Mesa A Hub

Subterranean Fauna Peer Review

Rio Tinto Iron Ore

June 2018

Mesa A Hub

Subterranean Fauna Peer Review

DOCUMENT STATUS				
Version No.	Author	Review / Approved for Issue	Approved for Issue to	
			Name	Date
1	Shae Callan Breanne Menezies	Brad Durrant	F. Bell (RTIO)	05/04/2018
2	S. Callan	B. Durrant	F. Bell	09/05/2018
Final	S. Callan	M. O'Connell	F. Bell	08/06/2018

IMPORTANT NOTE

Apart from fair dealing for the purposes of private study, research, criticism, or review as permitted under the Copyright Act, no part of this report, its attachments or appendices may be reproduced by any process without the written consent of Biologic Environmental Survey Pty Ltd ("Biologic"). All enquiries should be directed to Biologic.

We have prepared this report for the sole purposes of Rio Tinto Iron Ore ("Client") for the specific purpose only for which it is supplied. This report is strictly limited to the Purpose and the facts and matters stated in it do not apply directly or indirectly and will not be used for any other application, purpose, use or matter.

In preparing this report we have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request or enquiry were complete, accurate and up-to-date. Where we have obtained information from a government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware of any reason why any of the assumptions are incorrect.

This report is presented without the assumption of a duty of care to any other person (other than the Client) ("Third Party"). The report may not contain sufficient information for the purposes of a Third Party or for other uses. Without the prior written consent of Biologic:

a) This report may not be relied on by a Third Party; and

b) Biologic will not be liable to a Third Party for any loss, damage, liability or claim arising out of or incidental to a Third Party publishing, using or relying on the facts, content, opinions or subject matter contained in this report.

If a Third Party uses or relies on the facts, content, opinions or subject matter contained in this report with or without the consent of Biologic, Biologic disclaims all risk and the Third Party assumes all risk and releases and indemnifies and agrees to keep indemnified Biologic from any loss, damage, claim or liability arising directly or indirectly from the use of or reliance on this report.

In this note, a reference to loss and damage includes past and prospective economic loss, loss of profits, damage to property, injury to any person (including death) costs and expenses incurred in taking measures to prevent, mitigate or rectify any harm, loss of opportunity, legal costs, compensation, interest and any other direct, indirect, consequential or financial or other loss.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

1.1 Project Background

Rio Tinto Iron Ore (RTIO) owns and operates the Mesa A mine in the west of the Robe Valley approximately 50 kilometres (km) west of Pannawonica. The Mesa A mine was approved in November 2007 under Ministerial Statement (MS) 756. This operation includes above water table mining at the Mesa A deposit, which commenced in February 2010, and mining at the Warramboo deposit, which commenced in 2012.

RTIO referred a proposal to the Environmental Protection Authority (EPA) in November 2016 to expand existing operations at the Mesa A mine (the Mesa A Hub Proposal, hereafter referred to as 'the Proposal'). The Proposal includes extensions of existing mining operations at Mesa A and Warramboo, and new mining operations at the Mesa B, Mesa C, and Highway//Tod Bore deposits. Mining of the Warramboo and Mesa C deposits are proposed to extend below the water table. Extensions at Mesa A deposit propose to alter the Mining Exclusion Zone (MEZ).

Subterranean fauna assessments have recorded troglofauna throughout the Proposal areas, and it is thought that many of the troglofauna species recorded from Mesas A, B and C are restricted to their respective mesas. The Proposal has therefore been designed to retain troglofauna habitat on each mesa and to avoid troglofauna species of interest where possible (these areas of retained habitat are referred to as the MEZ).

The Proposal includes below water table mine at the Warramboo and Mesa C deposits. Subterranean fauna assessments have recorded stygofauna from within the local aquifers proposed to be dewatered to enable below water table mining at these deposits.

The Environmental Scoping Document (ESD) for the Proposal includes a requirement for a subterranean fauna peer review:

> *"A peer review is required to be commissioned by the proponent, in consultation with the OEPA, and included in the Environmental Review Document. A peer review of the impacts to subterranean fauna and management, focussing on the impacts on troglofauna and the troglofauna habitat that would remain if the proposal was implemented and its stability and suitability to sustain viable troglofauna populations and assemblages".*

To address the above requirement, RTIO has commissioned Biologic Environmental Survey Pty Ltd (Biologic) to prepare a Subterranean Fauna Peer Review for the Mesa A Hub Proposal (here-in referred to as the Review).

1.2 Objectives

The purpose of the Review is to undertake a review of available documentation related to the predicted impacts on subterranean fauna and subterranean fauna habitat from the Proposal, and proposed management of these impacts; as required by the ESD. The Review focuses on the following aspects:

1) a review of the troglofauna impact assessment work and proposed management;
2) a review of the troglofauna sampling, taxonomy, species assessment, and habitat assessment undertaken in support of the impact assessment;
3) a review of work undertaken at Mesa A under the Troglofauna Monitoring Plan (TMP), comprising troglofauna compliance monitoring and habitat monitoring;
4) a review of the stygofauna impact assessment work and proposed management;
5) a review of the stygofauna sampling and habitat assessment undertaken to-date, including hydrogeological assessments.

The review of the troglofauna EIA and proposed management strategies discusses the suitability of the proposed habitat retention zones (*i.e.* MEZ at Mesas A, B and C), considering location and total volume. It considers the suitability of the approach to sustain viable troglofauna populations and assemblages, focusing on the likely impacts on troglofauna and remnant habitats if the Proposal were implemented.

The review of the troglofauna sampling provides a summary of work completed to date (detailing the survey reports and information considered) and assesses the adequacy of the sampling undertaken in the Proposal area. An additional section addresses the findings from the compliance monitoring and troglofauna habitat monitoring reports.

The review of the stygofauna sampling provides a summary of work completed to date and assesses the adequacy of the sampling and habitat assessment undertaken. This section also provides a review of the hydrogeological assessments undertaken to support the Proposal.

Each section of the Review was structured in the following way:

- List of work/ reports reviewed;
- Summary of key findings relevant to survey, impact assessment, monitoring, and management;
- Discussion of any assumptions, omissions, or limitations of the work/ reports/ findings;
- Discussion of overall adequacy of the work/ suitability of the approach; and
- Suggested ways to improve adequacy/ suitability if relevant.

An overall summary of the key findings of the Review is presented at the end of the report, with weighting (major vs moderate) of the issues with the work to date, and suggested strategies to resolve these issues.

1.3 Legislation and Guidance

Western Australia's subterranean fauna is considered globally-significant due to an unprecedented richness of species and high levels of short-range endemism (EPA 2016a). The EPA's environmental objective for subterranean fauna is to "*protect subterranean fauna so that biological diversity and ecological integrity are maintained*" (EPA 2016d, p2). In this context, the EPA defines ecological integrity as "*the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements*" (EPA 2016d, p2).

Protection for conservation significant subterranean species and/ or Threatened or Priority Ecological Communities (TECs and PECs) is provided under State and Federal legislation, comprising:

- *Environmental Protection Act 1986* (EP Act) (WA);
- *Wildlife Conservation Act 1950* (WC Act) (WA);
- *Biodiversity Conservation Act 2016* (BC Act) (WA); and
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth).

Most subterranean species and assemblages are not listed under these Acts, due to incomplete taxonomic or ecological knowledge. Consideration of range-restricted subterranean fauna is therefore also important, including species that only occur within restricted habitats, as these have a higher potential of being Short-Range Endemic (SRE) species (Harvey 2002; Eberhard *et al.* 2009).

The Peer Review has been undertaken in consideration of the following EPA guidance statements:

- EPA (2016a) Technical Guidance Subterranean Fauna Survey;
- EPA (2016b) Technical Guidance Sampling Methods for Subterranean Fauna; and
- EPA (2016c) Environmental Factor Guidelines Subterranean Fauna.

2. REVIEW OF TROGLOFAUNA IMPACT ASSESSMENT AND PROPOSED MANAGEMENT

2.1 Proposed modifications to MEZ at Mesa A

Under the Proposal, mining extensions at Mesa A deposit propose to alter the MEZ. Numerous pit shell configurations were examined to preferentially obtain access to higher grade ore while retaining suitable troglobitic fauna habitat and meeting the requirement of Condition 8-1 of MS 756; these are reported in RTIO (2017a) and were reviewed by Biologic with a summary of key information provided below.

Known locations of singleton troglofauna were buffered and excluded within the proposed modifications to the MEZ to maximise the retention of troglofauna habitat with the proposed revised MEZ. The proposed mining areas will result in a reduction of 33 ha of MEZ (RTIO 2017a). The extraction of ore from beneath the currently approved pit floor at Mesa A was not considered a viable option, as it would result in the requirements of Condition 8-1 not being met (*i.e.* the retained troglofauna habitat beneath the pit floor must be at least 15 m and the volume of the material retained beneath the pit floor must be not less than the volume of the MEZ, to ensure adequate connectivity with the MEZ).

Three taxa are known from the proposed new areas of mining within the MEZ:

- Genus nov. sp. nov. (order Diplura);
- *Paradraculoides anachoretus*; and
- *Lagynochthonius asema*.

All three taxa have been recorded in the areas of the MEZ proposed to be retained (the proposed revised MEZ) (RTIO 2017a).

RTIO modelled the volume of potential troglofauna habitat proposed for retention after the proposed changes to the MEZ at Mesa A (RTIO 2017e). The assessment considered that suitable troglofauna habitat occurred within all above water table (AWT) Robe Pisolite geological units above the Tertiary Pisolite Base (TPB) (denoted as HTP, TPC TPD, TPH, and TPM), regardless of thickness. The assessment estimated that more than 50% of the pre-mining volume of potential troglofauna habitat will remain after the completion of mining within the proposed modified MEZ and beneath the pit floor at Mesa A (RTIO 2017e).

2.1A) MODERATE ISSUE

Due to the very limited size of the proposed changes to the MEZ (33ha), the Review did not consider issues affecting the assessment approach to be major issues. However, there are several unresolved uncertainties surrounding the current effectiveness of the MEZ as a strategy for conserving restricted troglofauna species and assemblages (as discussed in detail in section 2.2.2 below), and attempts should be made to resolve these to provide greater confidence in the assessment of both the changes to Mesa A MEZ and the strategies to conserve troglofauna at Warramboo and Mesas B and C.

2.1A) STRATEGY

Following a precautionary approach, the Review recommends precluding any additional (further) changes to the MEZ design or volume at Mesa A until a more rigorous and comprehensive assessment of the effectiveness of the MEZ for conserving troglofauna, and the minimum habitat requirements for troglofauna species and assemblages at Mesa A can be undertaken, and the effectiveness of proposed strategies (or changes to current strategies) is more thoroughly supported by data.

2.2 Warramboo, Mesa B and Mesa C Assessment and Proposed MEZ

RTIO undertook an internal assessment of the potential impacts of troglofauna habitat removal at Warramboo, Mesa B and Mesa C as a part of the Proposal (RTIO 2017b). A summary of key information relevant to the Review is presented below.

The assessment found that many troglofauna recorded at Mesa B and Mesa C appear to be restricted to their respective mesas and are unlikely to occur more widely, based on the known patterns of distribution of restricted troglobitic fauna throughout the Robe Valley Mesas. It was proposed that significant volumes of highly prospective troglofauna habitat at Mesa B and Mesa C would be excluded from mining and retained for troglofauna habitat in their proposed MEZ's, following the approach taken at Mesa A (RTIO 2016). Due to the Warramboo and Tod Bore/ Highway deposits being regarded as part of a contiguous high prospectivity troglofauna habitat that extends well beyond the impact area (mainly to the south west), no MEZ was proposed for Warramboo, or Highway/ Tod Bore, and impacts on species found in these areas were considered unlikely to be significant (RTIO 2017b).

Based on habitat assessment carried out by Biota (2014, 2017, 2017), Robe Pisolite (or Channel Iron Deposit, CID) thicker than 5 m AWT were considered to represent the most highly prospective habitat for troglofauna. Colluvium, alluvium, and Robe Pisolite <5 m AWT were considered to represent medium 'prospectivity' habitat; and all other geological units were considered to represent low 'prospectivity' habitat.

The assessment identified that the removal of troglofauna habitat has potential to impact members of the troglofauna community at Warramboo, Mesa B and Mesa C (Highway/ Tod Bore were not specifically mentioned). Each taxon recorded from these areas was given a 'priority' rank based on the relative number of locations within the proposed disturbance areas (*i.e.* mine pit). Priority 1 taxa (P1, singletons found only inside pit) and Priority 2 taxa (P2, species known only from multiple sites inside pit) were considered most at risk from the Proposal and formed the focus of the assessment.

The proposed MEZ's at Mesa B and Mesa C were designed to retain highly prospective habitat surrounding the known locations of the majority of troglobitic species, with the aim to include a minimum of one location of each P1 and P2 taxon. Nevertheless, owing to other considerations in the final design of the proposed MEZ's at Mesa B and Mesa C, 'residual impacts' could not be avoided to 17 P1 and P2 taxa known only from the proposed pits; comprising 11 P1 and P2 taxa Mesa B, three (3) P1 taxa at Mesa C, and four (4) P1 taxa at Highway/ Tod Bore (RTIO

2017b). One species, *Tyrannochthonius*, sp. 'Warramboo' was recorded at Warramboo in 2005 (Biota 2006) in an area proposed for mining as part of the Mesa A/ Warramboo Iron Ore Project. This area was assessed and approved for mining under MS 756. All other troglofauna species recorded in the proposed additional pit areas at Warramboo have been recorded elsewhere outside of pit boundaries.

Table 2.1: Species currently known only from proposed pit and waste dump areas (no known locations outside impact areas) at Mesas B, C, and Highway/ Tod Bore (adapted from RTIO 2017b).

Mesa B	Mesa C	Highway/Tod Bore
Armadillidae sp. 'OES23' (P1)	Cryptopidae sp. 'CHI026' (P1)	Armadillidae sp. 'ISA006' (P1)
Campodeidae sp. 'DCA001' (P1)	Parajapygidae sp. 'DPA008' (P1)	Armadillidae sp. 'ISA007' (P1)
Chthoniidae sp. 'PCH049' (P1)	Parajapygidae sp.'DPA004' (P1)	*Cryptops* sp. 'CHI002' (P1)
Chthoniidae sp. 'PCH050' (P1)		*Trinemura* sp. 'T1' (P1)*
Cryptops sp. 'nov' (P1)		
Hanoniscus sp. 'OES21' (P1)		
Hyiidae sp. 'PH001' (P1)		
Indohya sp. 'PSE073' (P1)		
Parajapygidae sp. 'DPA003' (P1)		
Prethopalpus sp. 'ARA051' (P1)		
Hanoniscus sp. '3' (P2)		
11 species	**3 species**	**4 species**

Note: * asterisk indicates species recorded within waste dump impact area

RTIO modelled the volume of potential troglofauna habitat proposed for retention after mining of the Mesas B and C deposits (RTIO 2017c, 2017d). These modelling assessments used the same approach as previously applied for the changes to the MEZ at Mesa A, considering that suitable troglofauna habitat occurs within all AWT geological units above the TPB. Waste dumps and stockpiles were proposed in areas that were considered lower 'prospectivity' for troglofauna, rather than on the Mesa landform, and were not included in the habitat retention calculations (RTIO 2017c, 2017d). The assessments estimated that more than 50% of the pre-mining volume of potential troglofauna habitat will remain after the completion of mining at Mesas B and C (RTIO 2017c, 2017d).

The Review found several potential issues which may cause residual risks for the assessment of troglofauna or for the degree of confidence in the MEZ as a strategy for conserving troglofauna species, as discussed in further detail below.

2.2.1 Habitat assessment

2.2.1A) MAJOR ISSUE

"Troglofauna habitat at Warramboo, Highway and Tod Bore is part of a contiguous system that extends beyond the Proposal Area. Troglofauna in these areas are, therefore, unlikely to be restricted to the proposed mining areas" (RTIO 2017).

Highly prospective, contiguous CID habitat at Warramboo/ Highway/ Tod Bore is assumed to be well-connected beyond the indicative impact area to the south west, based on detailed geological and geomorphological modelling conducted by Rio Tinto (RTIO 2018). Despite the modelling being based upon the best available data and robust in methodology, there are some areas to the south and west of Highway/ Tod Bore where the modelling relies upon less drill hole data and more widely-spaced drilling, which increases the reliance on interpolation/ extrapolation.

There is also a discrepancy with the interpretation of habitat connectivity to the south west: troglofauna sampling from CID habitats to the south-west (locality known as Dinner Camp Bore) showed a completely different troglofauna assemblage (Biota 2017a) to CID habitats within the Highway/ Tod Bore impact areas, despite the habitat model indicating contiguous, well-connected, highly suitable habitats.

These fauna results were based upon a single round of sampling (Bennelongia 2010) and are based on morphological results only (no genetic work was undertaken); therefore, it is difficult to rule out sampling artefacts as a factor explaining the absence of species from the Highway/ Tod Bore assemblage in this area. More work is required to validate the degree of species turnover between these two sampling areas and assess to what degree it may be explained by differences in sampling and/ or taxonomic identifications (including genetic analysis).

Nevertheless, the occurrence of a rich, highly dissimilar species assemblage in the CID habitats at Dinner Camp Bore suggests habitat discontinuity (*i.e.* a potential barrier to dispersal), habitat heterogeneity, or other reasons for high species turnover between this area and Highway/ Tod Bore. This finding brings into question the assessment that species found at Highway/ Tod Bore would be expected to occur throughout the wider extent of high prospectivity, contiguous CID habitats extending to the south west (as shown by the habitat modelling).

This has direct implications for the impact assessment of the following species currently known only inside impact areas at Highway/ Tod Bore:

- Armadillidae sp. 'ISA006' (Potential SRE);
- Armadillidae sp. 'ISA007' (Potential SRE);
- *Cryptops* sp. 'CHI002' (Potential SRE); and
- *Trinemura* sp. 'T1' (Potential SRE) (to some extent, owing to its location beneath a proposed waste dump).

Based on detailed habitat modelling (RTIO 2018), it is reasonable to expect that suitable habitats for these troglofauna species may occur in the immediate vicinity around the pits, but it cannot be concluded with confidence that "*troglofauna in these areas are, therefore, unlikely to be restricted to the proposed mining areas"* (RTIO 2017b). Rather, there is a current

knowledge gap surrounding the extent and continuity of suitable habitats at Highway/ Tod Bore beyond the impact areas towards the south west (i.e. towards Dinner Camp Bore).

2.2.1A) STRATEGY

Further investigation/ assessment of the potential local occurrence of suitable habitats for the above species should be undertaken in the following areas; A) highly and moderately prospective habitats surrounding pits and direct impact areas at Highway/ Tod Bore, and B) areas of highly and moderately prospective habitat extending to south west of the pits at Highway/ Tod Bore.

Troglofauna community comparisons and species distribution mapping should be undertaken between Warramboo, Highway/ Tod Bore and other adjacent or contiguous habitat areas to assess community similarity and validate inferred habitat continuity.

If required, further sampling in any of the highly or moderately prospective habitat areas immediately outside of pits at Highway/ Tod Bore would be the most robust way to provide additional opportunities to detect the above species outside of impact areas.

If no further investigations are possible, more detailed assessment of potential extent of troglofauna habitat (species found only at Highway/ Tod Bore) may be possible by integrating troglofauna species/ assemblage occurrence into geomorphological habitat modelling (see strategy 2.2.1B below).

2.2.1B) MAJOR ISSUE

A more detailed explanation of troglofauna habitat suitability and connectivity modelling has been provided (RTIO 2018), although there are still some questions regarding the thresholds for high vs moderate habitat suitability in terms of what this means for fauna occurrence. For example, Robe pisolite >5 m thickness AWT is regarded as high prospectivity, whereas the same geology <5 m thickness AWT is regarded moderate prospectivity habitat, but at the current time, there is no information justifying these thresholds or categories by way of linking them to fauna occurrence.

The utility of a threshold for determining high vs moderate prospectivity troglofauna habitat is clear; however, the reality of troglofauna habitat suitability is likely to be more complicated and may differ for various species based on ecological niches, environmental tolerances, or dispersal capabilities. As much of this detailed ecological knowledge has not yet been established, and because it is difficult to exclude sampling artefacts from occurrence data, this issue is challenging to resolve.

2.2.1B) STRATEGY

A clearer explanation of the framework used for categorising habitat prospectivity (based on available faunal data and modelling), and its application in defining the threshold levels between habitat categories may reduce potential perception issues or misinterpretations.

It may be possible to infer an optimal thickness of habitat for local troglofauna species or assemblages by spatially comparing occurrence records against the geological/

geomorphological habitat modelling. This information could then be used to infer and map the 'potential extent of habitat' for certain species in three-dimensions (based on known occurrence records and habitat connectivity modelling), and possibly for assemblages of species. The accuracy of such an approach is highly contingent upon the fauna data available and more work is required to assess the suitability of the approach for the data available. It is important to note that all assumptions/ limitations of the approach would need to be stated clearly *e.g.* how fauna absences and potential sampling artefacts are dealt with. Locally widespread species may need to be excluded from analysis. The analysis would need to incorporate logical 'stopping rules' where species/ assemblage turnover is known to occur, and a standardised way of dealing with absences where high intensity sampling failed to detect a species/ assemblage. This approach could be revisited in the future, to potentially investigate the local extent of habitat available outside impact areas for species known only from inside impact areas, or the amount of suitable local habitat retained after mining.

2.2.2 Design and effectiveness of the proposed MEZ

2.2.2A) MODERATE ISSUES

There are several design characteristics of the proposed MEZ at Mesas B and C that could use additional justification to avoid potential perception issues or misunderstandings, specifically:

1. 30 m minimum buffer retained around the locations of P1 and P2 species (*i.e.* why was 30 m chosen? What relationship does this have to habitat volumes retained and current understandings of troglofauna habitat requirements/ edge effects?);
2. The MEZ to include a minimum of only 1 known location for each P1/P2 troglofauna species (for example, if a species was found at 5 sites this may be interpreted as only 1/5th of its inferred habitat will be conserved, whereas the actual situation may be more complex/ nuanced); and
3. Statement that "*Ongoing sampling at Mesa A indicates that* [the MEZ] *is a suitable approach and that the MEZ is providing a suitable volume of habitat to maintain troglofauna representation*" (RTIO 2017) is poorly supported by current compliance monitoring data and analysis, which is discussed in more detail in Section 4 below.

2.2.2A) STRATEGIES

1. Provide a clearer explanation of design features for troglofauna in the MEZ, including where possible, use of evidence from habitat assessment/ modelling or fauna studies to justify relevant thresholds. This could include more descriptive mapping and diagrams of MEZ design features at scales more relevant to troglofauna habitat (*e.g.* 3D mapping of current and remnant potential extent of habitat as discussed for strategy 2.2.1B above). Alternatively, cross-sectional diagrams at scales relevant to the extent of habitat retained around each troglofauna record, showing the geological habitat layers, the proposed pits and remnant habitat extent, and the locations of bores/ holes where fauna were recorded.

2. Rewording statements around the current state of knowledge of the effectiveness of the MEZ as a strategy for conservation of troglofauna (based on comments detailed below in section 4).
3. Re-examine previous compliance monitoring data (including species level and genetic comparisons with baseline specimens, and community analyses where possible) to more accurately assess persistence of troglofauna species/ assemblages within the MEZ at Mesa A.
4. All future compliance monitoring at Mesa B and C MEZ must make all efforts to fully identify all specimens to species level and undertake more comprehensive analyses/ comparisons with the full suite of baseline specimens (and previous rounds of monitoring), as well as habitat information to assess the persistence of troglofauna species/ assemblages.
5. As a longer-term commitment, undertake or actively participate in more detailed research to determine minimum habitat size and extent, and desirable habitat conditions for key troglofauna species and assemblages in geological habitats relevant to current and future operations.

2.2.3 Troglofauna species prioritisation

2.2.3A) MODERATE ISSUE

In determining the numbers of troglofauna taxa affected RTIO (2017b) omitted "*species that were only ever recorded from the draft MEZ and thus never at risk of impact*" (RTIO 2017b). The wording of this statement appears to be logically flawed: if the assessment infers that species found only within the proposed pit are likely to occur within the MEZ (and thus be adequately conserved by its retention), then species found only within the MEZ must be equally likely to occur within the pit; therefore mining (reduction of available habitat) will have some degree of impact on all species found within the Mesa.

2.2.3A) STRATEGY

Remove or reword the statement "*species that were only ever recorded from the draft MEZ and thus never at risk of impact*" (RTIO 2017b) to avoid contradictions (mutual exclusivity) between this and previous (more important) inferences that species found only within the pit should also occur within the MEZ.

2.2.3B) MODERATE ISSUE

The current assessment classifies 'priorities' for potentially restricted troglofauna taxa as: Priority 1 (singletons found only inside pit), and Priority 2 (species known from multiple sites inside pit). There may be potential perception issues associated with this type of wording, as it implies that there is a first and secondary priority or consideration to these taxa, whereas the assessment treats them on a more equal footing with regards to management of impacts.

2.2.3B) STRATEGY

Reword or reconfigure P1 and P2 categories to give equal management/ conservation priority to all species known only from inside impact areas. Reword or reconfigure assessment of habitats remaining within the MEZ after mining to focus less on the MEZ containing any number of sites where P1/P2 species were found (although it is important to still show locations where priority species were known to occur within the MEZ). The focus should rather be on the volume of habitat that remains in the MEZ after mining, the size, extent, configuration and design of the MEZ (and the implications that this has for the effectiveness of the MEZ as a strategy for conservation of troglofauna), and the overall likelihood that priority species/ assemblages should occur within the MEZ, and persist within the MEZ during mining, based on available evidence.

2.3 Geotechnical Report – Landform stability of the MEZ

A geotechnical assessment was undertaken to determine the minimum safe stand-off distance required to ensure long term stability of the mesa façade. The assessment reviewed previous geotechnical studies from the Robe Valley area, along with current pit slope performance at Mesas A and J (Geo 2017). Consideration was also given to the façade stability during closure, particularly for those deposits requiring dewatering to access below water table ore.

The key focus of the assessment was to ensure preservation of most of the mesa façade to protect associated environmental, heritage and visual amenity values particularly the façade fronting the Robe River.

It was concluded that a minimum of 30 m stand-off distance from the façade to the pit crest is adequate for maintaining the long-term stability and integrity of the façade (Gao 2017).

2.3A) MODERATE ISSUE

The Review did not find any major flaws or issues with the geotechnical survey that have any significant bearing on the troglofauna findings or assessment for the current proposal. Nevertheless, there may be some perception issues associated with the coincidence of a 30 m threshold for landform stability and a 30 m minimum buffer retained around priority troglofauna species (RTIO 2017a, 2017b). Without sufficient justification, there may be a perception that the 30 m threshold was chosen for landform stability over troglofauna habitat needs.

2.3A) STRATEGY

This perception issue would be potentially mitigated by strategies listed in section 2.2.2 above.

3. REVIEW OF TROGLOFAUNA SAMPLING

This section (section 3) reviews the consultant reports listed below in section 3.1 and discusses implications for the troglofauna assessment but does not specifically review RTIO documents.

3.1 Baseline Surveying

Sampling for subterranean fauna was first undertaken at Mesa A in 2003 as part of environmental surveys for exploration investigations and was focussed on stygofauna (as reported in Biota 2004). No stygofauna were collected from the boreholes sampled, but four troglobitic taxa were collected from two of the bores. The collection of troglobitic fauna was unexpected, as troglobitic fauna had never been documented from mesa formations on the mainland Pilbara (Biota 2006a). Following this find, further troglofauna surveys were then commissioned.

The following troglofauna surveys have been undertaken in the Robe Valley area in the vicinity of the Mesa A Hub Proposal area:

- Biota (2004) Mesa A and Bungaroo Creek Exploration Areas Subterranean Fauna Survey;
- Biota (2006a) Mesa A and Robe Valley Mesas Troglobitic Fauna Survey;
- Biota (2006b) Mesa A Troglofauna Survey: Compilation of Sampling Results;
- Biota (2007a) Mesa A Troglobitic Fauna Studies Update;
- Biota (2014) Single Phase Troglofauna Sampling for Tod Bore, Hubert Well, Congo Bore and Highway Deposit (draft report superseded by Biota 2017a below);
- Biota (2017a) Mesa A Hub: Warramboo Troglobitic Fauna Assessment; and
- Biota (2017b) Mesa A Hub: Mesas B and C Troglobitic Fauna Assessment.

These troglofauna survey reports have been reviewed and are summarised in Table 2.1, along with key findings for each survey. Numerous troglofauna survey have also been completed for the surrounding area and mesas throughout the Robe Valley area that provide additional regional context for the Proposal.

Table 3.1: Survey effort summary for Troglofauna at Mesa A Hub.

Consultant (Year)	Biota (2004)	Biota (2006a)	Biota (2006b)	Biota (2007a)	Biota (2014)	Biota (2017a)	Biota (2017b)
Report Title	Mesa A and Bungaroo Creek Exploration Areas Subterranean Fauna Survey	Mesa A and Robe Valley Mesas Troglobitic Fauna Survey	Mesa A Troglofauna Survey: Compilation of Sampling Results	Mesa A Troglobitic Fauna Studies Update	Single Phase Troglofauna Sampling for Tod Bore, Hubert Well, Congo Bore and Highway Deposit	Mesa A Hub: Warramboo Troglobitic Fauna Assessment	Mesa A Hub: Mesas B and C Troglobitic Fauna Assessment
Report Type	Subterranean fauna survey[1]	Troglofauna survey and habitat characterization, and EIA/management	Troglofauna survey and EIA/management	Troglofauna survey and consolidation of previous reports for Mesa A	Troglofauna survey	Troglofauna survey (Level 2) and habitat characterization, and collation of previous records from the study area	Troglofauna survey (Level 2) and habitat characterization, and collation of previous records from the study area
Survey Dates	Dec 2003	Nov 2004 & Jan 2005 Jan-July & Mar-July 2005 July & Sept 2005	June & Aug 2006	Dec 2006 & Feb 2007 Apr & May 2007	Oct & Dec 2013	Apr, June & Aug 2015 Aug and Sep/Oct 2015	June & Aug 2015 Aug & Oct 2015 Jan & Mar 2016 July & Sept 2016
Sampling Effort	**Mesa A** - stygofauna hauls at 14 holes **Bungaroo Creek** - stygofauna hauls at 23 holes	**Mesa A** - 235 litter traps at 74 holes **Surrounding area[2]** - 362 litter trap at 112 holes	**Mesa A** - litter traps at 31 holes	**Mesa A MEZ and sub-grade zone** - 84 litter traps at 31 holes (phase 1) - 109 litter traps[3] at 36 holes (phase 2)	**Tod Bore** - 99 litter traps & 21 scrapes at 36 holes **Hubert Well** - 27 litter traps & 5 scrapes at 12 holes **Congo Bore** - 91 litter traps & 20 scrapes at 40 holes **Highway** - 84 litter traps & 19 scrapes at 28 holes	**Warramboo, Highway & Tod Bore** - 128 litter traps & 8 scrapes at 33 holes	**Mesa B** - 196 litter traps & 36 scrapes at 50 holes **Mesa C** - 233 litter traps & 54 scrapes at 63 holes

[1] Only stygofauna sampling undertaken

[2] Mesas B, C, F, G, H, J and K, Warramboo, Tod Bore and Middles Robe

[3] Trickle irrigation systems and inflatable packers sampling sub-grades trialled during Phase VI

3.1.1 Survey effort and layout (Baseline studies)

The survey effort for troglofauna within each of the Mesas and Warramboo largely followed or exceeded the minimum requirements of the relevant EPA guidance (2016a, 2016b) for troglofauna. It is acknowledged that for highly prospective habitats, and/or heterogeneous habitats separated by geological discontinuities (such as appears to be the case for the Robe Valley Mesas), the EPA's recommended minimum sampling guidelines would be applicable for each discrete habitat unit (*i.e.* approximately 60 troglofauna samples recommended for each Mesa, and similar numbers outside each impact area) (EPA 2016b). This has largely been met by the sampling to date, although there has been much less sampling outside of the Mesa landforms (or at least outside of the highly prospective CID habitats), owing to the location of most of the drill holes within the Mesa landforms.

It is also acknowledged that recent studies and surveys conducted in highly prospective habitats throughout the region have found that the EPA minimum sampling guidelines for troglofauna (*i.e.* 60 samples) are largely inadequate for the detection of a high proportion (>80%) of the troglofauna species present. In many cases where sampling has far exceeded the EPA minimum guidance, species accumulation curves for troglofauna rarely reach an asymptote indicating that most species have been detected (Halse and Pearson 2014). However, assessing troglofauna sampling adequacy is complicated by the major constraints of A) only being able to sample where available boreholes are located, B) the unknown habitat heterogeneity influencing species richness results, C) the rarity, dispersal limitations, and the complexities in detecting troglofauna species, and D) limitations to taxonomic knowledge and difficulties identifying many troglofauna species.

Owing to these constraints, it is very difficult to objectively and scientifically assess the adequacy of sampling effort for troglofauna in any given survey, and traditional species accumulation approaches rarely show high confidence in the sampling effort. This appeared to be the case for the two troglofauna species accumulation reports conducted for Mesa A (Biota 2006c, 2007b), which showed that the sampling conducted at the time had collected only 63% of the predicted troglofauna species present, notwithstanding some scientific errors in the data handling and use of unsuitable species estimator models as discussed further below in section 3.2. Nevertheless, the flaws in the species accumulation reports (Biota 2006c, 2007b) for Mesa A have little bearing on sampling adequacy questions for Mesas B, C, and Warramboo, which are the focus of this review.

The Review did not find any major flaws, omissions, or issues with the overall survey effort, the duration of surveys, or the methods used within each impact area that would be expected to have a significant bearing on the survey findings or the assessment of troglofauna for the current proposal.

Nevertheless, there were potential issues with the sampling effort during some of the surveys and potential sampling artefacts which may have had a moderate impact on the troglofauna findings, as well as a series of assumptions about habitat suitability and potential species

distributions (or subterranean status) made during the baseline surveys that may have had a greater impact upon the assessment of troglofauna species. Sections 3.1.2 and 3.1.3 below deal with issues surrounding habitat suitability and species distributions/ ecological status in more detail.

3.1.1A) MODERATE ISSUES

The following sampling issues are regarded as moderate issues for the troglofauna assessment:

1. Most of the sampling has focused on the Mesa landforms and highly prospective CID habitats, with very little sampling in medium or low prospectivity habitats (except at Congo Bore to the south of Highway/ Tod Bore).
2. The lack of a well-defined impact area vs reference area (MEZ and lower prospectivity habitats) at time of sampling has meant that most of the samples have been taken from inside impact areas, and there is little ability to compare the MEZ vs pit assemblages based on baseline data.
3. There is currently no overall assessment of the amount of sampling in impact areas vs reference areas for the whole proposal area, nor is there an assessment of overall numbers of samples taken from habitats of various geological habitat types or prospectivity categories, which would be useful for explanation/ justification of the habitat assessment and likelihood of troglofauna species occurring in the MEZ.

Owing to the issues described above, it is difficult to exclude the possibility that sampling artefacts may have had an influence on the assessment of species distributions/ SRE status/ subterranean status, assessment of habitat suitability categories, and inferred habitat extent and connectivity, without adequate testing of relevant hypotheses.

3.1.1A) STRATEGY

An overall assessment of sampling throughout the proposal area should be undertaken to identify the occurrence of any potential sampling gaps or artefacts (*e.g.* sampling discrepancies between impact areas vs reference areas, between areas of different habitat prospectivity, or geological formation) such that known sampling artefacts can be taken into consideration when inferring species potential habitat extent or potential occurrence.

3.1.2 Habitat assessment (Baseline studies)

Habitat assessment for troglofauna within the baseline studies (Biota 2017a, 2017b) mainly comprised broad generalisations and inferences based on 1:250,000 surface geology maps (to indicate aerial extent of CID habitats), combined with geological cross sections in key areas, and 'confirmation' of inferred habitat prospectivity by troglofauna sampling.

3.1.2A) MODERATE ISSUE

Habitat assessment categorisation within the baseline studies (*i.e.* habitats assessed as high, medium or low inferred prospectivity, with 'confirmed' prospectivity in areas sampled) is oversimplified and the inclusion of sampling data to 'confirm' the inferred habitat categories is

illogically applied. For example, the south-east corner of the Warramboo Study Area (Figure 6.1, Biota 2017a) (also known as Congo Bore, sampled by Bennelongia 2011) was regarded as 'confirmed low' prospectivity, despite collection of multiple troglofauna species (Figure 5.7 in Biota 2017a). The assemblage collected at this location contained a diverse suite of taxa typically regarded as confirmed or potential troglobites, indicating at least a moderately to highly suitable habitat for troglofauna.

The habitat assessment categorisation in the baseline reports thus contains a logical flaw: if a habitat is known to support a diverse assemblage of troglofauna species, it cannot be considered 'low' prospectivity, particularly not 'confirmed low' prospectivity. Such a category should only be used for habitat that has been shown to support no troglofauna or at least a relatively depauperate assemblage. In addition, the diverse troglofauna assemblage collected at Congo Bore (Bennelongia 2011) was highly dissimilar in species composition to that found in the ‘confirmed high prospectivity’ habitat at Warramboo/ Highway/ Tod Bore, suggesting that the assemblages may have evolved independently, rather than the former only comprising a less-significant part of the latter (as may be expected in the case of a ‘primary’ habitat and a smaller, satellite ‘secondary’ habitat).

3.1.2A) STRATEGY

Detailed geological/ geomorphological habitat modelling has recently been undertaken as part of the Environmental Review Document (ERD), based on all available habitat data, drill cores, drill logs, and detailed geological habitat modelling (RTIO 2018). This more detailed habitat assessment supersedes Biota’s (2017a, 2017b) habitat assessment and prospectivity categorisation, with the flow-on effect that some of the assumptions used to assess species’ ecological statuses in these reports are also superseded (refer section 3.1.3).

In areas of the proposal area not covered by this detailed habitat modelling (other than the Mesas), habitat assessment categories from baseline survey reports should be treated as preliminary and inconsistent with fauna information. Reassessment of habitat suitability in these areas, if required, should make use of more detailed surface geology, geological cross sections, bore logs and drill cores where available.

RTIO has advised that the detailed habitat modelling (RTIO 2018) has been used to re-interpret all potential distributions of troglofauna species for the ERD (F. Bell pers. comm. 2018). This approach appears more suitable, although a precautionary or conservative approach is recommended in areas where potential sampling gaps or artefacts may exist (as discussed in section 3.1.1) such as areas where drill holes are fewer and spaced more widely, as the modelling will be subject to inference over greater distances between data points (refer 3.1.2B below).

3.1.2B) MAJOR ISSUE

Highly prospective troglofauna habitat at Warramboo/ Highway/ Tod Bore is assumed to be well-connected and contiguous (based on baseline habitat assessment) beyond the indicative impact area to the south west (Figure 6.1, Biota 2017a, RTIO 2018). Nevertheless, sampling

data from the same inferred habitat further south-west of Warramboo (known as Dinner Camp Bore, sampled by Bennelongia 2011, shown in Figure 5.7 Biota 2017a) showed a completely different troglofauna assemblage, indicating potential habitat heterogeneity, a barrier to dispersal, or other reasons for species turnover. Biota (2017a) stated;

"*While inferred high-suitability habitat also extends southwest of the current survey area, collection results appear to differ between the survey area and previous collections south of the survey area... While there are no known faults or other structural features in the geology known to potentially isolate this south-western inferred portion of the study area, this finding may indicate a discontinuity in the habitat or change in extent of deeper and more complex subterranean habitats that may be utilised by more strongly obligate taxa"* (Biota 2017a).

If the Highway/ Tod Bore and Dinner Camp Bore CID areas were all part of the same, continuous, highly prospective habitat, the fauna data would be expected to show many troglofauna species in common. Notwithstanding potential sampling artefacts which may have influenced the current troglofauna data (as discussed in section 2.2.1), the occurrence of an entirely different assemblage of troglofauna species between Highway/ Tod Bore and Dinner Camp Bore suggests there may be reason to doubt the assessment of habitat connectivity. This brings into question the inference that troglofauna species found only at Highway/ Tod Bore are expected to occur outside of impact areas "*based on the occurrence of highly contiguous CID habitats to the south west"* (RTIO 2017a), as mentioned in section 2.2.

As stated above, more detailed geological/ geomorphological habitat modelling has recently been undertaken as part of the ERD (RTIO 2018). Although the habitat modelling provides significantly greater confidence regarding physical suitability and extent of prospective habitats, it does not fully account for the differences between troglofauna species assemblages in Highway/ Tod Bore impact area and Dinner Camp Bore to the south west.

3.1.2B) STRATEGY

The more detailed geological habitat modelling (RTIO 2018) should be used in preference to the habitat mapping in the baseline reports to assess habitat suitability and extent. Strategies 2.2.1B and 3.1.1A provide a framework for a more comprehensive combined assessment of fauna occurrence/ potential extent of habitat (including extent, suitability, and potential connectivity), which would assist in resolving this issue. Strategy 2.2.1A deals with additional data/ information that would be useful to address this issue directly.

3.1.2C) MODERATE ISSUE

Baseline habitat mapping in areas between and surrounding Mesas B and C does not appear to have been supported by the same degree of habitat data (*e.g.* drill logs or diamond cores, development of detailed cross sections/ modelling), and assessment of 'medium' and 'low' prospectivity habitats have not been validated by sampling. This may be largely due to the absence of suitable drill holes; nevertheless, it leaves inferences of 'medium' to 'low' prospectivity habitats in these areas untested. In relation to potential habitat connectivity between Mesas B and C, Biota (2017b) stated, "*Given the morphology of the mesas within the*

survey area and the wider Robe Valley, and the sampling bias to the geology of the mesa formation, the level of connectivity between the mesas and the surrounding colluvium and alluvium (medium inferred habitat suitability) is uncertain."

This uncertainty represents a knowledge gap that has implications for the understanding of species distribution patterns. As described further below (section 3.1.3), and as indicated from Table 3.2, the baseline survey reports (Biota 2017a, 2017b) relied heavily upon the assumption (developed from earlier survey results) that most obligate troglofauna species occur only within a single Mesa, or alternatively, that the Mesa habitats were fundamentally discontinuous. Consequently, many species that were found to occur in multiple Mesas were assumed to be 'likely troglophilic' or 'not potential SREs' (Table 3.2), without adequately testing hypotheses that there may be some level of habitat connectivity between mesas (or potential connectivity for some species).

Genetic testing conducted after the baseline studies for the ERD revealed potential gene flow (minimal genetic divergence within the mitochondrial gene COI) between populations of some troglofauna species in Mesa B and Mesa C (F. Bell pers. comm. 2018). This points to the possibility that some species may be able to inhabit or at least disperse via, intermediate 'low prospectivity' geologies between the mesas that have not been adequately sampled or assessed for troglofauna suitability to date.

3.1.2C) STRATEGY

Additional troglofauna sampling in the areas between and surrounding the mesas would be the most rigorous way to test assumptions about habitat connectivity or potential species barriers; however, this is contingent upon the availability of suitable drill holes, which have not been developed in these areas. If additional sampling is not an option, potential connectivity/ discontinuity could be assessed by wider, more detailed habitat assessment/ modelling (as suggested in Strategy 2.2.1B, and statistical comparisons between the mesa assemblages to assess similarity.

RTIO has advised that, leading in to the ERD, species likely distributions were reassessed based on the most up to date information (including genetic studies and detailed habitat assessment information); therefore, assessments made in the baseline reports regarding ecological/ subterranean status were superseded (F. Bell pers. comm. 2018).

3.1.3 Assessment of species distribution / SRE status (Baseline surveys)

As indicated above, assessment of habitat continuity/ discontinuity can greatly influence the assessment of a species' potential distribution (*i.e.* whether the species is considered likely to be restricted to certain geological habitats), and subterranean status (*i.e.* whether the species is considered obligate or non-obligate subterranean fauna). These issues are somewhat interlinked, as it may be reasonable in some cases to assume that species which can be found within more widely occurring habitats are less likely to be restricted in distribution, but it is very important in such cases to be clear about the facts vs the untested assumptions or inferences guiding the assessment. In either case, where there are clear standards, such as the SRE

distribution threshold of <10,000 km^2 (following Harvey 2002) or <1,000 km^2 (following Eberhard *et al.* 2009), assumptions about whether a species is more restricted at a local level (in respect to impact/ non-impact areas or to certain geological formations) should not be confused with categorisation under these accepted standards.

3.1.3A) MODERATE ISSUES

As detailed in section 3.1.2, there are considerable gaps in the understanding of habitat connectivity between Mesas that put into question the hypothesis that troglobitic species in the Robe Valley are usually confined to one Mesa. The Review found several inconsistencies and an over-reliance upon untested assumptions about habitat discontinuity in the assessment of troglofauna species potential distributions and SRE categorisations (as listed in Table 3.2).

Table 3.2: Species currently known to occur within more than one Mesa in areas relevant to the proposal, and their assessment in baseline survey reports

Species	Collection location	Species distribution assessment
Species assessed as 'widespread' (*i.e.* not SRE) despite ranges <10,000 km^2, due to occurrence in more than one mesa		
Armadillidae sp. 'ISA056/57'	Mesas C, H	Known range 28.4 km Troglophilic, widespread (Biota 2017b)
Carabidae sp.'CCA001/012'	Warramboo, Mesa B	Known range 12.8 km Troglophilic, widespread (Biota 2017a, 2017b)
Curculionidae sp.'CCU004/005'	Mesas A, B, C	Known range 27.9 km Troglophilic, widespread (Biota 2017a, 2017b)
Species assessed as Potential SRE despite occurrence in more than one mesa		
Hubbardiidae gen. nov. sp. 'SCH052'	Mesas B, C	Known range 3.2 km Potential SRE (Biota 2017b)
Paradraculoides bythius	Mesas B, C	Known range 4.4 km Confirmed SRE, Cons Sig Schedule 3. (Biota 2017b)
Oonopidae sp. 'Mesa B'	Mesas B, C	Range unspecified (nominally <5.5 km) Potential SRE (Biota 2017b)
Theriidae sp. 'AT001'	Mesas B, C	Range unspecified (nominally <5.5 km) Potential SRE (Biota 2017b)
Inconsistencies in species categorisation between reports		
Nicoletiinae sp. 'TN010'	Warramboo, Mesa B	Known range 11.1 km • Troglophilic/ widespread (Biota 2017a) • Potential SRE (Biota 2017b)
Tyrannochthonius basme	Warramboo, Mesa B	Known range 10.9 km • Potential SRE (Biota 2017a) • Troglophilic/ widespread (Biota 2017b)
Assumed sample contamination, despite known occurrence in more than one mesa		
Paradraculoides sp. 'SCH004/004a	Mesas A, L, M, N	Estimated range approx. 10-35 km Assumed contamination between Mesa A and eastern Mesas, but occurrence in Mesas L, M, N established (Biota 2017a)

Table 3.2 shows that the approach to species assessment for two species; Nicoletiinae sp. 'TN010' and *Tyrannochthonius basme* (both found at Warramboo and Mesa B), was inconsistent between Biota (2017a) and Biota (2017b).

An unexpected DNA result for *Paradraculoides* SCH004/004a (specimens from Mesa A aligning with specimens from Mesas L, M, and N in the eastern Robe Valley) was omitted from consideration due to putative contamination, *"…i.e. this specimen moved between the stored traps through an accidental tear in the zip-lock bags during transit*" (Biota 2017a). Notwithstanding other potential mechanisms for contamination that may have occurred in the lab, the report dismissed the DNA result owing to, "*the extreme short-range endemism prevalent within the Robe Valley troglobitic fauna communities*" (Biota 2017a). This line of reasoning failed to explore the possibilities of wider dispersal mechanisms, or sampling artefacts for this species, despite other taxa occurring across multiple mesas being classified as 'widespread' or 'troglophilic' in the same report.

It is true that subterranean schizomid species are regularly among the most restricted troglobitic taxa found in surveys throughout the region, but this should not preclude the possibility of more widely dispersed species within the group (as *Paradraculoides bythius* is known to occur at both Mesas B and C). By the same approach, occurrence within multiple mesas should not preclude taxa such as Armadillidae sp. 'ISA056/57', Carabidae sp.'CCA001/012', and Curculionidae sp.'CCU004/005' from being regarded troglobitic.

3.1.3A) STRATEGY

RTIO has advised that, leading in to the ERD, species likely distributions were reassessed based on the most up to date information (including genetic studies and detailed habitat assessment information); therefore, baseline assessments of species ecological status and potential distribution have been superseded (F. Bell pers. comm. 2018).

Allocating Potential SRE status to a species should not be confused with identifying which species are considered even more restricted within the nominal SRE threshold, *i.e.* those restricted to single mesas or narrowly defined geological/ hydrogeological habitats. Similarly, finding a species to be trogloxenic/ troglophilic (*i.e.* not obligate subterranean fauna) does not provide evidence that it occurs widely; if this was the case, there would be no terrestrial SRE species. The SRE status, ecological status and known distribution of each species should be assessed independently, based on available fauna and habitat information, taxonomic and ecological knowledge, and regional precedents from taxa in the same (lowest possible) taxonomic group.

The Review recommends that all troglofauna species with a known linear range <100 km be considered Potential SREs, unless there is a compelling scientific reason why this should not be the case. Given the number of taxa occurring in more than one mesa and the previously stated knowledge gaps regarding habitat connectivity between mesas, occurrence within more than one mesa should not influence distribution or ecological status. Therefore, all species listed in Table 3.2 should be considered troglobitic Potential SREs (Confirmed SRE in the case of *Paradraculoides bythius*). Based on regional data, there is some precedent that the beetles

(*i.e.* Carabidae, Curculionidae) may be troglophilic Potential SREs, but this would need to be assessed on a case by case basis.

3.2 Species Accumulation

To assess adequacy of sampling at Mesa A, two species accumulation reports were completed:

- Biota (2006c) Species Accumulation and Troglobitic Fauna Sampling Adequacy at Mesa A (RTIO-HSE-0063892); and
- Biota (2007b) Mesa A Troglobitic Fauna Species Accumulation Update.

Biota (2006c) provides a discussion of sampling adequacy in respect to Phase I to IV of sampling completed to date for the ongoing troglofauna programme at Mesa A. Predicted total troglobitic species richness was calculated using EstimateS, which generates output utilising several different species richness estimators, that were chosen due to their suitability to work with smaller sample sizes (Biota 2006c).

3.2A) MODERATE ISSUE

Although only 11 troglobitic taxa were recorded from Mesa A (Biota 2006c), a 'precautionary approach' was taken whereby undetermined specimens within the same genus were treated as if they represented an additional, different species. This approach was not supported by sufficient scientific justification and had the effect of artificially increasing the total number of putative species to 14. Biota (2007b) provided an update to the earlier report (Biota 2006c), using the same precautionary approach to deal with unidentifiable specimens.

Species estimation and rarefaction models work by assessing the sampling effort against the rate of species detected; therefore, as a rule, all attempts should be made to only use data that is consistent in terms of what is regarded as a 'species', and a 'sample'. Treating unidentifiable specimens (usually damaged, juvenile, or female specimens of various taxa) as additional species has the potential to skew results. In contrast, a parsimonious approach would omit data on unidentifiable specimens and focus only on species that have been positively identified as such.

3.2A) STRATEGY

A new, revised species accumulation assessment (based on overall/ cumulative RTIO data used for the ERD) is required to resolve uncertainties in the adequacy of sampling for troglofauna in areas of relevance to the current proposal. A reassessment of the data should use a parsimonious approach to uncertain species identifications or indeterminate taxa (*i.e.* exclude them from analysis), more clearly define what is considered 'one sample' (*e.g.* one scrape, one trap, or any combination thereof), and more clearly detail the data handling process (including presence or abundance data, number of runs/ repetitions, upper abundance limits for rare taxa, whether extrapolation was used, and a scientific justification for the species estimators used). Separate analyses (reported in the same report) could also be used to investigate capture rates/ fauna occurrence across different mesas or sampling areas (*e.g.* in pit and in MEZ), or via different sampling methods, to provide additional information that would

be useful for developing an optimum sampling plan for compliance monitoring of species and assemblages.

3.2B) MODERATE ISSUE

The application of certain species estimator models in EstimateS is particular to the type of data used in the analysis; with ACE and Chao1 applicable to species abundance vs samples data, and ICE and Chao 2 applicable to species incidence (presence/ absence) vs samples data. Neither species accumulation report provided a sufficient account of the data handling to enable assessment of whether the correct species estimator was applied to the correct data. Biota (2007b) used both ICE and ACE on the same data, suggesting that one or the other estimator would have been incorrectly used. Calculating the mean value of all species estimations as a 'best estimate' is logically flawed, as these results are already mean values from each model, with their own confidence intervals and standard deviations as reported through EstimateS: therefore, the creation of a mean from a set of a means is statistically invalid as it drastically increases the error of the result.

3.2B) STRATEGY

As recommended above, undertake a new, revised species accumulation assessment (based on overall RTIO data used in the ERD) that provides a more detailed account of data handling based on the recommendations of the EstimateS user guide and knowledge of the limitations and constraints of the statistical methods used, and a clearer justification for the richness models used.

3.3 Species Taxonomy

Troglofauna specimens were identified to the lowest level possible based on the taxonomic expertise available at the time of each survey; however, this varied between surveys over time, which inevitably causes some issues for comparability of results. The proportion of species-level taxa identified within the earlier surveys (*i.e.* Biota 2004, 2006a, 2006b, 2007a, 2007b) was vastly improved upon within later surveys (Biota 2017a, 2017b), and attempts were later made to align previous species nomenclature into a single, unified species nomenclature framework (Bennelongia 2015a, 2015b).

3.3A) MODERATE ISSUE

It is understandable that the number and diversity of groups considered to be troglofauna evolves over time, as does species nomenclature and taxonomic rigour; therefore, it is often difficult to reconcile results from previous studies with current survey results. An overall reassessment based on current taxonomic and ecological knowledge may help to clear up any species nomenclature and subterranean/ SRE status legacy issues.

3.3A) STRATEGY

RTIO has advised all species identifications and subterranean/ SRE statuses have been updated for the ERD based on cumulative/ overall assessment of species data, superseding previous baseline assessments (F. Bell, C. O'Neill RTIO pers. comm. 2018).

3.4 Taxonomic literature

Two published taxonomic articles and two species alignment reports that are relevant to the species known from the Mesa A Hub area were reviewed:

- Harvey and Edwards (2007) A review of the pseudoscorpion genus *Ideoblothrus* (Pseudoscorpiones, Syarinidae) from western and northern Australia;
- Harvey et. al. (2008) Molecular and morphological systematics of hypogean schizomids (Schizomida: Hubbardiidae) in semi-arid Australia;
- Bennelongia (2015a) Mesa A and Warramboo Troglofauna Alignment; and
- Bennelongia (2015b) Alignment of Troglofauna – *Ideoblothrus* sp. 'Mesa A2'.

3.4A) NO ISSUES

The Review did not find any major flaws, omissions, or issues within these taxonomic reports / articles that have any significant bearing on the survey findings or assessment of troglofauna for the current proposal.

4. REVIEW OF TROGLOFAUNA COMPLIANCE MONITORING

Following the approval of Mesa A in 2007, compliance monitoring was undertaken to satisfy Condition 5 and Condition 6 under MS 756. Condition 5 relates to a troglobitic fauna monitoring program and Condition 6 relates to the retention of troglofauna habitat under the pit floor after mining.

A Troglofauna Management Plan (TMP) was prepared by Biota (Biota 2009) with the intent of meeting MS 756 Condition 5 and Condition 6 (as well as Conditions 8 and 9); which aim to assess the response of troglofauna species and populations to the direct and indirect impacts of mining. In accordance with the approved TMP, sampling must take place once every two years (biennially). A selection of approximately 20 drill holes covering the spatial extent of the MEZ are to be sampled, and sampling of the subgrade habitats of the mesa below the mine at a selected monitoring site. The sampling is to be carried out via methods consistent with the baseline surveys (Biota 2017a, 2017b) and relevant EPA Guidance Statements (EPA 2016). Biota (2009) states that the objectives of the monitoring program are to:

- *"accumulate additional troglobitic species and add to the known troglofauna of the mesa;*
- *allow additional genetic and morphological identifications to be completed; and*
- *provide indicator data on the continued presence of troglofauna in sampling locations across the retained portions of Mesa A."*

The monitoring program is required to sample troglobitic fauna species and populations; and key habitat parameters (*i.e.* subterranean humidity and temperature). The monitoring shall provide for studies on the impacts of blasting and mining on the integrity of the troglobitic fauna habitat; and the effectiveness of re-creating troglobitic fauna habitat through such measures as replacement of waste rock. The proponent is required to report the findings of the monitoring program to the CEO, including an assessment of the risk to the survival of remaining populations of troglobitic fauna.

4.1 Troglofauna Monitoring

Following Condition 5 of MS 756 and the TMP, there are four troglofauna compliance reports for the Mesa A Operation:

- Biota (2011) Mesa A Troglofauna Compliance Report 2010 (RTIO-HSE-0110556);
- Biota (2012) Mesa A Troglobitic Fauna Compliance Monitoring 2012 (RTIO-HSE-0165609);
- MWH (2014) Mesa A Troglofauna Biennial Compliance Monitoring: 2014 (RTIO-HSE-0249208); and
- Bennelongia (2017a) Mesa A and Mesa B Annual Compliance Troglofauna Survey 2016 (RTIO-HSE-0306777).

These troglofauna compliance reports have been reviewed and are summarised in Table 3.1, along with key findings for each monitoring round.

Table 4.1: Summary and Key Findings of the Troglofauna Compliance Monitoring.

Consultant (Year)	Biota (2011)	Biota (2012)	MWH (2014)	Bennelongia (2017a)
Report Title	Mesa A Troglofauna Compliance Report 2010	Mesa A Troglobitic Fauna Compliance Monitoring 2012	Mesa A Troglofauna Biennial Compliance Monitoring: 2014	Mesa A and Mesa B Annual Compliance Troglofauna Survey 2016
Monitoring Dates	Trap Installation 25-29 July 2010 Retrieval 4-8 October 2010	Trap Installation 23-24 May 2012 Retrieval 19-20 July 2012	Scrapes and Trap installation 25-30 June 2014 Retrieval 3-5 September 2014	Scrapes and Trap installation 9 July - 18 Sept 2016 Retrieval 5-7 September 2016
Sampling Effort	**Mesa A MEZ and sub-grade zone** - 117 litter traps at 41 holes	**Mesa A MEZ and sub-grade zone** - 105 litter traps at 36 holes **Mesa B** - 30 litter traps at 10 holes	**Mesa A (focus on MEZ)** - 132 litter traps & 40 scrapes at 41 holes **Mesa B** - 26 litter traps & 10 scrapes at 10 holes	**Mesa A (focus on MEZ)** - 44 litter traps & 37 scrapes at 39 holes **Mesa B** - 6 litter traps & 5 scrapes at 6 holes
Key Findings	7 orders of troglofauna. 29 specimens/ individuals from 14 drill holes 8 species (2 identified to species level).	7 orders of troglofauna. 153 specimens recorded from 32 drill holes. 126 specimens from 25 holes at Mesa A. 27 specimens from 7 holes at Mesa B. 12 species (3 identified to species level) from Mess A. 9 species (4 identified to species level) from Mesa B.	8 orders of troglofauna. 71 specimens from 28 holes at Mesa A. 62 specimens from 7 holes at Mesa B. 11 species from Mesa A. 9 species from Mesa B. Recommendation that survey effort be reduced following introduction of scraping methods.	7 orders of troglofauna. 43 specimens from Mesa A. 11 specimens at Mesa B. 10 species from Mesa A. 3 species at Mesa B. Recommendation that survey effort be restored to previous size and extent but retaining scraping and trapping methods.

4.1.1 Taxonomy and data comparability

4.1.1A) MAJOR ISSUES

Most of the specimens collected during the earlier rounds of compliance monitoring were not identified to species level. The resulting conclusions regarding the persistence of species or assemblages during mining are therefore unable to be verified by the available data. Additionally, results from each round of monitoring were not consistently compared to previous monitoring rounds or to baseline results. In the instances where comparisons were made, it was based on presence/absence of taxonomic orders only; therefore, the current monitoring lacks a comprehensive assessment of whether key species or assemblages have persisted within the MEZ to date.

Some of the untested assumptions made during the baseline surveys regarding the ecological status of certain taxa, species distribution patterns, and habitat connectivity appear to have carried over into the compliance monitoring reports (Biota 2011, MWH 2014a). Some of these assumptions have been found to be incorrect or poorly supported by later findings; for example, based on information available at the time, Mesa A was assumed to contain only one species of schizomid (*Paradraculoides anachoretus*), thus multiple rounds of compliance monitoring did not attempt to identify schizomid specimens to species level. A second species of schizomid was subsequently detected at Mesa A in 2017 (Biota 2017c, refer section 4.2), casting doubt as to the identification of previous specimens detected during monitoring. This situation, although somewhat understandable based on knowledge at the time, provides a case in point that even long-standing hypotheses can be disproven by new evidence, therefore assumptions must always be treated as such.

Many of the current compliance monitoring reports lack the analysis required to indicate whether and to what extent troglofauna assemblages at Mesa A have been affected by mining. This is due to the lack of species level identifications for some groups and the coarse level (taxonomic order level) of comparisons with previous data. Additional analyses are required to assess the effectiveness of the MEZ as a strategy for conserving troglofauna species. Additional comparative analyses will be constrained by deterioration of genetic material over time, and further identifications or comparisons may only be possible for some groups based on current taxonomic expertise, specimen condition, and adequacy of preservation methods.

4.1.1A) STRATEGY

All future compliance monitoring shall identify all specimens to species level (using morphological and genetic taxonomy where necessary) and undertake comparisons with the full suite of specimens and data from previous baseline sampling and monitoring. This may require consultants to share information/ specimens, and/ or seek third-party specialist assistance with identifications and species alignments. Nevertheless, this should be an essential part of the scope for any compliance monitoring project. The Mesa A TMP and any future TMPs for other projects should be amended to reflect this requirement.

Genetic analysis should be undertaken to verify and align specimen identification from baseline surveying and monitoring, to allow more detailed comparisons to be made. RTIO should maintain (or require that a third party such as the WAM maintains) a reference collection of both specimens and genetic data that consultants are obliged to compare new material against every time monitoring is conducted. A consistent, unified morphospecies nomenclature standard (such as that used at the WAM) should be used to avoid confusion between reports. It is recommended that cosmopolitan/ surface species should be excluded from analysis to focus the monitoring on species of importance to the troglofauna assemblage in question.

Existing data from compliance monitoring should be re-analysed (and where available, specimens subject to additional taxonomic alignments or genetic analyses where possible) to facilitate pre- and post-mining species assemblage comparisons. Despite the limitations of previous data, it is essential that a comprehensive investigation is made into the effectiveness of the MEZ as a strategy for conserving restricted troglofauna species and assemblages.

4.1.2 Sampling Effort

4.1.2A) MODERATE ISSUE

MWH (2014) recommended a reduction of the sampling effort (numbers of holes, numbers of samples) for the compliance monitoring, due mainly to the inclusion of scraping methodologies in the sampling plan. This recommendation however was not based on substantive analysis of data, and the Review finds that there appeared to be little evidence at the time supporting this recommendation. The reduced sampling effort suggested by MWH resulted in reduced capture rates of troglofauna, with the subsequent compliance monitoring report stating, *"sampling effort in 2016 was too low to ensure the detection of the majority of the troglofauna assemblage known from Mesa A and Mesa B*" (Bennelongia 2017a). Bennelongia (2017a) reinstated the previous sampling intensity and retained scraping methodologies as an additional method.

Overall, the compliance monitoring program has yet to adequately assess or discuss the significance of species' absences from the monitoring data; neither has any of the existing reports attempted any analysis of potential changes to assemblage composition, diversity, evenness, capture rates, or any other statistical analyses to facilitate more meaningful comparisons with the baseline data or concurrent data between sampling areas.

4.1.2A) STRATEGIES

For reasons of data comparability and consistency, the sampling effort of future compliance monitoring should remain relatively unchanged between monitoring rounds (*i.e.* numbers of sampling, methods, time of year, duration of trapping, and location of holes sampled). It is recommended that a standard sampling effort, survey holes, and survey period be detailed in the TMP to ensure consistency. Future compliance monitoring programs should be designed from the outset with statistical analyses in mind and a clearer plan for how the data collected and the analyses employed will allow key hypotheses regarding fauna occurrence or persistence to be tested.

Wherever possible, consideration should be given to the development of relevant thresholds/ indicators for detecting change within the troglofauna assemblages. This necessitates a better understanding of the natural variability within the assemblages over time, and planning for a compliance monitoring program that aims to collect enough information, and the right kinds of information, to provide greater confidence in measuring the impacts (or lack of impact) of mining on key species or the assemblage as a whole.

Most of the compliance sampling should focus on the remnant MEZ habitat itself, although other contiguous and well-connected potential habitats of 'medium or high' prospectivity may be sampled if likely to support the same assemblage. In the case that non-contiguous habitats (such as Mesa B in the case above) are to be included as reference areas or to test related hypotheses, this should be reflected in the objectives, analyses and discussion of results.

4.2 Targeted In-pit Sampling

In response to Condition 6 of MS 756, targeted sampling was conducted within pit boundaries. Biologic reviewed two survey reports for targeted in-pit sampling:

- Bennelongia (2017b) Pit Floor Troglofauna Sampling at Mesa A 2016, memorandum prepared for Rio Tinto Iron Ore; and
- Biota (2017c) Mesas A and K Targeted Troglofauna Survey, report prepared for Rio Tinto Iron Ore.

To investigate whether troglofauna communities persist beneath the pit floors, Bennelongia (2017b) conducted trap sampling of eight bores within pit boundaries at Mesa A.

This sampling recorded a single schizomid of the genus *Paradraculoides*. The specimen was juvenile and could not be identified further, however Bennelongia (2017) considered it likely to belong to *P. anachoretus*, based on its collection from Mesa A, where this was the only known schizomid species at the time. This assumption was found to be demonstrably invalid, as subsequent DNA analysis revealed that the specimen belonged to a new species, *P.* sp. 'SCH034' (divergence of 5.6-6.3% COI) (Biota 2017c). Nevertheless, this record represented the first collection of troglofauna from beneath the pit floor at Mesa A.

Additional sampling was undertaken by Biota (2017c) to investigate the occurrence of troglofauna beneath the pit floors, and to investigate whether troglofauna persist beneath (or have become established within) waste dumps at Mesa A and Mesa K. No specimens were recorded from beneath pit areas at Mesa K during the sampling reported in Biota (2017c), although separate compliance monitoring studies recorded schizomids, isopods, curculionid beetles, and hemipterans at a formerly mined, rehabilitated pit at the same mesa (Biota 2012b, Outback Ecology 2013, MWH 2014b, Bennelongia 2015c). Two schizomids were recorded from beneath waste dumps at Mesa A; *P. anachoretus,* and the new species, *P.* sp. 'SCH034' although some uncertainties remained about the source habitat of these records, as the waste dump drill holes were found to extend beyond the waste dumps into habitats beneath the pit floor (Biota 2017c).

4.2A) MODERATE ISSUE

The results of these surveys were constrained by the limited number of holes available for sampling in the pit floor, the extension of holes developed in the waste dumps beneath the pit floor, and the assumptions regarding schizomid species occurring at Mesa A. As a result, there is still some uncertainty about whether the Mesa A troglofauna assemblage can persist beneath waste dumps and/ or the pit floor, but there is at least evidence that schizomid species can occur in these habitats. As the current proposal does not plan to retain troglofauna habitat beneath the pit floor at Mesa B (which is formed in basal pisolite, considered low prospectivity for troglofauna), and the proposed mining at Mesa C and Warramboo extends below water table, these findings are only relevant to the proposed waste dumps, which are mainly located on 'medium' to 'low' prospectivity geologies surrounding the Mesas.

4.2A) STRATEGY

Further sampling is required to confirm the persistence of the remainder of the Mesa A troglofauna assemblage beneath the pit floor and/or waste dumps at Mesa A. Nevertheless, these habitats are not likely to form a major refugial habitat for troglofauna in areas relevant to the current proposal; therefore, this work does not appear to be essential to the current proposal.

4.3 Troglofauna habitat monitoring: downhole optics

In accordance with the TMP, RTIO commissioned downhole optical imagery to investigate detectable changes in the physical structure of boreholes used to monitor troglofauna habitat at Mesa A and Mesa K, as well as control sites at Mesa B.

The TMP states that:

"Down-hole video logging of bores will also be carried out on an annual basis to provide more direct assessments of bores known to contain subterranean fauna. This would include:

- *qualitative assessment of vertical extent and type of fracturing and cavities;*
- *presence of fauna (identification to order level); and*
- *relative abundance quantification (based on nominal order level identifications)".*

Pilbara Wireline Services (2014) regarded detectable changes as those where there was a significant change in the size, occurrence or position of any voids, fractures or washouts. Of the 35 holes surveyed, six showed evidence of erosion or hole collapse. It was concluded that all the detectable changes were most likely associated with weathering and appear to be within normal variations (Pilbara Wireline Services 2014).

4.3A) MODERATE ISSUE

Comparisons of downhole optical imagery were undertaken visually, without a scientifically valid assessment framework, and are therefore highly subjective. There were also some differences noted in image quality that further complicated the visual assessment. The aim of the borehole structure assessment was to undertake a "qualitative assessment of vertical extent

and type of fracturing and cavities" (TMP, Biota 2009); however, the assessment framework was very loosely defined, and nothing conclusive or relevant to the quality of troglofauna habitat was able to be determined from the results.

4.3A) STRATEGY

Until a robust qualitative or quantitative framework for down-hole visual assessment of troglofauna habitat can be established and scientifically justified, this type of assessment may continue to be subjective and lack relevance for compliance monitoring. If this continues to be the case over time, it is suggested that more robust and scientifically justifiable methods for habitat monitoring should be investigated in preference to down hole optical imagery, particularly where the results can be more directly related to the faunal results.

4.4 Troglofauna habitat monitoring: Humidity and Temperature

Condition 5-2 of MS 756 and the TMP require periodic sampling of key habitat parameters, including humidity within the underground spaces which form the habitat of the troglobitic fauna.

Downhole temperature and relative humidity has been collected at uncased drill holes at Mesas A, B and K since 2009. Astron Environmental Services (Astron) was commissioned to undertake statistical analysis of this data with the aim to test for impacts of mining at Mesa A on downhole temperature and relative humidity (Astron 2017).

The data was subject to several limitations regarding the sensitivity of the probes and the need to change probes out over the course of sampling, which introduced error into the data set. Due to issues with temperature and humidity probe function, only data collected post 2013 could be analysed. These issues resulted in the exclusion from analysis of any pre-mining data at Mesa A (as mining commenced in February 2010), meaning potential impacts from mining were not able to be tested. The analysis therefore focused on "distance from mine pit" at Mesa A and "site type", with Mesa B and Mesa K sites used as controls.

Astron (2017) found that the mean subterranean temperature and humidity did not vary with proximity to the Mesa A mine pit, or with probe depth. With increased proximity to the Mesa A pit edge, variation in temperature did not change significantly, however the variation in relative humidity did significantly increase with proximity to the mine pit. The variability in humidity was within the bounds of measurement error when the probes are used at in atmospheres approaching 100% humidity (±5%) (Astron 2017). The analysis also suggested that the subterranean temperature and humidity at Mesa A had not changed significantly since January 2014, in areas either close, medium or far from the mine pit; therefore, it was concluded that current mining at Mesa A has had little discernible effect on the subterranean climate of the MEZ (Astron 2017).

4.4A) MODERATE ISSUE

The ability to compare the current temperature and humidity monitoring at Mesa A MEZ with baseline conditions is complicated by the lack of adequate baseline data and issues with the probes used to detect changes in the subterranean atmosphere.

Statistical comparisons of the humidity and temperature data with pre- and post-mining impacts at Mesa A was not able to be completed due to “issues with the probe function” resulting in pre-2013 data unable to be used. Data from mobile sites (the only ones measuring the sub-pit floor habitat) were removed from the analysis; therefore, the analyses were relevant only to the MEZ.

4.4A) STRATEGY

All efforts must be made to ensure that this situation is not repeated at Mesas B, C and Warramboo; therefore, a statistically valid troglofauna habitat monitoring program should be set up without delay to ensure adequate baseline data over the full range of seasons at each of the proposed new mining areas.

Once pre-mining information is available from Mesas B, C and Warramboo, there may be some potential to compare the results from the Mesa A MEZ with the baseline data from the other similar habitats in lieu of an adequate baseline from Mesa A. Standardised methods and a statistically valid sampling effort must be used for recording humidity and temperature data throughout all areas of monitoring (baseline Mesas and current and proposed MEZ areas), and wherever possible, the results should be analysed in conjunction with fauna sampling results to attempt to detect changes that may be indicative of impacts from mining.

5. REVIEW OF STYGOFAUNA SURVEYS AND ASSESSMENT

5.1 Baseline Sampling

Stygofauna sampling was first undertaken at Mesa A in 2003 as part of environmental surveys for exploration investigations (survey is reported in Biota 2004). No stygofauna were collected from the boreholes sampled.

A borefield was required to supply water for the proposed mining operations at Mesa A and Warramboo. The proposed location for this was on Yarraloola Station on the eastern side of the Robe River. Consideration was also given to the alternative of sourcing water from the Warramboo area. Stygofauna sampling of these areas was therefore undertaken by Biota in 2005 (Biota 2006d). The supply borefield comprises eight production bores located along the perimeter of the Warramboo mine pit.

Stygofauna sampling was also carried out by Biota at Warramboo and Mesa C, and the surrounding area, in 2015 to 2017 (Biota 2017d). This sampling was to support assessment of impacts to stygofauna from proposed below water table mining at the Warramboo and Mesa C deposits.

As detailed above, the following stygofauna surveys have been undertaken in with the vicinity of the Mesa A Hub Proposal area:

- Biota (2004) Mesa A and Bungaroo Creek Exploration Areas Subterranean Fauna Survey;
- Biota (2006d) Mesa A/ Warramboo and Yarraloola Borefield Development Baseline Stygofauna Assessment; and
- Biota (2017d) Mesa A Hub: Warramboo and Mesa C Stygofauna Assessment.

These stygofauna reports have been reviewed and are summarised in Table 5.1.

Notwithstanding potential duplication of holes sampled (Biota 2006d, 2017d), total sampling at Warramboo could be regarded as a maximum of 48 holes, and 23 holes at Mesa C. It is difficult to compare the two reports in terms of locations of sampling relative to potential drawdown zones (owing to limitations of the mapping), although the intensity of sampling was clearly greater in the latter survey, due to conducting five hauls in place of three at each hole, and sampling over repeated phases (Biota 2017d) rather than a single phase (Biota 2006d).

Table 5.1: Summary of Stygofauna sampling.

Consultant (Year)	Biota (2004)	Biota (2006d)	Biota (2017d)
Report Title	Mesa A and Bungaroo Creek Exploration Areas Subterranean Fauna Survey	Mesa A/ Warramboo and Yarraloola Borefield Development Baseline Stygofauna Assessment	Mesa A Hub: Warramboo and Mesa C Stygofauna Assessment
Report Type	Subterranean fauna survey	Stygofauna survey and impact assessment	Stygofauna survey and impact assessment
Survey Dates	Dec 2003	Oct 2005	Apr, Jun, Sep/Oct 2015, Dec 2016 & Mar 2017
Sampling Effort	**Mesa A** - stygofauna hauls at 14 holes **Bungaroo Creek** - stygofauna hauls at 23 holes	**Warramboo** - stygofauna hauls at 23 holes **Yarraloola** - stygofauna hauls at 30 holes	**Warramboo** - stygofauna hauls at 25 holes (18 within the drawdown) **Mesa C** - stygofauna hauls at 23 holes (13 within the drawdown)

Biota (2006d) reported that there are few taxa that are currently only known from the predicted drawdown zone for Yarraloola borefield, comprising:

- Amphipoda: Melitidae sp. A (predicted 0.5m - 0.3m drawdown);
- Amphipoda: Melitidae sp. F (predicted 0.5m drawdown); and
- Ostracoda: indeterminate (predicted 0.5m drawdown) (Biota 2006d).

The assessment at Warramboo and Mesa C reported that there are four stygofauna species currently known only from the predicted drawdown at Warramboo (three recorded during Biota 2017d sampling and one record from the desktop review):

- Bathynellacea: *Atopobathynella* sp. 'B25';
- Ostracoda: *Cypretta* sp. '4';
- Amphipoda: *Nedsia* sp. 'AMM003'; and
- Amphipoda: *Nedsia* sp. 'AMM005' (Biota 2017d).

Two amphipod species recorded from the predicted Mesa C drawdown (*Nedsia* sp. 'AMM004' and *Nedsia* sp. 'AMM031') were previously known from elsewhere in the surrounding area (Biota 2017d).

In addition to the above, the Pilbara Biological Survey carried out some previous stygofauna sampling within the areas surrounding Warramboo and Mesa C. Results from relevant sites sampled during this survey were incorporated into the results of the Biota 2017d assessment and have thus been reviewed herein.

5.1A) MODERATE ISSUES

Relative to the location and extent of predicted drawdown at Warramboo, the layout of stygofauna sampling was uneven, with sites concentrated in the eastern and southern parts of the predicted drawdown, leaving some significant knowledge gaps in the north and western extent. In relation to coverage of potential habitat units, some sampling was conducted in all potential habitat units as mapped in Biota (2017d) (within limitations and assumptions addressed below in section 5.2), although most sampling occurred in highly prospective CID habitats, and the sampling of medium (Yarraloola conglomerate) and low prospectivity habitats within the drawdown areas appeared less intensive or limited to certain areas.

This is somewhat expected given the constraint of sampling only available bores and holes; however, it may also have attributed to potential artefacts in the spatial layout of sampling (relative to drawdown areas or potential habitat units). This limitation was not fully considered in the discussion or analysis of results.

5.1A) STRATEGY

A more detailed discussion and analysis of all results to date would characterise and assess the potential effects of uneven sampling layout on fauna results and interpretations of species distributions. More in-depth analysis or cross-comparisons of sampling effort, faunal results and habitat assessment information could be used to assess whether the stygofauna assemblages

within and outside of drawdown areas are similar or dissimilar, and potential reasons explaining these results (*e.g.* sampling artefacts, habitat discontinuity, species turnover etc).

5.2 Habitat Assessment

Biota (2017d) suggested highly prospective groundwater habitats occur at Warramboo and Mesa C within Robe Pisolite (CID), while the alluvial aquifer adjacent Mesa C was considered a secondary highly prospective habitat (*i.e.* predominantly disconnected from the CID), and the Yarraloola conglomerate surrounding Warramboo was regarded as a moderately prospective, deep groundwater habitat. Aquitard/ aquiclude layers such as the Ashburton Formation surrounding/ beneath Mesa C were regarded as low prospectivity habitat (due to a lack of porosity) or potential barriers to stygofauna occurrence. Although the Biota (2017d) report cited hydrogeological modelling and hydrogeochemical information underlying this habitat assessment, there was little detail provided to corroborate or better illustrate the findings, and particularly the habitat mapping appears overly simplistic and lacking in useful detail, as well as comparison to faunal results.

5.2A) MODERATE ISSUE

The characterisation and mapping of potential stygofauna habitat in the baseline reports is oversimplified and lacks validation by assemblage comparisons to inform assessment of habitat connectivity. The simplicity of the broad scale habitat prospectivity mapping belies the known local stygofauna diversity and differences between assemblages sampled in ostensibly well-connected habitats. For example, assuming the prospective groundwater habitats are relatively broad and continuous (as mapped) between the Robe River alluvium, the Yarraloola conglomerate, and the Warramboo CID, the Biota (2017d) report lacks any explanation for why only 4 species out of a total 55 were shared between the Warramboo drawdown area and the wider 10 km buffer area. This broad, generalised mapping of habitat prospectivity also seems at odds with the shape and extent of groundwater drawdown in the Warramboo area, which does not appear to align in a logical way to the extent of permeable habitat within the CID and Yarraloola conglomerate.

5.2A) STRATEGY

A more detailed discussion and analysis, combining habitat assessment and faunal results, should be used to validate habitat suitability, extent and connectivity findings using faunal occurrence/ geneflow, and comparisons of assemblage similarity. Habitat mapping should be undertaken based on more detailed hydrogeological mapping or modelling in areas of relevance to the proposal, rather than using broad scale aerial geology as a proxy for hydrogeological habitats. The extent and magnitude of groundwater drawdown should then be overlaid as contours to facilitate the assessment of proportional impacts to stygofauna habitat in areas where species are known only from within the drawdown extent (*e.g.* Warramboo).

5.2B) MODERATE ISSUE

The habitat assessment at Mesa C suggested that the highly prospective CID aquifer is "*principally isolated"* (Biota 2017d) from nearby alluvial aquifers associated with the Robe River, which appears to be at odds with habitat mapping showing potential connectivity between these habitats in the north of Mesa C, and faunal results. While the report states that *"limited potential for groundwater throughflow is expected to occur due to the clayey nature of basal tertiary pisolite in this area*" (Biota 2017d), both amphipod species detected in CID at Mesa C were found to occur more widely in the local area, with current gene flow via the hyporheic zone of the Robe River and tributaries between Mesa C and Mesa H (confirmed by genetic testing Helix Molecular Solutions 2017a, 2017b). This finding is not problematic for the EIA of these species but raises questions about potential propagation of groundwater drawdown from the mining at Mesa C into the nearby Robe Valley alluvial aquifer.

5.2B) STRATEGY

As above, a more detailed discussion and analysis should be used to validate habitat suitability, extent and connectivity findings using faunal occurrence/ geneflow, and comparisons of assemblage similarity.

5.2C) MODERATE ISSUE

As per troglofauna habitat assessment for Warramboo (Biota 2017a), the categorisation of 'confirmed' and 'inferred' habitat prospectivity is illogically applied where stygofauna have been sampled in medium and low prospectivity habitats. Regardless of inferred habitat suitability from broad scale habitat mapping, any locations where diverse stygofauna assemblages have been collected should be regarded as confirmed high suitability habitats, while confirmed low suitability should be reserved for areas found to have no stygofauna or very depauperate assemblages after multiple rounds of sampling.

5.2C) STRATEGY

Sampling data and faunal results should be combined with habitat data to validate the assessment of habitat prospectivity such that the presence/ absence of stygofauna (assuming equal sampling effort) is related to 'confirmed/ inferred' status, and the diversity/ richness of the assemblages is proportional to higher habitat prospectivity.

5.3 Hydrogeological Assessments

RTIO completed a hydrogeological assessment for the Warramboo area to support proposed below water table mining (RTIO 2017e). This hydrogeological assessment was reviewed, and the key findings are summarised below.

Groundwater throughout the Warramboo area stands between 15 m and 20 m below ground level, inclusive of an existing drawdown of approximately 4 m across the Warramboo pit from the current water supply borefield. Modelling predicts total groundwater abstraction will be approximately 170 giga litres (GL) over the Life of Mine, resulting in a reduction in the aquifer saturated thickness of up to 70% at the maximum point of groundwater drawdown within the Warramboo area (RTIO 2017e).

Three major geological units were identified at Warramboo: CID (Robe Pisolite), Yarraloola Conglomerate and Ashburton Formation. RTIO (2017e) concluded that the largest habitat for stygofauna is likely to be the Yarraloola Conglomerate, a regional aquifer that extends to the west of Warramboo towards the coast. Alluvial, colluvial and Robe Pisolite units were also thought to provide habitat in the limited areas where they occur below the water table. The Ashburton Formation was regarded as an aquitard (low permeability) lying below the Yarraloola Conglomerate and was not considered to provide potential habitat for stygofauna.

It was reported that the potential groundwater habitats contain no known barriers to dispersal for any stygofauna species likely to occur in the Warramboo area. It was considered likely that deeper stygofauna habitat would persist during groundwater abstraction, as an estimated 30% of the saturated thickness of the local aquifer would be unaffected beneath the drawdown cone at the point of maximum depression, and a greater percentage of the aquifer would remain unaffected beneath the peripheral areas of the cone of depression. Suitable habitat would also likely occur widely beyond the drawdown extent, as it was estimated that the modelled cone of depression would impact less than 2% of the inferred extent of the Yarraloola regional aquifer (RTIO 2017e).

A hydrogeological assessment for the Mesa C area was also completed by RTIO to support proposed below water table mining (RTIO 2017f). Four key hydro-stratigraphic units were identified: Robe River Alluvial, CID (Robe Pisolite), Ashburton aquitard, and Ashburton aquiclude (RTIO 2017f).

The Ashburton aquiclude is not permeable due to shale and mudstone content and creates a groundwater divide through the basement rock at Mesa C. The local CID aquifer at Mesa C is therefore considered to be a closed system (*i.e.* a confined aquifer) that is separated from the nearby Robe River alluvial aquifer by less permeable layers.

The predicted groundwater abstraction volume from Mesa C deposit is estimated to be 6 GL over the Life of Mine, resulting in a complete depletion of the CID aquifer to enable dry mining conditions at Mesa C. Dewatering of the CID aquifer at Mesa C deposit was not expected to extend far beyond the mine pit due to surrounding impermeable layers, and it was concluded by RTIO (2017f) that the overall risk the environment and regional aquifer was considered low (although this did not include an assessment of stygofauna).

5.3A) NO MAJOR ISSUES

The Review did not find any major issues with the hydrogeological assessment in addition to the previously stated issues (section 5.2) regarding the low level of detail presented, and the way in which the habitat assessment is yet to be fully integrated into the analysis and discussion of stygofauna results within the baseline reports. RTIO's (2017e, 2017f) conclusions in relation to potential stygofauna risks are considered defunct, as these were made prior to specific stygofauna assessments (Biota 2017d).

6. SUMMARY AND CONCLUSION

Table 6.1 provides a summary of the moderate and major issues, and suggested strategies arising from the Review.

Based on recent advice from RTIO, many of the inconsistencies relating to species nomenclature and distribution assessment in the baseline survey reports have been addressed by a recent overall reassessment of species identifications, SRE status, ecological classification and potential distribution for the ERD.

It remains unclear how much of the current interpretations of species distribution and habitat connectivity could be affected by sampling artefacts. While this may be somewhat unavoidable due to the inherent difficulties in sampling troglofauna, a more rigorous overall assessment of sampling adequacy (species accumulation combined with other means of comparing sampling adequacy), would provide more confidence about the current results and potentially enable comparisons between each of the major habitat units and areas inside vs outside impact areas.

Recent detailed habitat modelling has provided a more confident assessment of the extent and thickness of troglofauna habitats than was available for the baseline survey reports, although this is yet to be integrated with fauna occurrence data. Combining the best available habitat data with species data to produce a three-dimensional estimation of the potential extent of suitable habitats at Warramboo could be very useful for conceptualising both potential species occurrence beyond impact areas, and potential extent and connectivity of habitats remaining after mining. A more detailed assessment/ modelling of hydrogeological habitats in combination with stygofauna data would similarly improve confidence in the stygofauna assessment.

Further targeted investigations remain the optimal method for validating predictions about habitat extent, connectivity and suitability (such as in putatively suitable habitats beyond impacts at Warramboo/ Tod Bore/ Highway, and beneath pit floor/ waste dumps), although these are contingent upon suitably placed, appropriate drill holes and bores.

Current and future troglofauna compliance monitoring can be improved by strengthening the design of the monitoring program to enable more precise detection of changes to species occurrence (and/ or assemblage composition) and habitat quality parameters (tested within more robust scientific frameworks) over time, and ensuring greater consistency (of methods, nomenclature) with baseline data and subsequent rounds of monitoring. The key objective to this is ensuring that troglofauna compliance monitoring data can be used to validate the success of the MEZ as a strategy for the conservation of troglofauna species and assemblages. Current compliance monitoring data may need to be re-examined where possible against baseline data from the same or similar habitats to establish the success of the current MEZ at Mesa A, particularly prior to making any further changes to design or reductions of volume.

Table 6.1: Summary of issues identified by the Review, classification, and key strategies to resolve.

NUMBER	CLASS	ISSUE	STRATEGY
Troglofauna Impact Assessment Documents			
2.1A	**MOD**	Small changes to MEZ (33 ha) unlikely to be significant to troglofauna. Unresolved uncertainties surrounding the effectiveness of the MEZ as a strategy for conserving restricted troglofauna species and assemblages.	Preclude any additional changes to the MEZ until uncertainties resolved and greater confidence in the effectiveness of the MEZ.
2.2.1A	**MAJ**	Geological connectivity between Highway/ Tod Bore and CID habitats to the south west (Dinner Camp Bore) indicated by detailed habitat modelling, but fauna data suggests high species turnover, possible habitat discontinuities. Although it is likely that some habitat occurs beyond impact areas at Highway/ Tod Bore, the current information does not allow accurate assessment of how much habitat will be retained following mining.	Further investigations for species/ habitat/ assemblage comparisons in the following areas; A) highly / mod prospective habitats immediately surrounding Highway/ Tod Bore pits, B) highly / mod prospective habitats extending to south west of the pits at Highway/ Tod Bore. If no further investigations possible, assess potential for MEZ around Highway/ Tod Bore pits.
2.2.1B	**MAJ**	Current fauna thresholds for high-mod-low prospectivity habitat are not validated by links to fauna occurrence. Although it is likely that some habitat occurs beyond impact areas at Warramboo/ Highway/ Tod Bore/, the current information does not allow accurate assessment of how much will be retained following mining, or what is the likelihood that species known only inside pits will occur there.	Integrate current fauna occurrence records with 3D habitat modelling to: A) validate habitat prospectivity categories B) investigate habitat thickness at known occurrence records of different types of troglofauna C) provide a tool for estimating wider potential extent of habitat surrounding known occurrences of a species or an assemblage D) based on potential extent of habitat surrounding all known occurrences of an assemblage, estimate potential amount of habitat retained after mining
2.2.2A	**MOD**	Design characteristics of the MEZ: A) 30 m buffer justification B) Minimum of 1 known location of P1/2 species C) Issues with compliance monitoring	A) Clarify justification of MEZ around modelled potential extent of habitat B) Add complexity to better describe current state of knowledge about MEZ effectiveness C) Re-examine compliance monitoring data to add justification of MEZ D) Improve scientific rigour of future monitoring plans E) Engage with current and future research to help determine troglofauna minimum habitat requirements
2.2.3A	**MOD**	Logical flaw: ”species [omitted] that were only ever recorded from the draft MEZ and thus never at risk of impact”	Remove or reword statement to avoid contradictions with other assumptions about species occurrence within MEZ. Check numbers of species included in assessment.
2.2.3B	**MOD**	Perception issues with wording: Priority 1 (singletons found only inside pit), and Priority 2 (species known from multiple sites inside pit).	Change wording to avoid perceptions of priority 1 and 2 species being treated differently
2.3A	**MOD**	30 m minimum buffer issue as in 2.2.2A	See strategy 2.2.2A

NUMBER	CLASS	ISSUE	STRATEGY
Baseline Troglofauna Survey Documents			
3.1.1A	**MOD**	Baseline survey issues: A) sampling gaps between Mesas and in moderate to low prospectivity habitats B) Most samples taken from within impact areas (information available at the time of sampling) C) No overall / cumulative assessment of sampling inside/ outside impact areas or comparing different habitat units	Assess any potential sampling gaps/ artefacts (flow-on effects to inferences regarding potential habitat extent and species occurrence).
3.1.2A	**MOD**	Baseline habitat suitability categories used in baseline reports illogically applied and over simplistic.	Habitat assessment in the baselines studies is superseded by RTIO geological/ geomorphological habitat modelling. For areas where this modelling does not extend, baseline habitat assessment categories should be treated as preliminary and inconsistent with fauna information.
3.1.2B	**MAJ**	Baseline habitat assessment assumes high connectivity of Warramboo/ Highway/ Tod Bore and Dinner Camp Bore to the south-west, assumptions that are directly contradicted by fauna sampling information showing high species turnover between these areas.	See strategies 2.2.1A, 2.2.1B, and 3.1.1A
3.1.2C	**MOD**	Baseline habitat assessment in-between high suitability habitats based on less habitat data, untested by sampling (implications for assumptions of habitat discontinuity)	Assessment of habitat connectivity between mesas would benefit from additional sampling/ investigations, pending development of suitable holes. If this is not possible, strategy 2.2.1B may help to highlight potential connectivity for some species.
3.1.3A	**MOD**	Inconsistencies in assessment of species ecological status, SRE status, potential distribution between or within baseline reports	RTIO has advised all species assessments have been updated for the ERD based on cumulative/ overall assessment of species ranges, superseding baseline assessments. All species in Table 3.2 should be considered Potential SRE troglobites.
3.2A	**MOD**	Baseline species accumulation studies considered unidentified specimens to represent additional species, potentially skewing results	Reassess species accumulation analyses based on RTIO overall data, using a parsimonious approach to indeterminate or unidentifiable specimens (*i.e.* omit them). Provide more detail regarding data handling in EstimateS.
3.2B	**MOD**	Baseline species accumulation studies inadequately described data handling methods and settings in EstimateS used in the analysis.	See strategy 3.2A
3.3A	**MOD**	It is difficult to reconcile results from previous studies with current survey results, due to the high number of reports and changes in nomenclature and subterranean/ SRE statuses.	RTIO has advised all species identifications and subterranean/ SRE statuses have been updated for the ERD based on cumulative/ overall assessment of species data, superseding previous baseline assessments

NUMBER	CLASS	ISSUE	STRATEGY
Troglofauna Compliance Monitoring Documents			
4.1.1A	**MAJ**	Compliance monitoring results unable to indicate whether and to what extent troglofauna assemblages at Mesa A have been affected by mining, due to inadequate species-level identifications and comparisons with previous data only at taxonomic order level.	Current and future TMP's to require: A) All future compliance monitoring to identify all specimens to species level and undertake full comparisons with baseline sampling and monitoring. B) Consistent framework for nomenclature, reference collections for specimens and genetic sequences
4.1.2A	**MOD**	Previous recommendation to reduce compliance monitoring sampling rates not justified by sufficient evidence.	Current and future TMP's to require: C) consistent methods and sampling design, seasonality and trap duration etc. D) consideration in sampling design to development of thresholds/ indicators for detecting change in species/ assemblages.
4.2A	**MOD**	Results of targeted sampling of waste dumps and pit floor limited by numbers of holes and extent of holes through multiple habitat zones	Further investigations required to establish persistence of troglofauna species/ assemblages beneath pit floor and under waste dumps
4.3A	**MOD**	Downhole visual monitoring lacked assessment framework which could be used to validate results	Either develop scientifically valid assessment framework for down hole visual survey, or pursue alternative methods for physical habitat monitoring
4.4A	**MOD**	Ability to compare current MEZ conditions to baseline habitat conditions constrained by lack of suitable baseline data and issues with environmental probes	Design a statistically valid troglofauna habitat monitoring program, using more suitable probes, for Mesas B, C, and Warramboo, and begin collecting baseline data without delay to capture full range of seasonal variability
Baseline Stygofauna Survey Documents			
5.1A	**MOD**	Stygofauna sampling uneven inside/ outside predicted drawdown and across putative habitat types. May have had an effect on sampling artefacts.	Undertake deeper analysis of sampling and fauna results to investigate whether the current data is affected by sampling artefacts or if species/ assemblage occurrence patterns concur with inferred habitat extent and connectivity
5.2A	**MOD**	Stygofauna habitat characterisation oversimplified and lacking validation by species assemblage comparisons (similar to issue 2.2.1A for troglofauna)	More detailed mapping and assessment of stygofauna habitat extent, suitability and connectivity, integrated with fauna occurrence records may improve the assessment (similar to strategy 2.2.1B for troglofauna)
5.2B	**MOD**	Habitat connectivity assessment for Mesa C/ Robe River aquifer at odds with occurrence of shared stygofauna species	Species assessment in the baselines studies is superseded by RTIO overall assessment for ERD. More detailed mapping and assessment of stygofauna habitat extent, suitability and connectivity, integrated with fauna occurrence records may improve the assessment (similar to strategy 2.2.1B for troglofauna)
5.2C	**MOD**	Stygofauna habitat suitability categories illogically applied and over simplistic (similar to issue 3.1.2A for troglofauna)	More detailed mapping and assessment of stygofauna habitat extent, suitability and connectivity, integrated with fauna occurrence records may improve the assessment (similar to strategy 2.2.1B for troglofauna)

7. REFERENCES

Astron Environmental Services (2017) Troglofauna Habitat Data Analysis, report prepared for Rio Tinto Iron Ore

Bennelongia (2010) Robe Valley Tenure; Congo Bore and Dinner Camp Baseline Troglofauna Survey. Unpublished report prepared for Rio Tinto, Bennelongia Environmental Consultants.

Bennelongia (2015a) Mesa A and Warramboo Troglofauna Alignment, report prepared for Rio Tinto Iron Ore

Bennelongia (2015b) Alignment of Troglofauna – Ideoblothrus sp. 'Mesa A2', report prepared for Rio Tinto Iron Ore

Bennelongia (2015c) Mesa K Remnant Mining Project: Troglofauna Compliance Report 2015, report prepared for Rio Tinto Iron Ore

Bennelongia (2017a) Mesa A and Mesa B Annual Compliance Troglofauna Survey 2016, report prepared for Rio Tinto Iron Ore

Bennelongia (2017b) Pit Floor Troglofauna Sampling at Mesa A 2016, memorandum prepared for Rio Tinto Iron Ore

Biota (2004) Mesa A and Bungaroo Creek Exploration Areas Subterranean Fauna Survey, report prepared for Rio Tinto Iron Ore

Biota (2006a) Mesa A and Robe Valley Mesas Troglobitic Fauna Survey, report prepared for Rio Tinto Iron Ore

Biota (2006b) Mesa A Troglofauna Survey: Compilation of Sampling Results, report prepared for Rio Tinto Iron Ore

Biota (2006c) Species Accumulation and Troglobitic Fauna Sampling Adequacy at Mesa A (RTIO-HSE-0063892), report prepared for Rio Tinto Iron Ore

Biota (2006d) Mesa A/ Warramboo and Yarraloola Borefield Development Baseline Stygofauna Assessment, report prepared for Rio Tinto Iron Ore

Biota (2007a) Mesa A Troglobitic Fauna Studies Update, report prepared for Rio Tinto Iron Ore

Biota (2007b) Mesa A Troglobitic Fauna Species Accumulation Update, report prepared for Rio Tinto Iron Ore

Biota (2011) Mesa A Troglofauna Compliance Report 2010, report prepared for Rio Tinto Iron Ore

Biota (2012a) Mesa A Troglobitic Fauna Compliance Monitoring 2012, report prepared for Rio Tinto Iron Ore

Biota (2012b) Mesa K Troglobitic Fauna Compliance Monitoring 2012, report prepared for Rio Tinto Iron Ore

Biota (2014) Single Phase Troglofauna Sampling for Tod Bore, Hubert Well, Congo Bore and Highway Deposit, report prepared for Rio Tinto Iron Ore

Biota (2017a) Mesa A Hub: Warramboo Troglobitic Fauna Assessment, report prepared for Rio Tinto Iron Ore

Biota (2017b) Mesa A Hub: Mesas B and C Troglobitic Fauna Assessment, report prepared for Rio Tinto Iron Ore

Biota (2017c) Mesas A and K Targeted Troglofauna Survey, report prepared for Rio Tinto Iron Ore

Biota (2017d) Mesa A Hub: Warramboo and Mesa C Stygofauna Assessment, report prepared for Rio Tinto Iron Ore

Eberhard, S.M., Halse, S.A., Williams, M., Scanlon, M.D., Cocking, J.S. and Barron, H.J. (2009) Exploring the relationship between sampling efficiency and short range endemism for groundwater fauna in the Pilbara region, Western Australia. Freshwater Biology 54: 885-901

Environmental Protection Authority (EPA) (2016a) Technical Guidance Subterranean Fauna Survey, December 2016. Perth, Western Australia

Environmental Protection Authority (EPA) (2016b) Technical Guidance Sampling Methods for Subterranean Fauna, December 2016. Perth, Western Australia

Environmental Protection Authority (EPA) (2016c) Environmental Factor Guidelines Subterranean Fauna, December 2016. Perth, Western Australia

Environmental Protection Authority (EPA) (2016d). Environmental Factor Guideline: Subterranean Fauna. December 2016. Perth, Western Australia.

Geo, X. (2017) Robe Valley Deposits Façade Stand-off Distance Memo, memorandum prepared for Rio Tinto Iron Ore

Halse, S., & Pearson, G. B. (2014). Troglofauna in the vadose zone: comparison of scraping and trapping results and sampling adequacy. Subterranean Biology, 13, 17.

Harvey, M.S. (2002). Short-range endemism among the Australian fauna: some examples from non-marine environments. Invertebrate Systematics 16: 555-570

Harvey, M.S. and Edwards, K.L. (2007) A review of the pseudoscorpion genus *Ideoblothrus* (Pseudoscorpiones, Syarinidae) from western and northern Australia

Harvey, M.S., Berry, O., Edward, K.L. and Humphreys, G. (2008) Molecular and morphological systematics of hypogean schizomids (Schizomida: Hubbardiidae) in semi-arid Australia

Helix Molecular Solutions. (2015). Report on the molecular systematics of subfauna from the Robe River Valley. Report to Biota Environmental Services. Appendix 4 to Biota 2017a.

Helix Molecular Solutions. (2016a). Report on the molecular systematics of subfauna from the Robe Valley– historical, Phase 3 and Phase 1 and 2 repeats: Part 3. Report to Biota Environmental Services. Part of Appendix 2 to Biota 2017d.

Helix Molecular Solutions. (2016b). Report on the molecular systematics of subfauna from the Robe Valley – Phase 4. Report to Biota Environmental Services. Part of Appendix 2 to Biota 2017d.

Helix Molecular Solutions. (2017a). Report on the molecular systematics of Amphipoda from the Robe Valley – Phase 5. Report to Biota Environmental Services. Part of Appendix 2 to Biota 2017d.

Helix Molecular Solutions. (2017b). Report on the molecular systematics of Amphipoda from Warramboo, and Mesas A, C and K (Biota 1080c). Report to Biota Environmental Services. Part of Appendix 2 to Biota 2017d.

MWH (2014a) Mesa A Troglofauna Biennial Compliance Monitoring: 2014, report prepared for Rio Tinto Iron Ore

MWH (2014b) Mesa K Troglofauna Annual Compliance Monitoring: 2014 report prepared for Rio Tinto Iron Ore

Outback Ecology (2013) Mesa K Troglofauna Compliance Report 2013. Report prepared for Rio Tinto Iron Ore

Pilbara Wireline Services (2014) Comparison of Downhole Optical Image Logs in Troglofauna Assessment Holes Rio Tinto Mesa A, Mesa B and Mesa K, report prepared for Rio Tinto Iron Ore

Rio Tinto Iron Ore (RTIO) (2016) Mesa A Hub Proposal Section 38 Referral Environmental Review Document

Rio Tinto Iron Ore (RTIO) (2017a) Mesa A / Warramboo Iron Ore Project Mining Exclusion Zone Review, internal Rio Tinto Iron Ore report

Rio Tinto Iron Ore (RTIO) (2017b) Troglofauna Habitat Removal Impact Assessment Process for Mesa A Hub Proposal, internal memorandum for Rio Tinto Iron Ore, dated 15 September 2017

Rio Tinto Iron Ore (RTIO) (2017c) Troglofauna Volume Calculation Memorandum – Mesa B, internal memorandum prepared by Rio Tinto Iron Ore, dated 30 October 2017

Rio Tinto Iron Ore (RTIO) (2017d) Troglofauna Volume Calculation Memorandum – Mesa C, internal memorandum prepared by Rio Tinto Iron Ore, dated 9 October 2017

Rio Tinto Iron Ore (RTIO) (2017e) Warramboo H3 Hydrogeological Level Assessment. V4,0, numerical modelling updated 21/05/2018.

Rio Tinto Iron Ore (RTIO) (2017f) Mesa C H3 Hydrogeological Level Assessment

Rio Tinto Iron Ore (RTIO) (2018) Troglofauna habitat modelling: Warramboo area. Powerpoint presentation.

[Page left blank intentionally]