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Dear Leanne

Re: Mulga Downs Project Troglifauna Assessment

Stratagen has requested Bennelongia to provide comment and/or opinion on the troglifauna sampling results contained within the subterranean fauna assessment report prepared by Phoenix Environmental Consultants for the Mulga Downs Project.

In summary, Bennelongia was asked to comment on:

- the level of survey effort in relation to EPA guidelines and whether sufficient information is available to undertake risk-based assessment.
- the extent of prospective habitat outside the impact area and the likelihood that this habitat could support similar troglifauna communities.
- whether it is reasonable to use the distributions of widespread species or surrogate species to infer distributions of other species. If so, what is the likelihood the six 'restricted' species occur outside the impact area?
- whether there are any data that could be used to further assess the troglifauna assemblage within the proposal area and improve the level of confidence regarding the effect of the proposal on troglifauna.

Bennelongia's comments are provided below under four headings that more-or-less match the information requested. The area where the proposed Project mine will be located is referred to in this correspondence as Murray's Hill.

The comments assume that a risk-based approach to assessment will be followed because "In 2011, the EPA resolved to pursue a more risk-based approach to environmental impact assessment of subterranean fauna related issues" (EPA 2012). An example of risk-based subterranean fauna assessment provided in EPA (2012):

- reported that more than 50% of troglifauna species were known only from the project impact area (i.e. were apparently restricted to the impact area).
- used geological mapping to infer the extent of troglifauna habitat and show that a significant proportion of potential habitat was outside the impact area and would remain undisturbed.
- used the distributional patterns of other troglifauna species to infer wider distributions of low-abundance, apparently restricted species.
- concluded that the risk of extinction of any troglifauna species as a result of the project was low because species distributions were likely to extend into areas that would not be disturbed.

A precautionary approach would have emphasized the lack of empirical evidence showing that all species had ranges extending outside the impact area and hence would have concluded there was a potential threat to species persistence.

Issue 1 - Level of survey effort

In relation to sampling effort it is useful to compare the effort for stygofauna (for which there are few assessment issues) and troglofauna.

Sampling effort for stygofauna in the Project impact area exceeded Guidance Statement 54A recommendations (EPA 2007) (see Table 1).

Whether the sampling effort for troglofauna met Guidance Statement 54A recommendations is slightly more complicated and depends on how sampling effort is interpreted. When Guidance Statement 54A was compiled only trap sampling for troglofauna was envisaged but since then the addition of scrape sampling has become routine. Consequently Guidance Statement 54A recommendations for minimal sampling effort in the impact area can be interpreted in three ways:

1. 60 trap samples should be collected as recommended in Guidance Statement 54A.
2. 60 scrape+trap samples should be collected as reflects subsequent best practice in recognition of the large sample effort required to collect most of the species of the troglofauna community.
3. 60 samples, from any combination of trap samples and scrape samples, should be collected. The justification for this position is that scrape sampling is as effective as trap sampling and trap and scrape sampling effort should be interchangeable.

Strictly speaking the sampling effort in the Project impact area met only the third interpretation of the guidelines but some flexibility in sampling effort is usually allowed and using the other two interpretations sampling effort was close to (c. 85% of) recommended effort (see Table 1). Actual sampling effort is under-estimated in these calculations because some trogofauna were collected during stygofauna sampling and *vice versa* and this inadvertent collecting increased the sampling effort beyond the formally recorded effort.

Table 1. Subterranean fauna sampling effort in Project impact area.

Number of rounds of sampling, number of samples collected and number of samples recommended by Guidance Statement 54A are shown. Effort calculated as trap sample = 0.5, scrape sample = 0.5.

	Rounds	Samples	GS 54A
Stygofauna	3	50	40
Troglofauna	3	52.5*	60

*Comprised 51 scrape samples, 59 litter trap samples, 4 banana trap samples.

Another way of viewing the adequacy of sampling is species accumulation curves. Phoenix (2013) followed the standard practice of including both reference and impact sampling in this calculation so that results apply to the Project survey area rather than the Project impact area alone. Phoenix provided results for seven estimators of total number of species present, representing four methodologies, from which sampling efficiency was calculated.

The Chao2 estimator (or ICE if the coefficient of variation for incidence is >0.5 and the ICE estimate is higher) is probably the most appropriate estimator to use because of the patchy nature of subterranean fauna species recovery through time (Colwell & Coddington 1994; Foggo et al. 2003). For stygofauna, sampling efficiency was 62%-70% (depending whether Chao 2 or ICE is more appropriate). For troglofauna, it was 75-84%. The stygofauna sampling efficiency is typical of Pilbara assessments, whereas the troglofauna efficiency is relatively high and similar to the 80% efficiency that has been suggested as a target for vertebrate work (Thompson et al. 2007).

Summary

In an overall evaluation, the number of troglofauna samples collected was adequate for the purposes of risk-based environmental impact assessment. Adequacy can be viewed in two ways and Phoenix (2013) sampling met the criteria relevant to both.

1. While there may be some discussion about the numbers of samples collected in relation to the Guidance Statement 54A, the use of trap and scrape sampling and inclusion of by-catch from stygofauna sampling raises sampling effort above that originally envisaged in Guidance Statement 54A.
2. If sampling is evaluated in terms of what has been collected, rather than effort of sampling, the 75-84% sampling efficiency of troglofauna sampling is greater than could reasonably be expected in a troglofauna assessment.

Issue 2 – Troglofauna habitat and similarity of troglofauna communities inside and outside impact area

Consideration of the distribution of troglofauna in relation to geology is frequently made more difficult by the array of geological descriptions applied to the same site depending whether it is being fitted into a broad geological classification or the finer details of mineralization and composition are being catalogued.

The key issue when considering the suitability of underground areas as habitat for troglofauna is that the extent and configuration of space within the rock and soil formations is the prime driver of habitat suitability rather the subtle chemical and derivational differences used in geological classifications. Thus, the degree of vugginess of rock formations and the size of interstitial spaces in gravels and soils, as well as broad biogeographic factors, will largely determine the richness and taxonomic composition of the troglofauna community at a site.

Geological units that are currently recognised as core habitat for troglofauna in the Pilbara include hardcap, various mineralized iron formations and tertiary detritals, including alluvium and calcrete (Biota 2006; Bennelongia 2008).

The Mulga Downs Project is based around a node of haematite-geothite that represents a highly mineralized outcrop of the Nammuldi member of the Marra Mamba iron formation. This outcrop is surrounded by alluvium and colluvium, with other nodes of haematite-geothite nearby and moderately extensive expression of less mineralized Marra Mamba to the north. This is illustrated in two figures in Phoenix (2013), most notably in Figure 4-59 which also shows the distribution of selected troglofauna species.

An analysis by Phoenix (2013) of troglofauna sampling results at the Mulga Downs Project showed no obvious associations between troglofauna species occurrence and the particular surface geologies most sampled. This suggested species were present in multiple geologies and, in fact, 82% of species occurred in the Nammuldi member, 74% in haematite-geothite and 63% in the alluvium and colluvium. Thus, while most, but not all, of the drill holes containing larger numbers of species were in areas of surface haematite-geothite, the troglofauna community in this geology seemed to extent into other geologies (see Figure 4-61, Phoenix 2013). Mineralised Nammuldi member, haematite-geothite and alluvium/colluvium all contain spaces and, in the Pilbara, would be expected to be at least moderately prospective for troglofauna.

Troglofauna are often divided into two categories. Troglobite species do not have surface dispersal phases and are considered to have small ranges. The significance of several troglobite species occurring in two different habitats or two different areas (called units hereafter) is that it provides strong evidence that the units are biologically connected. Thus,

it may be inferred that other troglobite species found to date in only one unit actually occur in both units and that their apparently restricted ranges are sampling artifacts.

All five of the troglobite species found in the haematite-geothite impact area of the Project and collected more than once were also found in surrounding alluvium-colluvium or Nammuldi member. These species were the spider *Anapistula* 'MH1' (Figure 4-9, Phoenix 2013), dipluran Japygidae 'MH1' (Figure 4-24), cockroach *Nocticola* 'MH1' (Figure 4-26), and thysanurans *Trinemura* 'MH1' and *Trinemura* 'MH2' (Figure 4-33).

It is also relevant that two troglobitic species of pseudoscorpion *Tyrannochthonius* 'MH1' and *Indohya* 'MH1' and one species of schizomid 'Schizomida MH2' were recorded from alluvium-colluvium (another schizomid *Schizomida* 'MH1' was collected once from the haematite-geothite impact area). Schizomids and pseudoscorpions are the troglobite groups that, together with cockroaches and spiders, have most characterized the troglofaunal communities of mineralized iron formations. The occurrence of all four groups in alluvium-colluvium near Murray's Hill raises the possibility that connection between iron formations and surrounding geologies in the Pilbara is be more common than previously thought.

Troglophile species usually have a surface dispersal phase, Therefore, it is unsurprising that six of the seven troglophile species found in the haematite-geothite impact area of the Project and collected more than once were also found in surrounding alluvium-colluvium or Nammuldi member.

Summary

Thirteen of the 27 troglofauna species at Murray's Hill were collected as single records and their distributions cannot be evaluated at this stage. Two species with multiple records were collected only from outside the haematite-geothite impact area. One species with multiple records was collected only from the impact area. Eleven species with multiple records occurred both inside and outside the impact area in a mix of geologies.

Prospective troglofauna habitat is extensive outside the impact area. Surface geological mapping shows it to consist mostly of colluvium and alluvium, with isolated occurrences of haematite-geothite and more extensive areas of mineralized Nammuldi member to the north.

From the above it is reasonable to conclude that:

1. There is a single troglofauna community in the Murray's Hill area containing, at least mostly, species that are not restricted to a single geology.
2. While there may be species in the community that have small-scale distributions, most of the species currently known from single locations are likely to occur in multiple geologies and to be more widespread within the local Murray's Hill area.
3. There is little evidence to suggest that species will be restricted to the haematite-geothite impact area of the Project.

Issue 3 – Inferring distributions from those of other species and the likelihood of the six species known only from the impact area being restricted to it

Many impact assessments for subterranean fauna have inferred species distributions from those of related species and the process has been endorsed by the EPA (2012) as part of a risk-based approach to assessment.

Five of the six species currently known only from the impact area of the proposed Project mine are represented by single records and one is represented by two animals from two drill holes. The hemipteran Meenoplidae 'USF' was collected in the Project survey area as a single animal in the impact area but was excluded by Phoenix (2013) from consideration as a restricted species. This conforms to the general belief that Meenoplidae have a surface dispersal phase and are widespread.

As indicated in the previous section, the distributions of species with single records cannot be evaluated directly and two records is also a very poor basis for estimating a species' range. In addition to the five or six singleton records from the impact area (depending how the data are interpreted), there were nine singleton records from outside the impact area where sampling was c. 40% greater. Thus, the occurrence of singletons in the impact area does not reflect anything biologically unusual about that particular area.

It is an important observation for assessment that the distributions of species with multiple records in the Project survey area nearly always included both impact and reference locations. This is strong evidence of biological connections between the different units (both geological and spatial) at Murray's Hill. Therefore, it is likely that each of the six restricted species has a range that extends beyond the haematite-geothite impact area.

If the known characteristics of the six species and their close relative (rather than other species of the community) are used to infer ranges, the above evaluation might be modified slightly but the modified assessment is unlikely to have any greater validity than the broad conclusion already drawn: An assessment based on known biology of related species would suggest:

1. Palpigradi 'MH1' – represented by a single animal and treated by Phoenix (2013) as a troglophile. The only described troglofaunal species known from the Pilbara (*Decapauropus tenuis*) is considered to be cosmopolitan (Scheller 2010). It is highly unlikely that a trogliphilic palpigrad species would be restricted to the area of <1000 ha associated with mine pit development.
2. Schizomida 'MH2' – represented by a single animal and a troglobite. Schizomids may have ranges as small as c. 100 ha if their distribution is constrained by strongly defined landscape features. Within continuous but strongly dissected features, such as the Hamersley Range, known linear ranges of only a few kilometres are quite common. However, given the evidence of the whole troglofauna community in the Project survey area extending outside the haematite-geothite impact area, it is considered unlikely that Schizomida 'MH2' would be restricted to the relatively small impact area.
3. *Cryptops* 'MH1' – represented by a single animal and treated by Phoenix (2013) as a troglobite. Information on the distribution of *Cryptops* and related genera is sparse and little can be said about the likely range of this species. Its likely range is better determined by the broad distributional characteristics of the troglofauna community in the Project area, which suggest that no species is likely to be restricted to the impact area.
4. Parajapygidae 'MH1' – represented by two animals from different drill holes and treated by Phoenix (2013) as a troglophile. Diplurans are considered to have moderately broad ranges for troglofauna (Halse 2010) although this view is based largely on what is known about Japygidae. However, given the trogliphilic characteristics of Parajapygidae 'MH1', what is known about the ranges of diplurans and their common occurrence in alluvium-colluvium, Parajapygidae 'MH1' is considered likely to extend beyond the haematite-geothite impact area.
5. *Troglarmadillo* 'MH1' – represented by a single animal and a troglobite. The taxonomy of isopods is poorly developed in Western Australia and many subterranean species occur with apparently small ranges. Little can be said about the likely range of this species, which is best determined by the broad distributional characteristics of the troglofauna community in the Project area, which suggest that no species is likely to be restricted to the impact area.
6. Pauropoda 'MH1' - represented by a single animal and treated by Phoenix (2013) as a troglophile. Although there is evidence that pauropods are speciose in the Pilbara and probably mostly have small ranges, it is considered that a trogliphilic species is unlikely to be restricted to the relatively small area of the haematite-geothite impact area.

Summary

While it is possible that one or more of the six species known to date only from the haematite-geothite impact area has a distribution restricted to this area, it is not the conclusion of a risk-based approach to assessment for the following reasons:

1. There is strong evidence that there is a local troglofauna community around Murray's Hill but the range of this community is much larger area than the Project impact area.
2. Most of this larger area occupied by the community will remain undisturbed.
3. All but one of the 12 species found in the haematite-geothite impact area and collected more than once were shown to have a distribution extending outside the impact area. A parsimonious interpretation of the likely distributions of the six 'restricted' species is that they also have wider distributions.

Are there additional data that could be used in assessment?

The troglofauna surveys have produced a considerable amount of data that have enabled the community of the Mulga Downs Project survey area to be well characterized by Phoenix (2013). The standard of taxonomic work and the analyses associated with the Phoenix (2013) report were conducted to a high standard. Accordingly, I am not aware of any additional data that could be used in the assessment.

Careful evaluation of the distributional information in the Phoenix report and the habitat-related geological information reveal a low abundance community that appears to be widely distributed on a local scale (the Murray's Hill area). Low abundance communities, which yield a high proportion singletons during sampling, provide difficulties for impact assessment that are best overcome by examining distributional patterns of the local community and related species. Further sampling may provide better distributional information for the species of original interest but in the process of acquiring this information it is likely other species will be collected for the first time.



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Managing Director

6 March 2013

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