impact Assessment Area</td>
<td>This is the indicative spatial area that is proposed to be impacted as part of the Proposal</td>
</tr>
<tr>
<td>Modified Indicative Additional Impact Assessment Area</td>
<td>This is the indicative spatial area that is proposed to be impacted as part of the Proposal following modification to reduce impacts to key factors including the ghost bat.</td>
</tr>
</tbody>
</table>
Fig. 1.1: Regional location and IBRA regionalisation
Fig. 1.2: Areas discussed in the assessment

Sources: Esri, HERE, DeLorme, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, Geologica, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.
2. GHOST BAT STUDIES

2.1 Legislation and Guidance

Where applicable, this document and all previous field surveys described in this document were carried out in a manner consistent with the Western Australian (WA) Environmental Protection Authority (EPA), WA Department of Parks and Wildlife (DPaW) and BHP Billiton Iron Ore’s requirements for the environmental surveying and reporting of fauna, as described in the following documents:

- EPA Position Statement No. 3, Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA, 2002);
- EPA Guidance No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004);
- Technical Guide - Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (WA Department of Environment and Conservation [DEC]/EPA, 2010); and
- Survey Guidelines for Australia’s Threatened Bats (Department of the Environment, Water, Heritage and the Arts, 2010).

The ghost bat is listed as a Vulnerable species under the State WC Act and the Federal EPBC Act.

2.2 Surveys and Monitoring

Surveys utilising methods suitable to record ghost bats have been undertaken in the Proposed Mining Area C Development Envelope since 2010, and have comprised both baseline (Level 2) surveys and targeted ghost bat surveys.

2.2.1 Baseline surveys

The first surveys to confirm the presence of ghost bat in the area were baseline surveys completed in 2010 and 2011. Significant survey effort was expended targeting suitable habitat features (e.g., caves) during baseline surveys at Mining Area C (Biologic, 2011a) and Southern Flank (Biologic, 2012a). Sixteen person days were spent searching for caves throughout Mining Area C and Southern Flank, resulting in the discovery of 73 caves with either evidence of ghost bat occupation or that were considered potentially suitable based on cave attributes (note some of these caves occur outside the Proposed Mining Area C Development Envelope) (Figure 2.1). Prior to the baseline survey undertaken within Mining Area C and the adjacent Packsaddle Range (Biologic, 2011a), the ghost bat had not been recorded in the area, despite at least two surveys targeting conservation significant bat species (Ecologia, 2005; Specialised Zoological, 2008).
Fig. 2.1: Location of caves recorded at Southern Flank and Mining Area C

Legend
- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Rail
- Mine Accommodation

Survey (information source)
- Area C and Surrounds Fauna Survey (Biologic 2011)
- South Flank Fauna Survey (Biologic 2012)
The lack of previous records in the Proposed Mining Area C Development Envelope is likely a result of the methods used; mist nets, harp nets, cameras, traditional AnaBat systems (utilising a minidisc recorder) and AnaBat systems equipped with a ZCAIM recorder had all been used to try to passively record this species in the area (e.g. Ecologia, 2005; Specialised Zoological, 2008). The 2010 and 2011 baseline surveys (Biologic, 2011a, 2012a) confirmed that the best survey method for determining the presence of ghost bat is extensive searches of gorge and gully systems for potential caves, rather than a reliance on passive recording techniques. This finding was applied to subsequent targeted and baseline surveys in BHP Billiton Iron Ore’s Central Pilbara area (considered to comprise Mining Area C, Southern Flank, Mudlark and Tandanya; see Figure 1.1 for locations).

Further baseline surveys completed in 2012 located 21 caves at Tandanya and 14 at Mudlark. The continuous presence of this species in and around Mining Area C, and the lack of knowledge around breeding (including important roost characteristics), prompted the decision to begin monitoring the species.

2.2.2 Monitoring surveys

The first monitoring surveys undertaken by BHP Billiton Iron Ore within the Proposed Mining Area C Development Envelope began in September 2010. Careful consideration was given to minimising disturbance to the ghost bat, and at this early stage, the capture and handling of ghost bats was not permitted until further information on their status in the area (such as the population size and security) was known. Bat Call WA (2010) completed investigations of roosts at Mining Area C and Southern Flank and concluded that there was a permanent presence in the western side of the Southern Flank area and a seasonal occurrence in the eastern side. The survey was also aimed at locating a maternity roost, should one exist within Southern Flank. While individuals were recorded within caves during the breeding season, no signs of breeding were recorded. It was concluded that ghost bats at Southern Flank were likely to be supported by immigration from a maternity colony elsewhere in the region as no maternity roost caves had been found to date within the Proposed Mining Area C Development Envelope; however, additional wet season survey work was required to confirm this (Bat Call, 2010).

Biologic completed a monitoring survey in early November 2011 (Biologic, 2011b) with the aim to determine if there was a permanent population of the species and if breeding was occurring at Southern Flank. It was concluded that breeding was occurring in the Southern Flank area during November 2011 based on the presence of the bats during the breeding season and the observation of one gravid female. This was considered a significant record, as a majority of published data indicated that ghost bats bred in a centralised maternity roost and there was no known centralised maternity roost within the Hamersley Ranges. The results from this survey suggested local breeding by individuals using a number of caves.
A classification system for ghost bat caves was developed so that the relative importance of caves could be compared locally and regionally and all caves were classified using this system. The categories were:

- No evidence of usage;
- Feeding roost – caves that are only utilised as locations to feed on prey items during the night;
- Feeding roost / Potential day roost – in addition to the above, this classification includes caves that are used for shelter during the day;
- Potential maternity roost (based on cave attributes and ghost bat presence during breeding season); and
- Maternity roost – in addition to the above, this classification includes caves that pregnant females or juveniles were recorded within.

Of the 23 caves that had shown signs of ghost bat use, only five showed evidence of recent usage. It was therefore inferred that the bats resident during November 2011 dispersed throughout the area during the other times of the year. It was also considered possible that other bats moved into the area during the non-breeding season, increasing the number of ghost bats in the area. From this survey, further questions and recommendations were made around ghost bat usage of the area and how to further investigate.

Monitoring of all known caves within the Southern Flank and Mining Area C (Packsaddle) project areas was undertaken during November 2012 to determine the presence and breeding status of the local population and the significance of each cave (Biologic, 2013b). It was noted during previous surveys that the low frequency of encounters with ghost bat during monitoring was hampering investigations. This was thought to be due to the low number of individuals present, the high number of caves used throughout the year and, contrary to studies in the Northern Territory and northern Pilbara, that the individuals were thought to use multiple caves rather than returning to a main roost throughout the year. Encountering individuals at a cave did not necessarily mean the cave would be occupied at any other given time, making it difficult to determine the importance of individual caves with respect to usage (time spent in each cave). Increasing survey length could have assisted with determining this; however, this was determined not to be a cost effective strategy and the continued presence of a surveyor may have resulted in a significance disturbance, reducing counts, as was the case during work at Mt Etna in Central Queensland (Toop, 1985). Counts of ghost bat scats were considered to be the best method to determine usage, so sheets of black cotton (1.5 m²) were placed at 12 caves on top of any middens or large scat piles present. The purpose of this was to collect any fresh scats dropped during the survey period, thereby indicating recent use and an estimated period of time spent in the caves by ghost bats (i.e. between the periods of sampling).
When individuals were observed, it was difficult to determine pregnancy or if juveniles were attached. A number of options were trialled to record evidence of breeding (see Section 2.2.6).

Due to the difficulties and ethical considerations associated with observing breeding directly (attached juvenile or pregnancy) further emphasis was placed on investigations of the cave attributes. The purpose of this was to determine if the caves had similar characteristics to other confirmed maternity roosts (as recorded at Southern Flank and described in the literature). Characteristics of the Southern Flank caves and those within the surrounding areas were measured (see Section 2.2.5)

Further monitoring was undertaken in August and November 2014 (Biologic, 2015). The aims were:

- Obtain information on the use of ghost bat roosts over two seasons (winter and spring);
- Reassess and, if appropriate, reclassify roosts based on ghost bat usage and cave characteristics;
- Obtain information on ghost bat diet using DNA analysis of ghost bat scats (see Section 2.2.7);
- Increase knowledge of roost morphology using 3D point cloud mapping (see Section 2.2.5);
- Trial a number of new survey techniques and comment on the appropriateness for use in further ghost bat studies (see Section 2.2.6); and
- Undertake hormone analysis to determine if this could be used to locate breeding caves (see Section 2.2.8).

Data collected during 2014 showed a permanent presence in the area, that use of individual caves was periodic, and at least seven of the 67 caves surveyed were used across multiple seasons.

In 2015, the monitoring program primarily focused on obtaining scats during the breeding period. Up to five black sheets (2 m by 1 m) were placed on top of scat piles, directly under ghost bat roosting locations inside each of the caves surveyed. Caves identified for survey were a subset of the total known from the area, and were those previously considered likely to be a day roost or maternity roost. The aim was to collect ghost bat material from a known time period, ensuring the material could undergo hormone analysis. Scats were collected and stored in a manner that would also allow genetic analysis.
2.2.3 Survey of Karijini National Park

Surveys of Karijini National Park were undertaken in 2011 and 2012 as prior to this survey there were only three records of ghost bat within the park (Biologic, 2012b). The field work for the first phase of the study was undertaken in November 2011 and comprised a helicopter survey to scan preselected gullies and gorges for prospective caves. Following identification of suitable habitat zoologists visited these areas on foot to determine ghost bat presence. A second survey was undertaken in June 2012 and comprised searches by a team of two zoologists for potential caves by vehicle and on foot. A total of 20 caves were assessed during the survey, of which ten contained evidence of ghost bat occupancy. The abundance of scats was very high (500-1000 or >1000 scats) in four of the caves, indicating a continuous use of those caves by ghost bats. No individuals were observed. Based on this work, it was concluded that suitable caves occur primarily in the southern section of the park (Figure 2.2), with no evidence of ghost bats within the prominent gorges in the north.

An additional Level 1 and targeted ghost bat survey (Biologic, 2013c) was completed in the south eastern section of Karijini National Park in 2013. A total of 15 caves contained evidence of ghost bat use confirming the southern and eastern sections of Karijini National Park are conducive for cave formation and ghost bat occurrence.

2.2.4 Data review and consolidation

In February 2012, Biologic in conjunction with Robert Bullen from Bat Call WA, was engaged to undertake a consolidation of available ghost bat information and provide a population estimate for the Hamersley Range and Pilbara bioregion.

The literature review and database searches (completed December 2013) identified 604 records of ghost bat in the Pilbara (Biologic and Bat Call WA, 2014), of which 317 were records at caves. The data collected on caves ranged from detailed morphological and environmental measurements to an approximate location.

Biologic (2014), in conjunction with Bat Call WA, estimated the population in the Hamersley subregion to be between 300 and 400 individuals. The Chichester subregion was estimated to have a population of 1500 to 2000 individuals, resulting in a population estimate of between 1800 and 2400 individuals for the Pilbara bioregion.
Fig. 2.2: Caves recorded in Karijini National Park

Legend

- Proposed Mining Area C Development Envelope
- Rail
- Karijini Ghost Bat Caves 2011 (Biologic, 2012b)
- Karijini Ghost Bat Caves 2012 (Biologic, 2013c)
2.2.5 Assessment of cave characteristics

During the November 2012 monitoring survey at Mining Area C and Southern Flank detailed measurements of caves were undertaken to determine if caves characteristics could be used to determine usage by bats (i.e. day or night roosts) (Biologic, 2013b). Parameters recorded were: cave position (upper, middle or lower slope); entrance orientation; exposure of entrance; entrance width and height; cave depth; habitat outside cave; number of chambers; height of highest chamber; temperature, humidity and light at entrance of cave; temperature, humidity and light at back of cave; temperature, humidity and light at roost (where the bats actually hang); water present, and if present, distance from cave; ghost bat guano abundance; and ghost bat guano age (Biologic, 2013b). Temperature and humidity data loggers were placed inside 13 caves for approximately three months over summer. The recording of this amount and type of detailed information across a number of caves had not been completed before, or information was not available in the public domain.

The report concluded with a specific summary of conditions inside caves that were classified as maternity roosts or possible maternity roosts (Biologic, 2013b).

During monitoring surveys undertaken in 2014, temperature and humidity were recorded in a number of caves between August and November and compared with ambient temperature recorded at the mouth of the cave (Biologic, 2015).

Mapping of cave morphology was undertaken in 2014 using Lidar technology (Biologic, 2015). The 3D laser mapping system “Zebedee” is a lightweight, self-contained system that does not rely on external positioning systems. It rapidly scans the environment and generates a 3D cloud map as the operator walks through a site. This cloud map can then be rendered to obtain a 3D map of the cave passage. A Zebedee unit was used to scan the interior of 14 caves with the aim to understand the size (length, volume), morphology (shape) and complexity of ten caves preferentially utilised by Ghost Bats, to determine if particular characteristics are consistent between roost types. Four feeding roosts were included in the analysis for comparison.

A detailed description of the Zebedee unit is available at: www.tinyurl.com/zebedee3d

2.2.6 Evaluation of survey techniques

During monitoring of caves at Southern Flank and Mining Area C (Packsaddle) in November 2012 (Biologic, 2013b) the following survey techniques were trialled:

- an infra-red (IR) lit motion detecting still cameras;
- a high definition HandyCam using nightshot;
- an infra-red (IR) lit high-speed video camera;
- Microsoft Kinect hardware and software;
• Evening cave observations; and
• Long-term deployment of SM2 detectors.

The motion cameras were placed on middens facing directly up, in an attempt to photograph roosting bats. While this technique worked on a handful of occasions, the cameras mostly did not trigger, probably due to the lack of thermal difference between the body temperature of the ghost bats and the cave walls and roof. The HandyCam was able to record ghost bats exiting and entering caves; however, identification to species was difficult due to blurry and grainy footage. Identification was only made possible based on size, as ghost bats are significantly larger than any other bat species present. Observing diagnostic features and identifying attached juveniles was impossible. With the IR lit high-speed video camera, significant challenges were overcome associated with the inability to capture clear images of fast moving objects in low light conditions of most commercially available video cameras. The IR lit high-speed video camera used during this survey was successfully tested on ghost bats at the Perth Zoo prior to deployment (Plate 2.1). The camera was set up at five caves for one night each, but no ghost bats were confirmed on the resulting footage.

Plate 2.1: A slide taken from the IR lit high speed camera trial.

The caves chosen for long-term SM2 monitoring (three months) were considered to be two of the most important caves for ghost bats in the area (based on continual ghost bat presence and inferred use from scat numbers). The long-term recordings showed usage at these two caves was quite low and very sporadic. Based on this it can be inferred that either the bats use a very large number of caves, and therefore use each of them a few times, or the bats that use these two caves use other caves preferentially (this was considered to be less likely). The other explanation could be the difficulties associated with detecting this species using its ultrasonic call and social call, both of which are only utilised occasionally. The ultrasonic call can also be difficult to identify with certainty.

It was determined that little additional information was gained by the various camera systems, evening cave observations and SM2 recordings, due mostly to their respective limitations and
low encounter frequencies with ghost bat, and that other additional techniques would need to be used to determine the presence of breeding individuals at Southern Flank. Cave searches for scats and middens are still considered to be the best technique to determine ghost bat presence in an area. Placement of sheets and counting scats within a cave can provide information on the period of use by the bats, but this relies on the bats defecating above the sheets (which only occurred in five of the 23 caves from which scats were collected, despite the fact that sheets were placed over the top of existing scat piles/ middens). Nevertheless, it is concluded that the detection of caves and collection of scats are the best techniques to record ghost bat and understand breeding in the area, especially considering the genetic and hormonal (breeding) information that can be obtained from scat material.

2.2.7 Diet analysis

Eighteen ghost bat scats collected from South Flank, Mudlark, Area C and Tandanya in 2012 were analysed for DNA to provide an indication of an individual’s diet. Metagenomic DNA analysis was undertaken and was completed by Murdoch University (White, in prep.). The aim was to determine if any species (and therefore habitat) was key to ghost bat presence or persistence in an area.

2.2.8 Hormone analysis

Scats collected during the 2014 breeding season (see Figure 2.3 for locations) were analysed by the University of Queensland for progesterone metabolite concentrations by enzyme-immunoassay (UQ, 2016 in prep). This was completed to investigate if metabolites could be used to determine the presence of pregnant females within caves, and therefore the presence of a maternity roost within the Proposed Mining Area C Development Envelope. Scats were also collected from individuals at the Perth Zoo in November 2014 for comparison; however, the zoo population did not breed that year so known pregnant samples were not available. Results from the preliminary analysis suggested that this was a suitable method to determine the presence of pregnant females within a cave and it was concluded that this should become one of the primary techniques for future monitoring. It was also concluded that the scat sampling program should be intensified both in the number of scats sampled and the frequency at which fresh scats were collected from sheets before, during and after the breeding period.
Fig. 2.3: Location of samples collected for hormone analysis

Legend

- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Rail

Samples collected for hormone analysis
- Maternity hormones not present 2014
- Maternity hormones present 2014
- Maternity hormones not present 2015
- Maternity hormones present 2015

BHP Billiton Iron Ore - MAC Revised Proposal Environmental Impact Assessment for Ghost Bat

Environmental Survey

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 15/08/2016
Faecal samples collected during the November 2015 breeding season were also analysed and reference material was collected from the captive population at the Perth Zoo, including collections from a single pregnant female (which was housed with six other females, so scats were not distinguished prior to analysis). Results from the Perth Zoo showed elevated metabolites prior to the birth of young, with a subsequent drop after this date suggesting that the presence of elevated progesterone metabolites is suitable for determining the presence of pregnancy in this species.

2.2.9 Genetics study

In 2016, a genetic study was commenced to investigate the population genetics of ghost bats within the Hamersley Range, including genetic diversity, structure and short-range spatial use. Genotyping from scat material at Southern Flank could also be used to quantify ghost bat numbers in the area, which caves are being used and at what time of year. In November/December 2015 and March/April 2016 scats and DNA samples were collected from individuals across the Hamersley Range, from API Management Pty Ltd tenure in the west (near Red Hill Homestead), across Fortescue Metals Group tenure west of Karijini National Park, and within BHP Billiton Iron Ore tenure east and south-east of Karijini National Park (Figure 2.4). Access was not approved for adjacent Rio Tinto Iron Ore (RTIO) tenements.

2.2.10 Design of artificial roost at Mining Area C and Cattle Gorge

Ghost bats are well known to roost within artificial structures such as mine adits and culverts in the northern Pilbara (TSSC, 2016, Biologic, 2012c). This suggests that attempts to recreate suitable roosting habitat for this species are likely to be successful. There has only been one attempt at habitat recreation for this species in the Pilbara and this is an anecdotal account that occurred in the 1990s using old haul pack tyres. The short-term success of this structure was not documented and eventually the structure collapsed. Other attempts in Western Australia have been targeted at other species and mostly centre on the recreation of tree hollow roosts using small tree boxes, which are often successful.

In 2014, BHP Billiton commissioned a project to design and construct an artificial roost for the ghost bat at Mining Area C. A number of factors were considered prior to this decision and included:

- Construction of a new roost, modification of existing man-made structures or alteration of natural voids (such as the case at Koodaideri (Bullen, pers. comm));
- The location, which had to be near existing caves but away from current and future mining operations;
- Longevity of the roost, within the confines of engineering capabilities (some cave structures are likely to be many tens of thousands of years old and may persist for many thousands of years more (J. Barnett, pers. comm).
- Morphology and internal physical characteristics of the roost (e.g. temperature, humidity and light attenuation); and
- Impacts of ground disturbance.

The initial concept design was created by BHP Billiton within the confines of what was feasible in terms of budget and construction techniques permitted on site. This was expanded on by a team of external engineers, with specialist input provided by Morgan O’Connell (Biologic), Norman McKenzie (DPaW), and Robert Bullen (Bat Call WA) and BHP Billiton Iron Ore’s in-house ecologists.

The final design was the best outcome taking into account design life and current engineering and construction techniques. The roost at Mining Area C was constructed in a greenfields location (undisturbed land) in 2015, and shortly after this two monitoring cameras were placed inside the main chamber. The cameras have to date not detected Ghost Bat; however three scats have been recorded approximately 3 m along the tunnel of the artificial roost.

A second artificial roost was constructed within a decommissioned and rehabilitated pit at BHP Billiton Iron Ore’s Cattle Gorge mine in the second half of 2016. The design was developed by BHP Billiton Iron Ore in collaboration with Biologic and BHP Billiton Iron Ore’s in-house ecologists. The roost design was based on that developed for Mining Area C, with slight modifications to roof morphology, concrete structure, and also to allow for colonisation by Pilbara leaf-nosed bats.
Fig. 2.4: Locations of samples collected for genetic analysis and estimated extent of population.
3. **GHOST BAT ECOLOGY**

3.1 **General Description**

Conventionally accepted as *Macroderma gigas* (Dobson, 1880; TSSC, 2016), *Macroderma* is a monotypic genus endemic to Australia. They can weigh up to 150 g, with an average weight of 130 g (McKenzie and Bullen, 2009), and have an average wing span of 686 mm. Ghost bats have pale grey or light brown fur with a lighter belly and pale cream to brown wing membranes. They have large ears, measuring on average over 50 mm, which join above the head, large eyes and a long simple-shaped nose leaf extending along the muzzle (Churchill, 2008).

3.2 **Distribution and Abundance**

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 (Figure 3.1), 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 (Figure 3.2). 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 (Figure 3.2). 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.).
Fig. 3.1: Location of Ghost Bat records within the Pilbara region

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Legend
- Proposed Mining Area C Development Envelope
- Rail
- Known Regional Ghost Bat Records

BHP Billiton Iron Ore - MAC Revised Proposal Environmental Impact Assessment for Ghost Bat

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 15/08/2016
The ghost bat population in the Pilbara is estimated to be between 1300 – 2000 individuals (TSSC, 2016). Biologic (2014) estimated the population in the Hamersley Range to be between 300-400. This estimate was based on limited field studies largely restricted to mining tenure. Numbers in Western Australia are considered likely to decline by over 30% in the future, with local extinction in areas such as the central and eastern Hamersley Range, and the extent of occupancy likely to decline by over 10,000 km² (TSSC, 2016).

Within the Proposed Mining Area C Development Envelope the population is estimated to comprise on average 50 individuals, with half of these occurring in the Packsaddle Range and the other half occurring along Southern Flank. Observations of individuals within caves have generally been limited to 1 or 2 animals; although during December 2015 fifteen individuals, including up to four juveniles, were recorded in SF15.

Preliminary genetic studies identified 98 individuals from analysis of 324 samples (Spencer and Tedeschi, 2016). The samples were collected from 21 locations between Newman and near Pannawonica (Figure 2.4). The genetic effective population size was estimated to be 78.6 (although this estimate needs to be viewed with some caution due to the limited sample size). The effective population size is generally considered to be only 10 % of the census population size, therefore the census size of Ghost Bats within the Hamersley sub-region could be as high as 700-800 individuals (cf Biologic (2014) estimate of 300-400 individuals for the Hamersley sub-region and TSSC (2016) estimate of 1300-2000 for the Pilbara bioregion).

Within the Indicative Additional Impact Assessment Area Spencer and Tedeschi (2016) identified 27 unique individuals. A further 12 individuals were identified from SF14 which is outside of the Indicative Additional Impact Assessment Area, but within the Additional Development Envelope. These numbers do not take into account mortality or dispersal, as it is possible that not all individuals detected during the sheeting period (scat collection) will survive or remain in the area. It does indicate; however; that during 2015/2016 at least 39 ghost bat individuals were present within the Southern Flank area. With further analysis, it is possible that more individuals will be identified resulting in a slightly higher population number than the original estimated average of 25 (Bat Call, 2010).

### 3.3 Habitat

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 m², that opened into larger chambers.
Three dimensional mapping of cave morphology (Figure 3.3) showed that caves considered most likely to be used as day roosts are relatively deep and show narrowing at some point, reducing light infiltration and possibly assisting with the maintenance of a stable temperature and, to a lesser extent, humidity. This is generally consistent with the findings of Armstrong and Anstee (2000).

Temperatures within caves in the Hamersley Ranges that were classified as day, potential maternity or maternity roosts were generally stable, while ambient temperature fluctuated throughout the day and night, and across the seasons (Figure 3.4). Relative humidity within the roosts was generally higher than ambient levels, although not considerably so, and fluctuated according to atmospheric changes (Biologic, 2014).

Armstrong and Anstee (2000) reported high relative humidity (82 and 84 %) at two known maternity roosts in the Hamersley Ranges. The remaining caves had relative humidity readings of between 14 and 31 %. Only two of the 13 caves assessed by Biologic (2014) had humidity levels comparable to the two maternity roosts described by Armstrong and Anstee (2000). One of these (AC17 – humidity ranging between approximately 30 and 70 %) is considered unlikely to be a maternity roost due to cave morphology, and there has been very little evidence of ghost bat use during the monitoring periods. Only one individual has been identified from genetic analysis of samples collected from this roost. The second cave (SF1 – humidity ranging between approximately 30 and 50 %) is considered to be used as a maternity roost and the presence of pregnant females has been confirmed from hormone analyses. Other caves from which pregnant females have been recorded have had much lower and fluctuating relative humidity levels (e.g. SF8; see Figure 2.3).

For the purposes of comparison, Biologic (2014) classified the caves into three types based on the inferred use and recorded presence of ghost bat: Feeding Roost; Feeding/Possible Day Roost; and Day/Possible Maternity Roost. For the three types of caves, the average width for the cave entrance ranged between 5.7 m and 7.58 m. Those classified as Day/Possible Maternity Roosts generally had a larger entrance; however, these also had the greatest range of sizes. Average entrance height ranged between 2.61 and 3.53 m, with the Day/Maternity Roosts generally having a lower entrance height.

Caves classified as Day/Maternity Roosts were much deeper than the other types of caves, averaging 33.94 ± 3.31 m deep. Day/Maternity Roosts also had more chambers averaging 2.9 ± 0.31. Average internal height of the caves ranged from 4.27 to 4.6 m.
Figure 3.3: A sample of caves that were 3D point cloud mapped.
Temperature within the caves was generally around 30°C (range of averages: 29.11 – 30.47°C), with average temperature at the Day and Feeding Roosts slightly cooler (range of averages: 27.62 – 29.94°C). Caves were generally two to three degrees cooler at the back of the cave than at the entrance.

Average relative humidity (RH) at the back of the caves ranged between 26.13 ± 2.35 and 36.16 ± 2.66%, whilst average RH at the roost locations (where ghost bats actually hang) ranged between 23.94 ± 6.77 and 37.02 ± 5.34%. Light at the back of the caves was lower in the Day/ Maternity Roosts.

### 3.4 Social and Spatial Organisation

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 the 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.

Studies undertaken by Biologic (2013a, 2014, 2015) are consistent with the findings of Armstrong and Anstee (2000) that small groups of ghost bats may move about within a local area and that multiple groups may use a cave. It was very unusual to observe a continual presence of bats in particular caves; although the scat collection and genetic analysis suggests that some may be used more than others and these may or may not correspond with breeding caves. Further work is required to gain a detailed understanding of how ghost bats utilise caves within the Proposed Mining Area C Development Envelope.

### 3.5 Breeding

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 3.1). Young are weaned on prey captured by the mothers, and hunt with the mothers until they become completely independent. Known breeding observations from the Pilbara are:

- Young have been observed attached to their mother during November and December at West Angelas (Armstrong and Anstee, 2000);
- Twenty females carrying pups were observed by Robert Bullen on the 16th November 2014 at the Lalla Rookh adit (Bullen, pers. comm.);
- A maternity group of fifteen, including up to four juveniles, was recorded in cave SF15 within the Proposed Development Mining Area C Development Envelope in December 2015. The juveniles were not being carried by their mothers, and some
showed a weak flying ability suggesting that birth took place well over a month prior; and;

- Gravid females were observed in the Klondyke and Bulletin mines in late September 1992 and early October 1993. A gravid female was also observed at Klondyke in July 1994; and

- The hormone analysis from 2015 picked up high levels of progesterone in a scat that was collected on a sheet from cave M1 that was in place from the 16th of November to the 16th of December. This suggests at least one female was still pregnant on the 16th of November which is towards the end of the known birthing period.

Table 3.1: Approximate breeding cycle of ghost bats in the Pilbara

<table>
<thead>
<tr>
<th>Month</th>
<th>Breeding Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>July - August</td>
<td>Mating</td>
</tr>
<tr>
<td>August - October</td>
<td>Gestation</td>
</tr>
<tr>
<td>September - November</td>
<td>Birth</td>
</tr>
</tbody>
</table>

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 (see Table 3.2) and the concept of a centralised maternity roost is unlikely to be applicable in this region. The hormone analysis has shown that within approximately 30 km of the Proposed Mining Area C Development Envelope, ten caves have been used by female ghost bats in the latter stages of pregnancy.

In regards to the Proposed Mining Area C Development, nine of the 21 caves sampled in 2014 and three of the seven caves sampled during 2015 contained scats with high levels of progesterone (ie. pregnant females; see Table 3.2). While the sampling during 2014 sampled more caves (21), and included those from around Mining Area C, the 2015 analysis processed more scats from fewer caves (7). A total of nine maternal-use caves are now known within the Proposed Mining Area C Development Envelope, of which three are in the Additional Development Envelope, and two are known from other BHP Billiton Iron Ore tenements (Tandanya and Marillana). Eight of the nine caves within the Proposed Mining Area C Development Envelope occur in proposed or approved mining pits or overburden storage areas.

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, 2011, Biologic, 2012; 2014). Hormone analysis has supported this finding with numerous caves containing scats with progesterone levels indicating pregnancy (UQ, 2016 in prep). This was further confirmed when the maternity group was encountered in 2015 in a small cave that had previously shown little evidence of ghost bat occupancy.

**Table 3.2: Roost Sites with Presumed Pregnant ghost bats (> 1000 ng/g)**

<table>
<thead>
<tr>
<th>Cave</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SF5</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>SF15</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AC 4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AC 8</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AC9</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AC13</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>ACW10</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MARXX</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 3.6 Diet and Feeding

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).

Within and around the Proposed Mining Area C Development Envelope, the diet primarily consists of small mammals (including other bat species such as *Taphozous georgianus*) and
birds, with the majority of species detected regarded as common and widespread within the Pilbara (Biologic, 2014) (Table 3.3).

Table 3.3: Summary of potential prey species, as detected within ghost bat scats (Biologic, 2014)

<table>
<thead>
<tr>
<th>Taxonomic Group</th>
<th>Taxa recorded within ghost bat scats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invertebrates</td>
<td>Austacris guttolosa (Spur-throated Locust)</td>
</tr>
<tr>
<td></td>
<td>Blattodea spp (cockroach)</td>
</tr>
<tr>
<td></td>
<td>Diptera spp. (fly)</td>
</tr>
<tr>
<td></td>
<td>Lepidoptera (Noctuidae) Owlet moths</td>
</tr>
<tr>
<td></td>
<td>Lepidoptera (Sphingidae; Hyles) Hawkmoth</td>
</tr>
<tr>
<td></td>
<td>Lepidoptera spp. (moths and butterflies)</td>
</tr>
<tr>
<td></td>
<td>Polia borbicina (Pale Shining Brown Moth)</td>
</tr>
<tr>
<td></td>
<td>Tachinid flies (parasitoid of moths, butterflies, beetles, grasshoppers, etc.)</td>
</tr>
<tr>
<td></td>
<td>Trapdoor spider</td>
</tr>
<tr>
<td>Birds</td>
<td>Aegothelis cristatus (Owlet-Nightjar)</td>
</tr>
<tr>
<td></td>
<td>Emblemata pictum (Painted Firetail Finch)</td>
</tr>
<tr>
<td></td>
<td>Geopelia cuneata (Diamond Dove)</td>
</tr>
<tr>
<td></td>
<td>Geopelia sp. (Dove)</td>
</tr>
<tr>
<td></td>
<td>Laridae (Gull family)</td>
</tr>
<tr>
<td></td>
<td>Malurus (Fairy Wren)</td>
</tr>
<tr>
<td></td>
<td>Meliphagidae (Honeyeater)</td>
</tr>
<tr>
<td></td>
<td>Melopsittacus undulatus (Budgerigar)</td>
</tr>
<tr>
<td></td>
<td>Smicrornis brevirostris (Weebill)</td>
</tr>
<tr>
<td></td>
<td>Taeniopygia guttata (Zebra Finch)</td>
</tr>
<tr>
<td></td>
<td>Ternix vari (Painted Button-quail)</td>
</tr>
<tr>
<td>Reptiles</td>
<td>Ctenotus sp.</td>
</tr>
<tr>
<td></td>
<td>Egernia sp.</td>
</tr>
<tr>
<td></td>
<td>Oedura sp. (Velvet Gecko)</td>
</tr>
<tr>
<td>Mammals</td>
<td>Leggadina lakelandensis (Short-tailed Mouse)</td>
</tr>
<tr>
<td></td>
<td>Leggadina sp. (native mouse)</td>
</tr>
<tr>
<td></td>
<td>Mus musculus (House Mouse)</td>
</tr>
<tr>
<td></td>
<td>Pseudomys desertor (Desert Mouse)</td>
</tr>
<tr>
<td></td>
<td>Pseudomys hermannsburgensis (Sandy Inland Mouse)</td>
</tr>
<tr>
<td></td>
<td>Pseudomys sp. (native mouse)</td>
</tr>
<tr>
<td></td>
<td>Taphozous spp.</td>
</tr>
</tbody>
</table>

3.7 Genetics

Populations are potentially distinct at local and regional scales (Worthington Wilmer, 1994). It is conceivable that low gene flow is occurring between the northern and southern Pilbara due to the partial barrier of the Fortescue Marsh; although a ghost bat was captured (mist net) during surveys within the Fortescue Marsh (J. Turpin, pers. comm.) many kilometres from suitable roosting habitat suggesting the flat expanse of the Fortescue Marsh is not a total barrier.

Preliminary results from genetic studies on ghost bats occurring in the Hamersley Range (south of the Fortescue Marsh / River) are summarised below (Spencer and Tedeschi, 2016).
This study was undertaken using scats and tissue collected in November/ December 2015 and March/ April 2016 (Biologic, 2016 in prep). The study was considered to be remarkably successful amplifying significantly more faecal material than comparable studies. It is noted however that due to the relatively small number of individuals determined from the analysis, the interpretation of the data is somewhat limited.

In this study, DNA extractions were carried out on 321 ghost bat samples collected across the Hamersley sub-region (16 tissues, 305 scats, see Figure 2.4 for locations). From these samples, three failed to amplify anything, 78 failed at 5 or more loci, and 112 samples were duplicated genotypes and so were not used in any analysis. Genetic variation was examined at 10 nuclear genes (microsatellite markers) from the final individuals.

Genetic analyses of nuclear markers were shown to provide a powerful approach to infer patterns of genetic structure within ghost bats, and the study allowed analysis of 98 individuals from the Hamersley subregion of the Pilbara. The Southern Flank population samples clustered within the main Hamersley Range population. This population appears to be extensive, extending from Pannawonica to Newman.

Genetic diversity is high in the Hamersley Range population, and there is no evidence of recent or long-term population declines (detected using bottleneck analysis).

Spatial autocorrelation was used to define how the species is able to disperse at the local level. The spatial structure analysis identified that neighbour size (movement distance) was somewhere between 10 and 15 kilometres.

The genetic effective population size for the Hamersley subregion was estimated to be 78.6, although this number may change with more sampling. The effective population size is generally considered to be 10% of the census population size; therefore based on these data the population of the Hamersley sub-region was estimated to be between 700 and 800 individuals.
4. **IMPACT ASSESSMENT**

4.1 **Existing impacts from Mining Area C operations**

Environmental Impact Assessments (EIAs) for Mining Area C have been undertaken since the initial approval in 1997 as part of the EMP update process (see Section 1.3).

Due to the lack of records, impacts to the ghost bat were not considered until Revision 4 of the EMP in 2009. The quality and number of caves within areas disturbed prior to this is unknown; however, given the number of caves recorded in adjacent areas, it seems likely that a number of caves and foraging areas had already been impacted. The Revision 5 EMP was completed in 2011 after targeted surveys had recorded the majority of caves in the area, which allowed for a greater level of confidence in the assessment of impacts.

Revision 6 of the EMP was completed in October 2015 and the ghost bat was considered a key receptor species with the greatest exposure to potential impacts from the proposed development (Biota, 2015). It was noted that 12 feeding and day roost sites would be directly affected by the additional deposits, with the majority of these considered nocturnal feeding roosts. A number of direct and indirect impacts were also detailed but most were considered data deficient due to knowledge limitations. No confirmed maternity roosts were considered to be affected by the proposed development.

Approval to mine all deposits within the Mining Area C Revision 6 Life of Asset Management Plan, which includes parts of the Packsaddle Range, was provided to BHP Billiton Iron Ore in January 2016. No formal monitoring to assess ongoing impacts has been undertaken to date within the Packsaddle Range. Scats collected during November 2014 that were subsequently analysed as part of the hormone analysis study indicated that four caves within the area approved to be impacted under Revision 6 of the EMP had contained pregnant females during the 2014 breeding season (see Table 3.2 above).

4.2 **Impacts to Ghost Bat**

Removal of habitat to accommodate development is the most direct factor likely to impact the ghost bat. The proposed development will result in the removal of native vegetation, rocks, caves and soil, and the loss of individual fauna (ghost bats and their prey) will likely occur.

Impacts arising to the ghost bat from expansion of mining activities are generally consistent with those impacts assessed under previous revisions of the Mining Area C EMP and are discussed in detail in this section.

4.2.1 **Loss of Roosts**

As some caves are of higher value to the ghost bat than others, the cave classification system previously developed by Biologic (see section 2.2.2) has been simplified for the purposes of
this impact assessment into high value and low value caves. This system conservatively places any cave previously classified as a feeding roost or showing no signs of use into the low category. All other caves i.e feeding roost / potential day roost, potential maternity roost, or maternity roosts are placed in the high category. This is the most appropriate way to compare the caves as it is evident from the hormone analysis (Section 2.2.8) that within the Proposed Mining Area C Development Envelope there is no centralised, single maternity roost, that different caves may be used as a maternity roost across different years and it is considered possible that most high value caves would be maternity roosts at some point. Should further data indicate that maternity roosts are used consistently over multiple years, or that some high ranked roosts aren’t used by pregnant females over an extensive period of monitoring, the categories will be reclassified into high, medium and low so that the maternity roosts are given the highest ranking.

In total, 63 caves have been recorded to date within the Proposed Mining Area C Development Envelope (Figure 4.1, Table 4.1). Thirty three caves (12 high value and 21 low value) have been recorded within the Additional Impact Assessment Area (Figure 4.1). The 12 high value caves range from potential day roosts to confirmed maternity roosts and the 21 low value caves are all considered to be likely feeding roosts. Eighteen caves have been recorded within the Current Approved Impact Assessment Area (eight high and ten low). Within the Proposed Mining Area C Development Envelope a total of 51 caves have been recorded within approved or proposed areas of impact (Current Approved Impact Assessment Area and Indicative Additional Impact Assessment Area).

**Table 4.1: Comparison of the number of high and low value roosts within the Proposed Mining Area C Development Envelope**

<table>
<thead>
<tr>
<th>Area</th>
<th>Suitable roosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known caves in in the Pilbara region (Biologic and Bat Call, 2014)*</td>
<td>317</td>
</tr>
<tr>
<td>Estimate for Hamersley sub-region</td>
<td>Not available</td>
</tr>
<tr>
<td>Within Proposed MAC Development Envelope</td>
<td>High: 25 Low: 38</td>
</tr>
<tr>
<td>Approved Mining Area C (Northern Flank) Development Envelope</td>
<td>High: 12 Low: 15</td>
</tr>
<tr>
<td>Current Approved Impact Assessment Area</td>
<td>High: 8 Low: 10</td>
</tr>
<tr>
<td>Additional Development Envelope</td>
<td>High: 13 Low: 23</td>
</tr>
<tr>
<td>Indicative Additional Impact Assessment Area</td>
<td>High: 12 Low: 21</td>
</tr>
</tbody>
</table>

* Obtained from publicly available information
Fig. 4.1: Known Ghost Bat roosts in the Proposed Mining Area C Development Envelope

Legend
- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Approved Impact Assessment Area
- Indicative Additional Impact Assessment Area

Roost classification:
- High importance
- Low importance

Rail
Mine Accommodation

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

INSET 1
INSET 2
INSET 3
Following implementation of EMP Revision 6 and the current approval, the total number of caves available to the individuals within the Proposed Mining Area C Development Envelope will be 12 (five high and seven low value) caves; reduced from a pre-impact total of 63. Of the five high value caves, none are currently considered to be maternity caves, and all occur within 750 m of the Additional Impact Assessment Area or the Current Approved Impact Assessment Area (Figure 4.1: AC32, AC18, AC14, SF26 and SF14). The seven low value caves are AC15, SF21, SF22, AC20, SF10, AC5 and AC6 (Figure 4.1) with most occurring within 750 m of proposed disturbance.

The 12 caves set to remain are widely spaced (approximately 10 km apart, which falls within the neighbourhood distance of 10-15 km) but given that ghost bats appear to move from cave to cave regularly (probably to access emerging high value foraging areas as they exhaust previous foraging areas), the low number and wide spacing of caves may not provide the necessary spatial organisation to allow ghost bats to persist in the area. One of the five high value caves (SF14) that will remain is 200 m from a proposed road and a conveyor. This cave and the surrounding area appear to be relatively undisturbed, therefore it is possible that individuals will continue to use this cave.

It is also unknown if Ghost Bats will fly over operating pits or OSAs. Ghost bats have persisted in the vicinity of iron ore mining operations in the Pilbara (e.g. RTIO West Angelas; Biologic, 2014) and at Cattle Gorge in the northern Pilbara ghost bat is known to frequent caves on either side of the pits and OSAs (a distance of 2 km). It is not known if they fly directly over them or around, and it should also be noted that the Cattle Gorge operation is considerably smaller than that proposed at Southern Flank. It is possible that the records on the west and east side of the operations are from different individuals or groups, although this seems unlikely given the lack of suitable roosting habitat to the east, north and west. It is considered likely that ghost bats will fly over closed/ rehabilitated pits and OSAs so any disruption to behaviour is unlikely to be permanent.

Twenty one low value caves, all of which are considered night feeding roosts, occur within the Indicative Additional Impact Assessment Area. It is possible that ghost bats could utilise other areas to feed such as trees or other natural overhangs (that have not been documented) or culverts; there is evidence of ghost bats feeding in culverts along BHP Billiton's mainline rail (Biologic, 2012c) and Goldsworthy rail (M. O'Connell, pers. obs).

Retention of low value caves is considered important as it is possible that some of the low value caves could deepen through the process of erosion, and become suitable for day/ maternity roosting or changes in climate may increase the viability of these caves in the future.

Given the low proportion of high value caves retained and their proximity to existing mining operations, it seems unlikely that the ghost bat would persist within the Proposed Mining Area C Development Envelope in similar numbers or at all. Whilst there are numerous caves to the
west and north east that may accommodate displaced individuals (21 known caves are within 10 km of the Proposed Mining Area C Development envelope (Figure 4.2)), this would likely put pressure on the surrounding area that is assumed to be operating at carrying capacity. Displaced individuals would likely perish or outcompete other groups.

It is considered likely that without mitigation there will be a loss of individuals from the Proposed Mining Area C Development Envelope, including reproducing individuals. Therefore while not reducing the overall range of the ghost bat in the Hamersley Range, a relatively small reduction in the population and available habitat will occur.

4.2.2 Loss of Foraging Habitat

Clearing will reduce the area available for foraging and therefore the removal of habitat could have either a high or low impact on the bats, depending on whether it corresponds with their foraging grounds.

Studies in the Northern Territory showed that ghost bats forage over a large area (>60 ha each night) which was located on average 1.9 km from their day roost, and they generally return to the same foraging grounds each night (Tidemann et al. 1985). There are no data available for ghost bat foraging distance in the Hamersley Range; however the use of multiple caves suggests that foraging areas are likely to be larger. In lieu of information on foraging areas within the Hamersley, foraging habitat is considered to be all habitat within 2 km of a roost. This approach was implemented by Biota (2015a) for impacts assessed under Revision 6 of the Mining Area C EMP.

An estimated 20,920 ha of foraging habitat occurs within the Proposed Mining Area C Development Envelope, of which 6,418 ha occurs within the Approved Impact Assessment Area and 8,694 ha occurs within the Indicative Additional Impact Assessment Area. If all of this area is cleared, approximately 70% of available foraging habitat will be removed. Some of this area will be rehabilitated, either progressively or at closure, and given that ghost bats have a varied diet that includes common species, such as the house mouse, it is likely that at least some of these areas will again be utilised by ghost bats.

The most likely foraging areas for ghost bats occur to the west of the Proposed Mining Area C Development Envelope within the Coondewanna Flats Priority Ecological Community (PEC) and adjacent lowland areas, and the floodplain between Southern Flank and Mount Robinson. This floodplain will be partially covered by an OSA (see Figure 4.3).
Foraging grounds are unlikely to be affected by dewatering with discharge management to include reuse or aquifer recharge (reinjection). With regards to the Coondewanna Flats specifically, a number of studies addressing aspects of the ecohydrology have been completed and it appears that the vegetation communities are not groundwater dependent. No changes to vegetation and foraging areas at Coondewanna Flats are expected (AQ2, 2015).

Overall, a significant portion of foraging grounds will be disturbed or lost within the Proposed Mining Area C Development Envelope resulting in increased flying distances from the remaining roosts to undisturbed foraging areas. The additional energy required for this may result in the local individuals being more susceptible to natural disturbances such as fire and extended dry periods where prey items are decreased and further travel may be required. If breeding was to continue in the area, pregnant and lactating females would be further affected when their energy requirements are increased.

Table 4.2: Amount of foraging area in each boundary type. Note that foraging area was considered to be 2km around cave locations following Biota (2015a).

<table>
<thead>
<tr>
<th>Area</th>
<th>Foraging habitat (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Proposed Mining Area C Development Envelope</td>
<td>20,920 ha</td>
</tr>
<tr>
<td>Current MS491 Development Envelope</td>
<td>13,384 ha</td>
</tr>
<tr>
<td>Additional Development Envelope</td>
<td>7,535 ha</td>
</tr>
<tr>
<td>Current Approved Impact Assessment Area</td>
<td>6,418 ha</td>
</tr>
<tr>
<td>Indicative Additional Impact Assessment Area</td>
<td>8,694 ha</td>
</tr>
<tr>
<td>Outside Proposed Mining Area C Development Envelope (as mapped fig 4.3)</td>
<td>3,148 ha</td>
</tr>
<tr>
<td>Outside all Impact Assessment Areas</td>
<td>8,956 ha</td>
</tr>
</tbody>
</table>

4.2.3 Ghost Bat Numbers

Unlike the large colonies of ghost bat in Chichester subregion, which predominantly roost in abandoned mines and adits, ghost bats in the Hamersley subregion live in small family groups spread thinly across a wide area, and are almost certainly completely reliant on natural caves (Bat Call WA, 2010; Biologic and Bat Call, 2014). This pattern is likely to be reflective of the pre-European population structure of this species and living in smaller groups is potentially an adaptation for the more arid conditions of the Pilbara region.
Fig. 4.3: Ghost Bat foraging extent

Legend
- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Approved Impact Assessment Area
- Indicative Additional Impact Assessment
- Ghost Bat roosts
- Estimated foraging extent (2km radius)

BHP Billiton Iron Ore - MAC Revised Proposal
Environmental Impact Assessment for Ghost Bat

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 15/08/2016
The population estimate for ghost bats in the Hamersley subregion is much smaller than the Chichester subregion (which has been artificially inflated by man-made roosts), and totals between 300 and 400 individuals (versus 1300-2000 for the Pilbara bioregion; TSSC, 2016) (Table 4.3). Their density appears to be highest in the west of the Hamersley Range where rainfall, and therefore productivity, is higher, and in the central east where numerous caves have been recorded.

The current population estimate for the Proposed Mining Area C Development Envelope is approximately 50 individuals; although this will likely fluctuate from year to year and across the season. It may also increase with further genetic analysis. The population estimate for the Current Approved Impact Assessment Boundary is 25 individuals (Biologic and Bat Call, 2014).

Table 4.3: Population estimates for the Pilbara and Proposed Mining Area C Development Envelope

<table>
<thead>
<tr>
<th>Area</th>
<th>Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate for Pilbara region (TSSC, 2016)</td>
<td>1300 - 2000</td>
</tr>
<tr>
<td>Estimate for Hamersley sub-region</td>
<td>300-400</td>
</tr>
<tr>
<td>Within Proposed MAC Development Envelope</td>
<td>~50</td>
</tr>
<tr>
<td>Approved Mining Area C (Northern Flank) Development Envelope</td>
<td>~30</td>
</tr>
<tr>
<td>Additional Development Envelope</td>
<td>~25</td>
</tr>
<tr>
<td>Approved Impact Assessment Area</td>
<td>~25</td>
</tr>
<tr>
<td>Indicative Additional Impact Assessment Area</td>
<td>~25</td>
</tr>
</tbody>
</table>

There are two possible scenarios considered for the impact assessment, and these will likely be validated by further genetic studies:

1. The ghost bat population at Southern Flank occurs predominantly in caves that are restricted to the Proposed Mining Area C Development Envelope and removal of these caves will likely result in a loss of the whole group. Any individuals that are displaced into adjacent areas are either unlikely to survive or will compete with other ghost bats for food and shelter resources (assuming that the population is at carrying capacity); or

2. The ghost bat population at Southern Flank occurs over a wider range, including adjacent BHP Billiton and Rio Tinto tenure. As such, the removal of these caves is unlikely to result in a loss of individuals; rather it will reduce the area available for roosting and foraging making them more susceptible to other natural and anthropogenic processes such as fire, drought, loss of food resources and habitat fragmentation. This may see a longer term reduction of individuals.
During mining activities ghost bat presence in the Proposed Mining Area C Development Envelope may persist; however, this is likely to be from individuals that mostly occur outside of it and where the boundaries of the Proposed Mining Area C Development Envelope form the edge or a component of an individual’s home range. Given the cumulative removal of caves, a reduction in foraging habitat and other secondary impacts, there are few resources available within the Proposed Mining Area C Development Envelope to support a permanent presence during mining and in the future. Following closure and rehabilitation there may be an increase in ghost bat activity as areas begin to provide useable foraging habitat; however, due to the small number of remaining high value caves and their wide spacing, plus a net loss of foraging habitat in the vicinity of remaining caves, it is unknown if breeding would be possible in the area.

Current population estimates for the Hamersley Range is 300 to 400 and for the entire Pilbara is 1800 to 2400 individuals (Biologic and Bat Call, 2014), although this has recently been estimated at 1300 to 2000 (TSSC, 2016). The genetic study has shown that ghost bats within the Hamersley sub-region form one widely distributed population, which has a high level of genetic diversity. From recent genetic work, and within the limitations associated with using few samples, there is evidence to suggest the population could be greater than this with an effective population size estimate of 78.6 for the Hamersley Range and a census size of around 780.¹

The loss of individuals within the Indicative Additional Impact Assessment Area could be as many as 25, reducing the Hamersley Range population by 6 – 8%. When combined with further reduction in numbers within the Current Approved Impact Assessment Area of up to 25, the Hamersley Range population could be reduced by a total of 12 – 17%. When this is placed in a bioregional context, the reduction is around 1 % for the loss of 25 individuals and 2 – 3% for the loss of 50 individuals. At the species level, the loss of individuals is negligible.

It should be noted that the estimates for the Hamersley Range and Pilbara bioregion do not take into account the security of habitat for ghost bat. For example, the number of ghost bats in the northern Pilbara is almost certainly increased due to the presence of man-made adits. These adits are in various states of collapse and some may no longer provide habitat (TSSC, 2015). The species is also under a broader threat from the cane toad (Rhinella marina), with populations in the Chichester subregion particularly vulnerable.

¹ Effective population size is the number of individuals of a population contributing offspring, and is generally regarded as 10% of the census size.
4.2.4 Other Mining Related Impacts

Other mining related activities that may impact on ghost bats include:

Artificial light

Very strong light sources may confuse or blind ghost bats, although there is no information available to the extent that this occurs. Ghost bats have persisted adjacent to mining operations at Cattle Gorge where operations occurred up to 500 m from a ghost bat roost.

Noise and vibrations

Little work has been done on the impact of noise and vibrations on ghost bats; however, if disturbances occur close enough to daytime roosts they could cause the bats to abandon their roost, or the roost could collapse, making it unusable. Noise modelling was undertaken by SVT (2016) to determine potential noise levels at the entrances to known caves within the Additional Development Envelope and Indicative Additional Impact Assessment Area. All levels were predicted to be below 70 dB, with the highest levels ranging between 65 dB and 69.1 dB at three caves: SF 15 (High), SF22 (Low) and SF31 (Low). SF15 falls within the Indicative Additional Impact Assessment Area, so may potentially be destroyed by mining activities. A study undertaken by Bullen and Creese (2014) suggested that sound levels up to 70 dB are unlikely to result in ghost bats leaving their roost. Recent work (Biologic 2016, in prep) has shown that caves AC4 and AC9, located 400 m and 1.8 km from active mining respectively, have shown recent signs of continual and frequent use by ghost bats. Another cave (AC13) is located approximately 1.1 km from mining operations at Hope Downs 1. This cave continues to be used by ghost bats, and hormone analysis shows that pregnant females were using this cave in 2014.

It is suggested that ghost bats will be able to tolerate vibrations of up to 15 mm/s (R. Bullen, pers. comm.), although there has been no specific research undertaken to support this. Further it would be very difficult to undertake an assessment of vibration tolerance at Southern Flank given the low likelihood of locating individuals within a cave for a long-term study. A vibration assessment undertaken by SVT (2016) predicted likely vibrations levels at various distances for single hole and simultaneous blasting of 10 holes in soft and hard ground types. For 10 holes in soft ground, the received vibration levels are predicted to be 3.4 mm/s at 1 km and 0.4 mm/s at 2 km, whilst for hard ground, the received vibration levels are predicted to be 19.6 mm/s at 1 km and 6.9 mm/s at 2 km. It is predicted that at 1.1 km a vibration of 15 mm/s will be experienced. It is considered highly likely that the soft ground type would be applicable to caves at Southern Flank, but further study would be required to confirm this.
Dust

Vegetation clearing, mining, hauling and vehicle movements will result in an increase in airborne particulate matter. A result of this could be a decline in vegetation quality, although no prior studies have been able to detect a significant adverse impact of airborne dust on plant function in the Pilbara (Grierson, 2015). If vegetation was to be affected this could impact faunal assemblages by reducing both food and habitat resources. Even though ghost bats detect prey via sound, they also have excellent vision and it is possible that high dust levels could irritate the eyes or reduce vision and affect their ability to capture prey. The dust modelling for the Proposal (Pacific, 2016) indicates that high dust events are likely at certain locations; however a low risk rating (based on impacts to humans, which could be comparable to ghost bats) is predicted for the majority of the year. Provided that existing dust suppression strategies continue to be implemented, the likelihood that the ghost bat will be affected is low.

Infrastructure

Ghost bats are known to become entangled in barbed wire due to their low elevation flying pattern (Armstrong and Anstee 2000). Recently, a mummified adult male was retrieved from a barbed wire fence in the Juna Downs pastoral lease (Biologic, 2016 in prep). The use of barbed wire fencing within mining areas is limited to areas required to comply with safety guidelines, and the likelihood of entanglement can be reduced by placing reflective discs on the wires. The impacts from infrastructure are considered negligible.

Invasive species

There is recent evidence that ghost bats predate on cane toads and are susceptible to their toxicity (Purtill 2014; White et al., 2016). If cane toads expand into the Pilbara (some models predict this, e.g. Urban et al. [2007]; Kearney et al. [2008]; Molloy [2015]) populations in the Chichester sub-region (where populations are at their highest) will be particularly susceptible. Recently, a study was completed which concluded the cane toad has the capacity to invade an approximately 300 km wide strip along the north-west coast, with a possibility that this invasion will spread further inland and to the south (Molloy, 2015). This invasion scenario will potentially see the cane toad inhabiting the Proposed Mining Area C Development Envelope which will place further pressure on the species in the area. Climate change may assist in reducing the potential range of the cane toad with at least one climate change scenario showing a significant potential reduction in distribution (Molloy, 2015). Mining activity may assist in the rate of spread of this invasive species, through vehicle movements and available surface water in the form of turkey nests and waste water treatment facilities. No surface water discharge is planned for the Proposal; excess water will be used to recharge local aquifers. Other invasive species such as buffel grass (Cenchrus ciliaris), or any plant species that excludes native species, may degrade habitat in the area; however this is considered to be unlikely to impact on the ghost bat. Standard weed control measures will assist in reducing
the impact of introduced plant species. Disturbance and mining activities (such as refuse disposal) may increase populations of the introduced house mouse (*mus musculus*), which appears to form a significant component of the ghost bat diet in the Hamersley subregion (see Section 3.6).

### 4.3 Mitigation and residual impacts

Following a review of preliminary impacts from implementation of the Proposal, BHP Billiton Iron Ore has modified the Indicative Additional Impact Assessment Area to reduce impacts to the ghost bat; this area is hereafter referred to as the Modified Indicative Additional Impact Assessment Area. An assessment of how this change alters the impact assessment for ghost bats is provided in the following sections.

#### 4.3.1 Loss of Roosts

With implementation of the Modified Indicative Additional Impact Assessment Area the number of high value caves within impact areas is reduced from 12 to 5 caves and the low caves is reduced from 21 to 12. The number of caves retained in the Proposed Mining Area C Development Envelope will be increased from 12 to 27 (11 high value; 16 low value). Importantly, caves SF8, SF4 and SF5 will be retained, which form a cluster of three high importance caves in the western end of the Proposed Mining Area C Development Envelope (Figure 4.4). This area is in close proximity to the Coondewanna Flats PEC, which is considered a likely foraging area for the species. The Indicative Modified Additional Impact Assessment Area also avoids a number of high value caves in the east.

A significant factor in connecting the east and west caves is the availability of roosting habitat in the central area. The gap between the west and east caves is over 8 km (which is slightly reduced following mitigation) which could represent a barrier to movement along the range. There are four caves to the immediate north of the Indicative Modified Additional Impact Assessment Area that may reduce this impact.

#### 4.3.2 Loss of Foraging Habitat

The Indicative Modified Additional Impact Assessment Area reduces impacts to foraging habitats by 288.38 ha. The original foraging area within the Indicative Additional Impact Assessment Area was 8693.53 ha while the foraging area within the new mitigation boundary is 8,405.92 ha. The foraging area outside of the Indicative Additional Impact Assessment Area was 8956.71 ha while the foraging area outside the new mitigation boundary is 9245.10 ha. The Coondewanna Flats PEC and surrounding areas remain unaffected.
Fig. 4.4: Indicative Modified Additional Impact Assessment Area and cave locations

Legend

- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Approved Impact Assessment Area
- Indicative Modified Additional Impact Assessment Area
- Rail
- Mine Accommodation
- Roost classification
  - High importance
  - Low importance

BHP Billiton Iron Ore - MAC Revised Proposal
Environmental Impact Assessment for Ghost Bat

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 15/08/2016
Fig. 4.4a: Indicative Modified Additional Impact Assessment Area and cave locations (western)
Fig. 4.4b: Indicative Modified Additional Impact Assessment Area and cave locations (central)
Fig. 4.4c: Indicative Modified Additional Impact Assessment Area and cave locations (eastern)
Retained caves in the west are in close proximity to suitable foraging grounds at Coodewanna Flats (Figure 4.5). The Modified Indicative Additional Impact Assessment Area also avoids some of the floodplain east of Mt Robinson to Pebble Mouse Creek. This area is near to caves retained in the east.

4.3.3 Ghost Bat Numbers

Impacts to a number of high value caves and foraging areas in the west and east is reduced with implementation of the Modified Indicative Additional Impact Assessment Area. This will likely reduce the number of individuals impacted during mining and increase the number of individuals that may return post mining when compared to predicted impacts without mitigation. The short-term loss of individuals will also be dependent upon the progressive mining plan.

Depending on the mine sequencing, ghost bats may persist in the western and / or eastern end of the Additional Development Envelope during mining operations. It is unlikely that individuals will persist in caves that are in close proximity to mining and infrastructure (Table 4.4) due to localised levels of noise, dust and light; however as the life of the Proposal is 30 years, the disturbance to caves will unlikely occur concurrently and ghost bats should be able to move to areas within the Proposed Mining Area C Development away from active mining areas.

Table 4.4: Retained high value caves and the distance to Modified Indicative Additional Impact Assessment Area

<table>
<thead>
<tr>
<th>Cave</th>
<th>Distance to Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC18</td>
<td>462 m</td>
</tr>
<tr>
<td>AC14</td>
<td>480 m</td>
</tr>
<tr>
<td>AC17</td>
<td>96 m</td>
</tr>
<tr>
<td>SF4</td>
<td>95 m</td>
</tr>
<tr>
<td>SF5</td>
<td>100 m</td>
</tr>
<tr>
<td>SF8</td>
<td>93 m</td>
</tr>
<tr>
<td>SF18</td>
<td>156 m</td>
</tr>
<tr>
<td>SF27</td>
<td>130 m</td>
</tr>
</tbody>
</table>
Fig. 4.5: Indicative Modified Additional Impact Assessment Area and foraging areas.

Legend
- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank)
- Proposed Southern Flank Development Envelope
- Approved Impact Assessment
- Indicative Modified Additional Impact Assessment
- Ghost Bat roosts
- Estimated foraging extent (2km radius)
If the ghost bat is unable to persist within the Proposed Mining Area C Development Envelope during mining, the retention of caves in the west and east is likely to provide sufficient habitat for re-establishment of individuals and breeding upon closure, particularly once rehabilitated areas can support prey species. Nevertheless, a reduction in numbers would be expected as approximately half of the high value caves are planned to be removed and the gap between the east and west caves could reduce the ability of ghost bats to respond to natural or man-made events such as fire, drought and noise.

An estimate of the actual reduction in numbers is difficult but given that half of the high value caves in the immediate area and surrounds are planned for removal, a reduction of individuals by approximately half could reasonably be expected.

4.4 Cumulative impacts

There are two other mining areas in close proximity to Proposal; Hope Downs (~50 m to the east) and West Angelas (~15 km to the south-west), both operated by Rio Tinto or its joint ventures.

The ghost bat was first recorded at West Angelas in 1979 (Biologic, 2014), and monitoring has been occurring since August 2000. It is still detected around West Angelas, based on the presence of fresh scat material in the monitoring caves and calls on SM2 detectors (Biologic, 2014); however, how they are utilising the area is unknown.

The ghost bat has been recorded at Hope Downs (Bullen, pers com) and within the boundary of the Baby Hope area (Biota, 2012). Impacts to the ghost bat were not assessed for the Baby Hope proposal, and detailed information on roost locations and numbers is not available. Given the proximity of this project to the Proposal it is likely that ghost bats using Southern Flank also occur at Baby Hope. Genetic studies would be required to confirm this.

Cumulative impacts to the species within the Hamersley Range are difficult to assess due to a number of reasons:

- The species has only recently been listed as a threatened species, and hence may not have been targeted during surveys for conservation significant species;
- Most surveys for bats in the Pilbara rely on detection using acoustic recorders or to a lesser extent harp trapping or mist netting. Both techniques rely on detection of individuals during the survey period, and based on current data (see Section 2) these techniques are considered unlikely to record ghost bats utilising an area. Acoustic detectors are particularly unreliable for ghost bats;
- There are few, if any, surveys undertaken within the region that have similar survey intensity and methods to those undertaken on BHP Billiton Iron Ore tenure. Data that are available in the public domain, generally lack detailed information on roost locations; and
• Surveys that have recorded ghost bats have generally been undertaken for mining companies, and therefore most records will correlate with mining tenure.

An overlap of known ghost bat roosts and future mining footprints identified in the eastern Hamersley sub-region during BHP Billiton Iron Ore’s Public Environmental Review Strategic Proposal (BHPBIO, 2016) is shown on Figure 4.6 Almost all known roosts occur in BHP Billiton Iron Ore tenure, or areas surveyed for BHP Billiton Iron Ore in Karijini National Park. Detailed surveys are required outside BHP Billiton Iron Ore tenure before an accurate cumulative impact assessment can be undertaken.

4.5 Constraints and Assumptions

This impact assessment is largely constrained by the lack of information available on the ecology of the ghost bat, its distribution within the Pilbara and in particular the location of roosting habitat, and the species’ response to disturbance. The vast majority of information available on the ecology of the ghost bat has been collected from Northern Australia where conditions are different to the arid Pilbara region and the species appears to behave differently. The ghost bat is difficult to study due to the remoteness of roosts, and their cryptic nature. Significant effort has been expended during the past six years within, and in the vicinity of, the Proposed Mining Area C Development Envelope to better understand the species, particular in the south eastern and central Pilbara. This has included the trial of a number of survey techniques, of which some failed to record any additional information.

There are limited data available for records outside BHP Billiton Iron Ore tenure, and that which is available is generally limited to a species record rather than information about roosting habitat. Most surveys undertaken outside BHP Billiton Iron Ore tenure have relied on acoustic detectors which are not reliable for detecting ghost bats. Ghost bats in the Hamersley Range move around frequently, with recaptures infrequent (Armstrong and Anstee, 2000); therefore a lack of records from an acoustic detector may not mean that a ghost bat does not use a cave or is present within an area. Further, as the ghost bat has only recently been listed it may not been have been targeted during surveys for conservation significant species prior to late 2015.
Legend

- Proposed Mining Area C Development Envelope
- Approved Mining Area C (Northern Flank) Development Envelope
- Proposed Southern Flank Development Envelope
- Approved Impact Assessment
- Indicative Additional Impact Assessment

- Known Pilbara Ghost Bat Roosts
- Rail
- Karriini National Park
- Third-Party Development Footprints
- Full Development Scenario (Strategic Assessment)

Fig. 4.6: Known Ghost Bat roost caves and potential future disturbances
The genetic study needs to be interpreted with some caution due to the limited dataset that was generated. The study initially used 324 samples, of which 19 were tissue (e.g. wing membrane) and 305 samples extracted from scats. Samples were included in the study on the basis that at least five loci were generated, allowing a probability of >0.99 individual confidence in assigning individuals (based on probability of identify statistics). The generation of only 98 individuals makes the interpretation of the data somewhat limited, particularly at the scale used (the Hamersley subregion) (Spencer and Tedeschi, 2016). For the hormone analysis, attempts were made to confirm that patterns in faecal hormone levels are reflective of biologically relevant changes in physiology (such as pregnancy). Scats could only be acquired from a single confirmed pregnant female at the Perth Zoo that gave birth in November 2015, providing only a single pregnancy for comparison. The genetic and hormone analysis work is ongoing and the current report presents the information available at the time of writing.

Sampling and cave searching is mostly restricted to BHPBIO tenure; however sampling for the genetic work took place at a few locations across the Hamersley Range, including FMG and APIM tenure.
5. CONCLUSION

There has been a considerable amount of work undertaken for BHP Billiton in the last six years which has greatly increased our understanding of the ghost bat. Nevertheless, information on the ecology of the ghost bat in the Hamersley Range and its response to disturbance is limited and it is therefore difficult to make conclusive statements on impacts to the species. A conservative approach to impacts has therefore been undertaken using information currently available.

Without mitigation, removal of caves within the Proposed Mining Area C Development Envelope is considered locally significant as it is unlikely that ghost bats will be able to persist in the area during and post mining. This is primarily due to the lack of suitable roosting habitat retained within the area.

Modification of the Indicative Additional Assessment Area reduces the number of caves impacted by 15, with a number of high value caves retained at the western and eastern end of the range. It is considered likely that ghost bats will persist in the Proposed Mining Area C Development Envelope over the long term if the Indicative Modified Additional Impact Assessment Area is implemented. Due to limited ecological data it is uncertain if ghost bats will occur within the Proposed Mining Area C Development Envelope during the 30 year period of mining.

The EPA’s objective for terrestrial fauna is ‘To maintain representation, diversity, viability and ecological function at the species, population and assemblage level. Considering this project in isolation and at a species level, the impacts to the ghost bat are considered low; however as roosting habitats are lost in northern Australia (either due to an increase in mining projects or the collapse of artificial adits) pressure on the species will increase.

Population estimates for the Hamersley Range Population are between 300 and 400 individuals and any loss of individuals in a regional context would be considered significant. It is considered likely that with mitigation the ghost bat will persist in the Proposed Mining Area C Development Envelope, although likely at lower numbers. It is therefore considered likely that with mitigation the Proposal meets the EPA objectives for terrestrial fauna with respect to the ghost bat.
6. REFERENCES


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