Technical Guidance

Subterranean fauna survey

The content of this Guidance has not yet been updated to reflect the EPA's framework for environmental considerations in environmental impact assessment

Environmental Protection Authority

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Acknowledgment: Cover photo *Paradraculoides gnophicola* courtesy of the WA Museum.

FOREWORD

Western Australia's subterranean fauna has been recognised as being globally significant because of its extraordinarily high species richness and high levels of endemism. It has been estimated that the total number of subterranean fauna species is around 4000, many of which are unnamed or yet to be recorded.

The history of scientific discovery, policy development and consideration during environmental impact assessment was presented in March 2012 in *A review of subterranean fauna assessment in Western Australia* (EPA 2012) along with a suggested way forward.

This document has been developed to provide guidance on the relevant impact assessment methods where subterranean fauna is likely to be a factor, particularly the standards of survey and type of information required to understand impacts. It differs from previous guidance by introducing the use of surrogates, where survey alone has not provided sufficient evidence to determine distribution. It requires specimens to be offered to the WA Museum for the State collection to enable knowledge sharing and to improve understanding of subterranean fauna.

The EPA was assisted by a five member advisory group (Dr Paul Vogel, Chairman EPA; Dr Rod Lukatelich, member EPA; Prof. Lyn Beazley; Prof. Linc Schmitt and Dr Mark Harvey) which provided direction and guidance on a more strategic and risk-based approach for assessing proposals. The EPA Advisory Group recognised the need to improve consistency and transparency of assessment procedures and the need to develop an appropriate method of risk assessment, and made recommendations to the EPA in June 2012.

Public comments on the discussion paper and expert advice from a Subterranean Fauna Technical Group have informed the development of this guideline.

This document provides advice on the EPA's approach in assessing subterranean fauna. This approach will help to ensure that the information provided to the EPA is sufficient to avoid unnecessary effort and delays to assessment of proposals.

Dr Paul Vogel
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1. INTRODUCTION

1.1 Purpose

This Environmental Assessment Guideline (EAG) addresses how subterranean fauna are considered in environmental impact assessment (EIA) in Western Australia and provides advice to proponents on the level of information and survey required and how to analyse the results as part of the EIA process.

This document supersedes Guidance Statement 54 *Consideration of subterranean fauna in groundwater and caves during environmental impact assessment in WA* (EPA 2003).

1.2 Subterranean fauna

For the purpose of this document subterranean fauna are defined as fauna which live their entire lives (obligate) below the surface of the earth. They are divided into two groups:

- stygofauna - aquatic and living in groundwater; and
- troglofauna - air-breathing and living in caves and voids.

Subterranean fauna often display evolutionary adaptations to underground life, particularly reduced pigment and reduced, poorly functioning or non-existent eyes. Fauna that use a subterranean environment for only part of the day or season (e.g. soil-dwelling or burrowing species, cave-dwelling bats and birds) are not considered as subterranean fauna for this EAG. International discussion regarding classification of and links between surface, soil and subterranean fauna are acknowledged, however this definition has been chosen because it focuses attention on those species which are restricted to subterranean environments. This obligate underground existence greatly increases the likelihood of short range endemism and the possibility that a species conservation status may be impacted as a result of implementation of a proposal.

The absence of light in subterranean ecosystems results in limited energy resources originating from surface environments or chemo-autotrophic processes (e.g. bacterial films) being available. As a consequence, subterranean fauna are often highly specialised with morphological, physiological and biological adaptations that reflect severe environmental constraints, and have evolved to survive in unique environments (Gibert & Deharveng 2002).

There are both invertebrate and vertebrate subterranean species, although invertebrates predominate. Examples of invertebrate groups with subterranean representatives in WA include crustaceans (remipedes, ostracods, isopods, copepods, syncarids, amphipods and decapods), insects (cockroaches, crickets, beetles, bugs, thrips and springtails), arachnids (spiders, pseudoscorpions, schizomids, mites, harvestmen, scorpions), myriapods (millipedes), chilipods (centipedes), worms and gastropod snails. Stygofauna communities are often dominated by crustaceans whereas troglofauna can include a wide range of taxonomic groups.

There are only a few examples of vertebrate subterranean fauna recorded in WA. These are from Cape Range, Barrow Island and mainland Pilbara and include three fish (two gudgeons and an eel) and one reptile (blind snake).

1.3 EPA's objective for the environmental factor of subterranean fauna

The EPA's objective for subterranean fauna is to maintain representation, diversity, viability and ecological function at the species, population and assemblage level.

1.4 Rationale

This guidance should be used for all development proposals that are referred to the EPA under Part IV of the *Environmental Protection Act 1986* (EP Act) for which there are likely to be impacts on subterranean fauna.

Environmental impact assessment is generally based on predictions of environmental impacts. Predictions are based on the information/evidence gathered as part of the assessment. Prediction of impacts and the environmental management of a proposal together form the basis for EPA judgements as to whether its objective for an environmental factor can be met, and hence that the project is environmentally acceptable.

The assessment of subterranean fauna is often more complex than for other biodiversity factors due to limited knowledge of species distributions and habitat requirements, and the difficulties of survey. Adequate survey is integral to understanding the species present, nevertheless the EPA recognises that the use of surrogates can augment existing information. The use of surrogates together with the information gathered during survey, aims to raise the level of confidence in the predictions of impacts and provide sufficient confidence that the environmental objective can be met. Where projects can demonstrate higher overall confidence based on evidence from survey and predictions from the use of surrogates to demonstrate that the risk to the environment is low, these projects are likely to attract fewer conditions and management programs (see Figure 1).

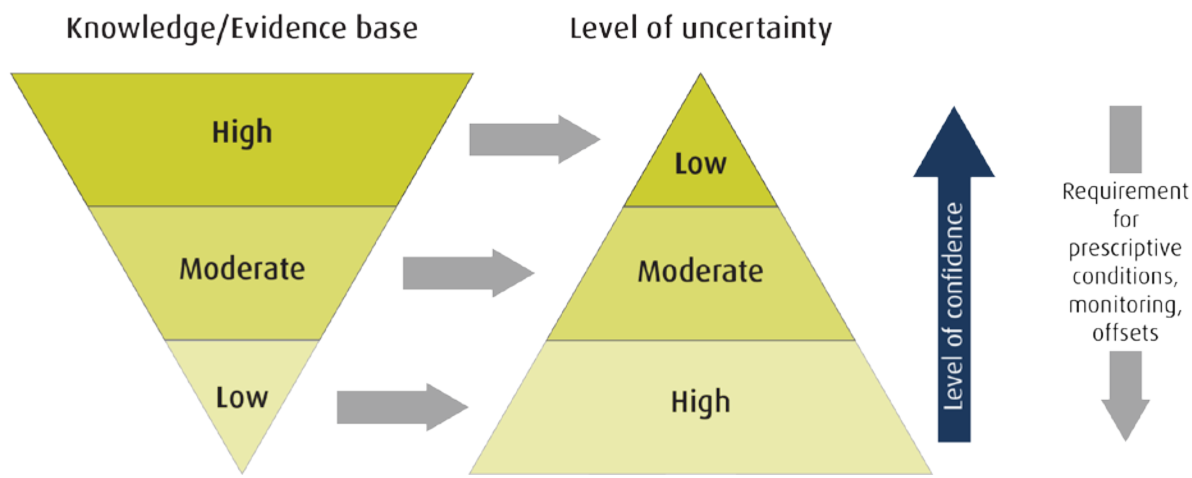

Figure 1: The knowledge/evidence and level of uncertainty determine the likely level of confidence in predictions for decision making.

1.5 Role of this EAG

This EAG sets out the expectations of the EPA while recognising the difficulties associated with the assessment of subterranean fauna in the context of limited knowledge. It provides a policy framework outlining how subterranean fauna should be considered in EIA and is designed to promote a more consistent approach to assessment and subsequent approval outcomes. This EAG does not provide prescriptive advice on sampling or analysis techniques.

2. CONTEXT

2.1 Background

Western Australia's subterranean fauna is recognised as being globally significant because of its extraordinarily high species richness and high levels of endemism. It has been estimated that the total number of subterranean fauna species is about 4000 (Guzik *et al.* 2010), most of which are unnamed or yet to be recorded.

Subterranean fauna occur in most regions of the State (Humphreys 2000, 2006, 2008), with particularly high diversity occurring at Cape Range, Barrow Island (Humphreys 2000), and the Yilgarn and Pilbara regions (Eberhard *et al.* 2005; Humphreys 2006, 2008). The significance of subterranean fauna at Cape Range has been recognised globally (UNESCO 2011). The best studied region for subterranean fauna in WA is the Pilbara where it is estimated that about 500-550 stygofauna species are likely to be recorded (Eberhard *et al*. 2009).

Knowledge of subterranean fauna has significantly increased in WA in recent years, with a strong focus on the description of new species and determination of evolutionary relationships. Research is increasingly showing that subterranean habitats contain more species than previously recognised and these are a significant proportion of global biodiversity (Gibert & Deharveng 2002). There are still many gaps in knowledge regarding the natural history of subterranean fauna such as mobility, reproduction and mechanisms for dispersal. These have implications for understanding population size, viability, distribution and ecological limitations.

The presence of subterranean fauna is strongly linked to geology and hydrology, and the availability of suitable micro-habitats, e.g. air-filled voids or caves for troglofauna, or aquifers that are not hypersaline (Hancock *et al.* 2005; Schmidt *et al*. 2007) for stygofauna. Despite these known associations between subterranean fauna, geology and hydrology, it can be difficult to predict the presence of subterranean fauna with confidence due to the lack of understanding of habitat requirements.

2.2 Legislation

Legislation relevant to the assessment of impacts on subterranean fauna in Western Australia includes the EP Act, the *Wildlife Conservation Act 1950* (WC Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This EAG provides information which the EPA will consider when assessing proposals where subterranean fauna is a factor. It takes into account:

- protection of the environment as defined by the EP Act with a focus on the conservation and protection of biodiversity values of subterranean fauna;
- the conservation of subterranean fauna species as listed by the WC Act; and ecological communities endorsed by the WA Minister for Environment; and
- the conservation of subterranean fauna species and ecological communities as listed by the EPBC Act.

2.3 History of assessment

The inclusion of subterranean fauna as a key environmental factor in impact assessment was triggered as a result of a development proposal, near Exmouth in 1994, in an area already known to support subterranean fauna. This also prompted significant scientific interest in subterranean fauna of the Cape Range area (e.g. Humphreys 1993). During the late 1990s a number of other development proposals where subterranean fauna was a factor were formally assessed in the Cape Range area. As a result the then Department of Environmental Protection commissioned a report *Karst Management Considerations for the Cape Range Karst Province of Western Australia* (Hamilton-Smith *et al.* 1998). The report highlighted the importance and uniqueness of subterranean fauna of the Cape Range area on a world scale and recommended environmental protection and consistent conservation management; maintenance of water quality and quantity; and assessment of environmental impacts resulting from development. This was followed by the release of Position Statement 1 *Environmental Protection Cape Range Province* (EPA 1999).

Subterranean fauna has been recognised as a key environmental factor for about 40 major projects assessed between 1994 and 2011 and, since 2000, the Pilbara region has become the main focus for assessment (approximately 60% of proposals included subterranean fauna as a factor). In 2003 the EPA released Guidance Statement 54 *Consideration of subterranean fauna in groundwater and caves during environmental impact assessment in Western Australia*, followed by the prescriptive technical Guidance Statement 54a *Sampling methods and survey considerations for subterranean fauna in Western Australia* (draft) in 2007 (EPA 2003, 2007).

3. GUIDE TO LEVELS OF SURVEY

Proponents need to consider the likely presence of subterranean fauna and potential impact on its habitat in planning environmental studies and surveys for their project and developing their referral to the EPA. Appropriate survey will be required when subterranean fauna are likely to occur. Two levels of survey, Level 1 and Level 2, can be used to inform the consideration and assessment of subterranean fauna and are described below. Figure 2 shows the process for undertaking subterranean fauna survey for EIA.

3.1 Level 1 survey

A Level 1 survey consists of a desktop study and usually a basic reconnaissance survey. Where the desktop component indicates uncertainty or significant data limitations, the reconnaissance survey may also include selective low-intensity sampling for the purpose of confirming whether subterranean fauna are present or likely to be present.

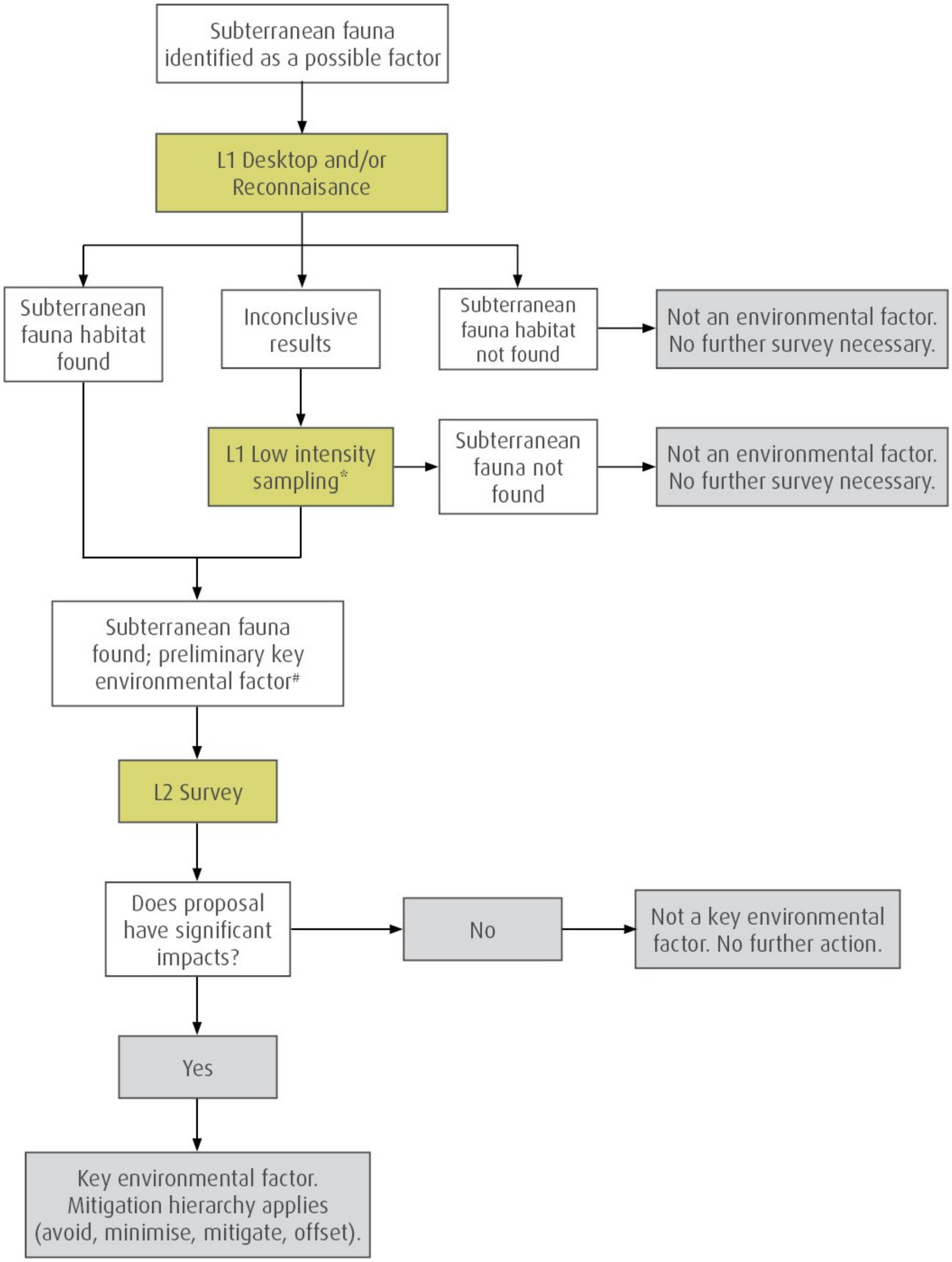

Figure 2: Diagram showing the process for undertaking subterranean fauna survey for EIA.

* Go direct to L2 without L1 Low intensity sampling if preferred.
# Dependent on likely degree of impact.

Desktop study

The purpose of a desktop study is to gather background information on a project area. A thorough desktop study assists in determining the level of survey necessary and is fundamental in determining whether sampling is required. A desktop study should be undertaken for proposals where subterranean fauna is a potential factor. The results should be used to determine whether further survey is required and if so the appropriate level. A desktop study should include a search of regional and project/site specific habitat data, including geological and hydrological information, previous studies of the area (published and unpublished), site photographs and databases including fauna records. As many areas are poorly studied and site-specific information can be limited, a realistic appraisal of the adequacy of the existing data to inform the desktop study is crucial. The desktop study should place the project area into a regional context, and make conclusions about whether the area is likely to provide habitat for subterranean fauna and consider impacts of the proposal.

Reconnaissance survey

A reconnaissance survey should provide on-site verification of the findings or accuracy of the desktop information and clarify whether subterranean fauna habitat is likely to be present. Where the presence of potential subterranean fauna habitat based on the site geology and hydrology information cannot be determined, low-intensity sampling may be required to determine whether a Level 2 survey is necessary. Standard sampling procedures (as for Level 2) are used but the number of samples taken will vary according to the local area and information obtained during the desktop survey.

3.2 Level 2 survey

A Level 2 survey can be either targeted or comprehensive. The purpose of a Level 2 survey is to gain a more detailed understanding of the subterranean fauna present or likely to be present in the project area.

Comprehensive

A comprehensive survey should provide detailed information to allow an understanding of the subterranean faunal values of an area and to place it into appropriate context. Comprehensive survey requires repeated sampling.

Targeted

The purpose of a targeted survey is to provide answers to specific questions building on existing information, e.g. where data are only available for part of a project area. A targeted survey requires repeated sampling of those areas where data are limited or insufficient. This will then allow the faunal values of the proposal area to be placed into context. For example, where only a proportion of the area likely to be occupied by subterranean fauna has previously been surveyed a targeted survey would involve sampling other parts of an aquifer or geological feature to provide context. This could also determine whether two adjoining troglobitic fauna habitat areas are connected and support an inter-breeding population, or if there is connectivity between one aquifer and another.

3.3 Determining survey level

The level and amount of survey undertaken to inform the assessment process is governed by the likely presence of habitat supporting fauna and the likely degree of impacts.

3.3.1 Determining presence of subterranean fauna habitat

While understanding of subterranean fauna habitats in Western Australia is patchy, it is accepted that suitable pores or voids are necessary to allow air or water to be present. Some types of geology and/or hydrology have a low likelihood of supporting either stygofauna or troglofauna because they do not contain these particular habitat components. Examples where subterranean fauna are unlikely to occur include deep sands or clays (especially over solid rock) or hyper-saline (exceeding marine concentration) groundwater (Schmidt *et al*. 2007).

Conversely, some types of geology have a high likelihood of comprising subterranean fauna habitat as pores or voids are present (and also groundwater in the case of stygofauna). The types of geology known to support stygofauna include calcretes (Humphreys 2006; Humphreys 2008; Hancock *et al*. 2005; Page *et al.* 2008; Karanovic & Cooper 2012); alluvial formations particularly when associated with alluvial or palaeochannel aquifers (Tomlinson & Boulton 2008); fractured rock aquifers, and karst limestone (Humphreys & Adams 1991; Knott 1993; Humphreys 2000; Page *et al.* 2008). Troglofauna are likely to be present in karst (Humphreys & Adams 2001; Humphreys & Shear 1993; Eberhard & Moulds 2007; Edward & Harvey 2008; Humphreys 2012), channel iron deposits (Biota 2006; Harvey *et al.* 2008), banded iron formations (Eberhard 2007), alluvium/colluviums in valley-fill areas (Biota 2010), and weathered or fractured sandstone.

The presence of subterranean fauna habitat needs to be evaluated as part of the desktop study, as this helps to determine whether further survey is required. The likelihood of habitats supporting subterranean fauna is shown in Table 1. The information collated through the desktop study should be used in conjunction with the information contained in Table 1 to assist in determining the appropriate level of survey.

Table 1: Likelihood of habitat supporting subterranean fauna.

	Stygofauna	**Troglofauna**
LOW	Groundwater not present, too saline for stygofauna or lacking voids or fractures, e.g. • profiles are entirely clay; • hypersaline mudflats (common along the Pilbara Coast); • unsuitable water quality, e.g. where salinity exceeds marine levels.	Geology without cavities, voids and caves, e.g. • substrate is dominated by sand and/or clay stratigraphy without spaces over solid rock; • areas that have been submerged during sea level rise in the Holocene period.
HIGH	Groundwater and voids present, e.g. • karst limestone; • calcretes; • alluvial formations (particularly when associated with palaeochannel aquifers); and • fractured rock	Geology with cavities, voids and caves, e.g. • karstic limestone; • channel iron deposits, particularly pisolite in inverted landscape geomorphology; • groundwater calcrete formations above water table (e.g. Weeli Wolli) • alluvium/colluvium habitats in valley-fill settings; • banded ironstone formations, especially where hydrated zones occur or there is a lot of jointing or fracturing; and • sandstone, where weathered and/or fractured

3.3.2 Identifying impacts and their likely significance

Predicting the likely degree of impact is important in determining the level of survey. This can be difficult during early planning when the size of a proposal footprint and the location of infrastructure are not fully known, nevertheless some understanding of the predicted impacts is required.

Impacts on subterranean fauna may be direct or indirect. Direct impacts include the removal, disturbance or compaction of habitat, drawdown of groundwater, inundation, or water quality changes. Indirect impacts include changes to hydrology, siltation, alteration to nutrient balance, and contamination.

The likely degree of the impact can be determined from a series of characteristics including the proportion and extent of habitat removal, duration of impact, effects on water quality and hydrology, and degree of ecological isolation if contiguous habitat is interrupted. Justification of the measures used to define the scale for each characteristic should be outlined when evaluating the degree of impacts. The measures used should be based on the unique impacts of a proposal.

Examples of impact types

- Excavation of rock
- Groundwater extraction/dewatering (single bore/borefield)
- Groundwater reinjection
- Changed surface topography due to compaction or creation of hard surfaces resulting in altered groundwater flow paths and increased runoff and reduced infiltration and aquifer recharge
- Potential leaks resulting in alterations to ground water quality including waste water, introduction of toxins or radiation
- Salinisation due to pit voids or intrusion
- Vegetation clearing - leading to sedimentation and changed nutrient inputs.

For example the degree of impact to stygofauna is likely to be low where the project impact is only above ground. Examples of groundwater abstraction on stygofauna could range from a single bore impacting on a relatively large aquifer to a series of bores impacting on a similar sized aquifer. In the former, if the duration was short and the spatial extent was low, the degree of impact would be low. In the latter, if the duration was long, the spatial extent was moderate or high and the level of water drawdown was several metres, the degree of impact would be high. Excavation or mining of rock would impact permanently on troglofauna. Depending on the proportion of the geological feature containing the troglofauna habitat proposed to be excavated, the overall degree of impact would be moderate to high.

3.3.3 Appropriate level of survey

Conducting an appropriate level of survey is necessary to ensure that the information collected is sufficient for consideration of subterranean fauna in the EIA process.

The level of survey will depend on the likely presence of subterranean fauna habitat and likely degree of predicted impacts as discussed in Sections 3.3.1 and 3.3.2 above. Surveys should be adequate to inform decisions as to whether a proposal meets the EPA's objective and tailored to the circumstances of the proposal. The likely presence of subterranean fauna habitat as outlined in Table 1, together with the degree and likely significance of the impact referred to in Section 3.2.2 are used to determine the survey level required as indicated in Table 2.

Where a desktop study provides clear evidence that subterranean fauna habitat is unlikely to be present, no surveys are warranted. However, where there is insufficient information, or the findings of the desktop study are inconclusive, a reconnaissance survey will be necessary to determine whether subterranean fauna habitat is present.

Table 2: The level of survey required based on the likelihood of habitat supporting subterranean fauna and degree of impact as determined in the desktop study.

Likely degree of impacts	**Likelihood of habitat supporting subterranean fauna**		
	Low	**Unknown/ Inconclusive**	**High**
Low	No survey required	Level 1*	Level 1*
Moderate or High	Level 1	Level 2	Level 2

If the results of the reconnaissance survey are sufficient to clearly demonstrate that the area is unlikely to contain subterranean fauna habitat, no further surveys are warranted. However, if the results are inconclusive, low-intensity sampling is recommended as part of the Level 1 survey to determine the presence of subterranean fauna within the impact area.

If the results of the Level 1 survey (at either the desktop study, reconnaissance survey or low intensity sampling) indicate fauna or fauna habitat are likely to be present, and a preliminary assessment indicates that the impacts of the project are likely to be significant, a Level 2 survey is required. Where there is limited information on a specific geology or aquifer, or where particular parts of a project area have no information, a Level 2 targeted survey may be appropriate.

Two hypothetical examples which explain how level of survey is determined are outlined below:

Example 1 Stygofauna

A proposal footprint is located over part of an aquifer and the project will require dewatering. Sampling data needs to be provided from throughout the aquifer, not just the impact area. Therefore, in the absence of data, a Level 2 survey is required to spatially represent the entire aquifer. Where suitable existing data are available from the aquifer but not from within the impact area, a targeted Level 2 survey should be conducted of the footprint to determine the level of impact on the aquifer as a whole. Similarly, if suitable data are available from the area of impact but not from the aquifer outside the project area, it will be necessary to conduct a targeted Level 2 survey of the aquifer outside the footprint.

Example 2: Troglofauna

A proposal requires excavation of a channel iron deposit. Geological mapping of the deposit is available as well as data for part of the footprint area from a previous troglofauna survey four years before. The geology and

* Dependent on findings of survey and degree of impact further survey may be required.

results of the previous survey indicate that the deposit has troglofauna species. The previous survey included adjacent areas but only part of the footprint. A Level 2 targeted survey is required to extend the study to those parts of the deposit within the footprint not currently surveyed.

4. SURVEY DESIGN

4.1 Sampling

This section outlines some considerations that should be taken into account when sampling for subterranean fauna, but does not prescribe technical detail on sampling methods.

Surveys should be coordinated and led by specialists who have had training and experience in subterranean fauna survey and identification of subterranean fauna.

Sampling should take account of a range of issues including the environmental conditions, any access constraints, both within and outside the footprint area, and the location of existing and proposed sampling boreholes. Sampling for stygofauna and troglofauna require different techniques and surveys should be designed accordingly for each group.

The survey needs to be sufficient to ensure that the subterranean fauna is adequately understood in the context of the project footprint and surrounding areas. Survey techniques for sampling subterranean fauna continue to evolve, therefore to maximise the effectiveness of surveys the most contemporary techniques and standards should be used. The amount of sampling required should be based on the site characteristics, likely significance of impacts, and existing sampling information. Adequacy of sampling should be determined on a case-by-case basis.

4.2. Use of genetics

New species are frequently collected during environmental impact assessment surveys for subterranean fauna. As the process of formally naming new species often takes considerably longer than an individual project assessment process, there may be considerable uncertainty regarding which or how many species are present in a particular project footprint. This uncertainty is compounded by the fact that many subterranean fauna species already collected still await formal description. The use of genetics can provide important tools to resolve some of the uncertainty regarding species identification and distribution.

One useful technique is DNA barcoding. This uses genetic markers in an organism's DNA to determine whether it is different from or the same as another individual. As mitochrondial DNA (mtDNA) has a relatively fast mutation rate there is usually significant variation in DNA sequences between species compared to a smaller variance within species. DNA barcoding can provide a rapid, efficient and relatively inexpensive method for delineation of taxa and identification of specimens. This is useful when determining whether specimens collected in a project footprint are the same as, or different from, those known from other areas. This does not require species to be formally described. A caveat, however, is that the degree of distinctness between species varies among taxonomic groups, so barcoding is more reliable in those groups where research has determined the likely levels of divergence between species. These determinations should be made by people with relevant expertise.

A second genetics tool commonly used in subterranean fauna studies to explain differences between samples is population genetic analysis of frequencies of different genotypes (haplotypes in the case of mtDNA). This can be used to infer gene flow and interbreeding between individuals in different parts of a species range and thus demonstrate that there are unlikely to be barriers to distribution within a particular range. This may then be used to infer that a species that was recorded only in localised areas within this range is also likely to have a similar wider distribution.

4.3 Use of surrogates

A surrogate is the use of information on one species to infer the likely distribution of another poorly sampled species. Where a reasonable amount of sampling is unlikely to reveal the full range of a species because of demonstrated low capture rates in the habitat sampled, surrogates can be used to estimate whether the habitat is restricted. A surrogate can be based on either biological features of a species (or group of species) or physical characteristics of the habitat.

The use of surrogates is appropriate only at the local scale, and not at a regional scale, because knowledge of habitat requirements and distributions for many subterranean species remains poor.

A biological surrogate is a species, preferably with similar morphological characteristics, that is likely to have similar trophic and dispersal attributes to the species found in low abundance. If genetic analysis of a surrogate species demonstrates that there is genetic continuity between two areas, it may be reasonable to conclude that there is continuity of habitat. Therefore it can be argued that if a species found in low abundance in one area but not recorded in the other area is similarly not likely to be restricted.

Subterranean fauna habitat is difficult to define, even where significant sampling and analysis have been conducted. The use of physical surrogates assists in the prediction of habitat extent and connectivity based on faunal distributional data from monitoring bores and drill holes. Predicted faunal distribution may be inferred if there is a habitat type that is continuous, assumes continuity between data points, and which is believed to be suitable for the species in question.

A physical surrogate is the use of habitat, known to support a particular species, to infer the likely presence of that species in the same habitat beyond the area surveyed. A physical surrogate can be used only where continuity of the presumed habitat can be clearly demonstrated with site-specific data.

Data from surrogates can be used to infer whether species are likely to be found both within and outside the footprint area. The combined use of habitat mapping, analysis of distributions and population genetic studies may allow inferences to be drawn about whether species are likely to have wider distributions than shown by the limited number of specimens collected. There are limitations associated with the use of surrogates to predict impacts on subterranean fauna and as knowledge improves there is scope for significant improvement. A hypothetical example of the use of a surrogate is outlined below:

> A project footprint is located over part of a series of hills which have been sampled for troglofauna. A number of species were recorded both within and outside the project area (with varying numbers of individuals) including three species which were only recorded within the project footprint. Two of these species were recorded only as singletons and another was recorded from 37 individuals. To determine whether this was a survey anomaly or whether these species were likely to be restricted to the impact area a surrogate species, with a high number of individuals from both the impact and non-impact area, could be used to demonstrate contemporary gene flow and thus predict continuity between impact and non-impact areas.

5. SPECIMEN VOUCHERING AND LODGEMENT

Specimens collected during the surveys and investigations for EIA are important in improving knowledge of subterranean fauna. Information from these surveys should be widely available, and will improve the efficiency and timeliness of the assessment and approval process. The specimens together with DNA material and accompanying data are critical to inform decision making.

Specimens, accompanying data, and DNA sequences must be offered to the WA Museum for inclusion in State collections by the time the project report is submitted to the EPA. Specimen data collected via permit under Section 17 of the WC Act must be submitted to the DEC, as per the terms of the permit. This will enable identifications to be verified, and ensure that biodiversity data are safely and permanently stored.

To ensure appropriate taxonomic, morphological and genetic analysis, specimens should be preserved according to current WA Museum guidelines (http://museum.wa.gov.au/consultation/submissions).

5.1 Nomenclature

Where a species has been formally described, nomenclature should use current published names. For species that have not yet been formally described or named in the scientific literature the WA Museum alpha-numeric code system must be used for those groups for which a system has been implemented by the Museum. This code system provides a consistent taxonomic framework for use by environmental assessment practitioners. Use of this system enables a species, whether named or not, to be placed in a regional context.

6. INTERPRETATION AND REPORTING

The results of surveys should be clearly presented and the report should include sections outlining the methodology, results and analysis. The report should consider all the information obtained from the results from the surveys, to quantify the likely degree of direct and indirect impacts to subterranean fauna.

The Introduction should provide background information and outline the project scope and objectives including the duration and spatial extent. A brief summary of the survey outcomes and predicted impacts should be included.

Methodology should include, but not be limited to, descriptions of site selection, sampling techniques and survey effort, specimen collection, identification and any molecular analysis undertaken as part of the survey. Justification of the level of survey used and any limitations should be outlined. Each persons' role in the survey, analysis and reporting, including acknowledgement of any specialists consulted, should be listed together with their qualifications and experience.

Clear reporting of the results is essential to allow an understanding of the subterranean fauna present in the project area. Results should include the identification of specimens together with WA Museum registration numbers. The number of individuals and the collection locations for each species, together with a description of the boreholes sampled. Results of the habitat assessment should compare sampling areas within and outside the development area and should be put into regional context. Any unique or diverse assemblages should be noted. Figures, maps and tables should be used to clearly present the results, with raw data submitted in appendices. Mapping can be used to illustrate the known extent or predicted extent of subterranean fauna habitats and the predicted impacts (e.g. proportion of resource to be used, drawdown/reinjection contours, hydrology and geology, location of sampling sites and location of boreholes sampled including those where no specimens were recorded).

Interpretation and analysis of the data should be undertaken and unexpected results explained where possible, for example if the survey resulted in unusually low diversity where high diversity was expected. The likely proportion of species detected by the survey should be discussed and comparison of sites should show all taxa recorded at each site. The analysis should consider the significance of the predicted impacts on subterranean fauna.

7. DEFINITIONS AND ACRONYMS

7.1 Definitions

Aquifer	groundwater contained within an underground layer of water-bearing permeable rock or unconsolidated materials such as gravel, sand or silt. The aquifer may be confined or unconfined.
Calcretes	composite rock deposits formed in arid environments by groundwater evaporation which causes the cementation of superficial gravels by calcium carbonate.
Dewatering	extraction of water from an aquifer such that the watertable is lowered in part or all of the aquifer.
Groundwater	any water located below the surface of the ground. For purposes of subterranean fauna assessment it does not include surface expressions of groundwater (eg. rivers, springs, seeps).
Karst	an area of exposed limestone with distinctive features such as caves, caverns and sinkholes and often with underground streams.
Palaeochannel	a remnant of a stream or river cut in older rock and filled by sediments of younger overlying rock.
Playa	an ephemeral inland salt lake.
Short Range Endemic (SRE)	species having a distribution of less than 10,000 km^2 (Harvey 2002)
Stygofauna	aquatic fauna which inhabit various types of groundwater.
Subterranean fauna	obligate subterranean fauna consisting of air-breathing troglofauna or aquatic groundwater fauna.
Taxon (plural taxa)	A group of organisms of known or inferred relationship. May refer to a formal taxonomic unit such as a species or subspecies or a higher category.
Troglofauna	air-breathing fauna which inhabit air-filled voids or caves below the ground.
Void	an air-filled space in rock.

7.2 Acronyms

DEC	Department of Environment and Conservation
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
OEPA	Office of the Environmental Protection Authority
SRE	Short Range Endemic
WAM	Western Australian Museum

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