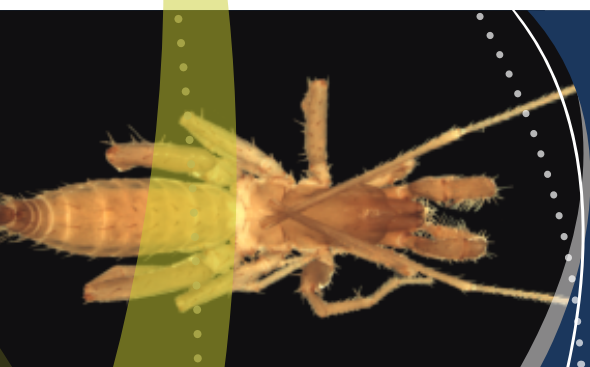




Office of the
Environmental Protection Authority



A review of subterranean fauna assessment in Western Australia

DISCUSSION PAPER

February 2012

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EPA Chairman's foreword

The Environmental Protection Authority (EPA) has legislative responsibility to protect the environment and to prevent, control and abate pollution and environmental harm.

It fulfils these duties in part by conducting environmental impact assessment (EIA) of major projects and providing advice to Government on whether the environmental risks and impacts can be managed.

While the EPA has been conducting assessments for four decades, it is only in the last 17 years that subterranean fauna has become prominent as a key environmental factor in around 40 major project assessments.

Questions have been raised about:

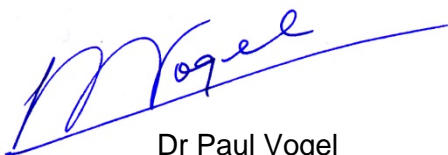
- the legal and policy drivers behind EPA consideration of subterranean fauna;
- the changing state of knowledge of subterranean fauna in WA;
- what has been learned through EIA practice since subterranean fauna was first identified as an environmental factor;
- the effectiveness of current assessment practices in meeting the EPA's objectives;
- opportunities to move towards a risk-based approach in considering subterranean fauna; and
- potential alternative assessment procedures.

In 2011, the EPA resolved to pursue a more risk-based approach to environmental impact assessment of subterranean fauna related issues. The need for and possible approaches to such a change are laid out in this discussion paper.

Stakeholder feedback on this discussion paper is invited and will assist the EPA when producing an Environmental Assessment Guideline, which will provide advice to proponents on future requirements for environmental assessment of subterranean fauna. Comments on the following questions are particularly sought, however comments are welcomed on any part of the discussion paper:

1. Your views of the current assessment procedures and what aspects could be changed.
2. The EIA review (EPA 2009a) stated that a risk-based approach to assessment requires the establishment of a systematic, consistent and transparent way of identifying key environmental issues and determining the scale and acceptability of impact. What is your view on applying a risk-based approach?
3. What is your view on using habitat mapping and analysis of gene flow as a surrogate to demonstrate landscape connectivity? This would represent a risk-based approach and an alternative to additional sampling for species found in low numbers.
4. A strategic approach could use regions or geology to predict the likelihood of finding subterranean fauna. This is consistent with the approach used for short range endemic invertebrates (Guidance Statement 20) and current procedures for terrestrial vertebrate fauna. Regional context, type of impacts and existing site knowledge about subterranean fauna could then be used to determine the information required for assessment. In your view, is this a valid approach for subterranean fauna assessment?

Your comments to policy@epa.wa.gov.au would be appreciated by **30 March 2012**.



Dr Paul Vogel

Executive summary

Subterranean fauna occur below the surface of the earth and include two groups - stygofauna (aquatic) and troglafauna (air-breathing). Micro-habitats are provided by geology, water and spaces, ranging from small pores to aquifers. Subterranean fauna are known from karst (such as limestones and calcretes) and non-karst (banded iron formations, alluvial deposits and fractured rock aquifers) geologies. Species now occupying subterranean habitats have evolved from the fauna which lived at the surface before the aridification of the Australian continent.

There are several ecological characteristics of subterranean fauna;

- They are restricted to specific habitat types;
- They often display evolutionary adaptations such as reduced pigment and reduced, poorly functioning or non-existent eyes;
- They have simple food webs with few trophic links, species are either predators or detritivores;
- They are thought to have slow metabolism, be slow-growing and long-lived, and have few young (although the life-histories of WA subterranean fauna are poorly known); and
- They often have discontinuous distributions.

The challenges faced in understanding the subterranean environment are significant and fauna can defy orthodox understanding of species and genetic diversity. In addition, the nature of the subterranean environment means that fauna may be vulnerable to local impacts if they have limited ranges and poor dispersal abilities.

Western Australia has a diverse subterranean fauna, estimated to be over 4000 species including 500 – 550 species thought to occur in Pilbara groundwater alone. Subterranean fauna found at Cape Range and Barrow Island, the Yilgarn and the Pilbara have been recognised as significant (diversity and endemism of species). The Cape Range area has been inscribed on the World Heritage list for its biodiversity values (including the subterranean fauna). WA is home to forty threatened subterranean fauna species (two fish and 38 invertebrate) and nine threatened subterranean ecological communities.

The EPA has released two guidance statements regarding subterranean fauna (dealing with consideration during environmental impact assessment in 2003 and sampling and survey in 2007) which have informed assessment of environmental impacts. Subterranean fauna were first recognised as a key environmental factor in the mid-1990s and subsequently about 40 proposals have included the factor. Since 2000, the Pilbara has become the main focus of subterranean fauna assessment, as a result of the significance of the fauna and number of resource developments. The EPA may recommend conditions for implementation that are designed to increase knowledge and reduce risks to subterranean fauna. The Minister for Environment is responsible for issuing a statement to allow implementation, and in almost all cases, the EPA's recommendations have been included by the Minister.

This discussion paper includes a series of case studies which show the evolution in environmental impact assessment thinking and methodology. Many advances in knowledge of subterranean fauna have been made, particularly in the description of new species, however there are still major gaps in the knowledge of biology, environmental requirements and impacts on subterranean fauna. In addition, the information gained in assessment and post-approval conditions is often not used effectively to improve knowledge of subterranean fauna, although the EPA acknowledges the reasons for this are complex. Despite this, WA's approach, when compared to other jurisdictions is integrated and consistent in assessment of subterranean fauna.

There are a number of limitations with the EPA's current approach to assessment of impacts on subterranean fauna. These include:

- requirements to advise the Minister regarding the risk of species extinction;
- interactions between genetic and morphological variations;
- understanding assemblages and distributions when the representativeness of survey is arguable and many species are sampled infrequently;
- difficulties with access to the subterranean environment (e.g. requirement for drill holes or bores) and surrounding areas for comparison as part of assessment;
- distinguishing environmental impacts from background environmental variability; and
- inconsistency between existing guidance for subterranean fauna and other EPA policy (notably that relevant to short range endemic invertebrates).

The EPA has identified the need to adopt a more strategic and risk-based approach to the assessment of impacts on subterranean fauna. This discussion paper examines options for future directions in assessment and how this may be applied.

The EPA proposes using information on the distribution and population structure of widespread species as surrogates and the extent of relevant habitat to demonstrate landscape and genetic connectivity. Multiple lines of evidence and on-ground survey (although perhaps different from that which is undertaken currently) would be necessary to satisfy the EPA that subterranean species are not restricted to an area impacted by development. The EPA is also considering a strategic approach which could use regions or geology to predict the likelihood of finding subterranean fauna (consistent with the approach for short range endemic invertebrates). Requirements for information during assessment could be based on regional context, type of impacts and existing site knowledge about subterranean fauna, but this would likely result in significant differences across WA.

This discussion paper forms the basis for a stakeholder comment process to determine direction and content for a future Environmental Assessment Guideline, which will provide advice to proponents on future EPA requirements (including specific procedures, methodologies, minimum requirements, when a strategic approach would be appropriate and managing uncertainty) where subterranean fauna is a likely to be an environmental factor.

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Appendix 2: Subterranean Threatened Ecological Communities of WA

Appendix 3: Summary of major EPA decisions, Ministerial decisions and conditions where subterranean fauna is a relevant environmental factor

1.0 Introduction

Subterranean fauna have long been studied in other parts of the world, but their importance has only recently been appreciated in Western Australia.

The EPA is responsible for providing advice to the Minister for Environment regarding the environmental acceptability (or otherwise) of significant development proposals. This responsibility requires assessment of environmental impacts on a wide array of environmental factors, one of which is subterranean fauna. The EPA has identified the need to adopt a more strategic and risk-based approach to the assessment of impacts on subterranean fauna.

The EPA has convened an advisory group to assist with providing direction and guidance on the adoption of a more strategic and risk-based approach for assessing proposals where subterranean fauna is a factor. The five member advisory group comprises Dr Paul Vogel, Chairman EPA; Dr Rod Lukatelich, member EPA; Prof. Lyn Beazley; Prof. Linc Schmitt and Dr Mark Harvey.

This discussion paper summarises developments in subterranean fauna science, how the EPA's assessment of subterranean fauna has changed over time, concerns with current EPA guidance statements, and provides some options for the future direction of subterranean fauna assessment. It is divided into three parts:

- current knowledge and scientific research;
- existing legislative, policy and environmental impact assessment frameworks; and
- options for future direction in the assessment of impacts on subterranean fauna.

The EPA provides detailed guidance in Environmental Assessment Guidelines (EAGs, formerly known as Guidance Statements) in relation to the practice, procedures, and requirements to be met by proponents. It is anticipated that the existing guidance statements relevant to assessment of subterranean fauna (54 and 54a) will be replaced with an EAG in 2012.

2.0 Current knowledge

2.1 Definition of subterranean fauna

Subterranean fauna are defined as fauna which live their entire lives (obligate) below the surface of the earth (EPA 2003a). They are usually divided into two groups:

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

Fauna that use a subterranean or cave environment for only part of the day (e.g. soil-dwelling and burrowing species or cave-dwelling bats or birds) are not defined as subterranean fauna. Subterranean fauna often display evolutionary adaptations to underground life, particularly reduced pigment and reduced, poorly functioning or non-existent eyes.

The EPA recognises that it is difficult to draw boundaries around fauna groups found in continuous environments. In particular, the term stygofauna has been applied differently across ecosystem types (Tomlinson & Boulton 2008) but, for the purpose of consideration for environmental impact assessment, the EPA accepts a wide definition of stygofauna that includes all species found in groundwater. However, primary concern regarding impacts on subterranean fauna is for those stygofauna which are restricted to groundwater and not those that occur in both subterranean and surface water habitats.

Other fauna groups (such as those with restricted ranges in surface waters) are included in other guidance statements and policies.

2.2 Key taxonomic groups

Examples of subterranean fauna are found within a large number of invertebrate fauna groups, and invertebrate groups dominate the subterranean fauna of WA. Crustacean groups including subterranean representatives are remipedes, ostracods, isopods, copepods, syncarids, amphipods and decapods. Hexapod groups include Blattodea (cockroaches), Orthoptera (crickets), Coleoptera (beetles), Hemiptera (bugs), Thysanura (thrips), Diplura and Collembola (springtails). Subterranean arachnid groups include Araneae (spiders), pseudoscorpions, schizomids, Trombidiformes (mites), Opiliones (harvestmen), and scorpions. Myriapod groups are also represented – diplopods (millipedes) and chilipods (centipedes). Oligochaete, polychaete and aphanoneuran worms are represented. Two main gastropod groups are known to include subterranean fauna - Neotaeniglossa (family Hydrobiidae) and Basommatophora (family Planorbidae). Stygofauna communities are often dominated by crustaceans whereas troglofauna can include a wide range of taxonomic groups which have adapted to underground life.

Vertebrates are rarely recorded as subterranean fauna in WA, however are known from Cape Range, Barrow Island and a mainland Pilbara site. Three fish are recorded - two gudgeons and an eel, and there is some evidence of a subterranean reptile but this has not been formally recorded.

2.3 Why are subterranean fauna important?

Subterranean communities share the following characteristics (from Gibert & Deharveng 2002):

- High endemism but low local diversity relative to regional diversity;
- A relatively small number of genetic lineages resulting in species which look dissimilar to related groups;
- Many relicts from previous climatic conditions; and
- Truncated food webs

The importance of retaining subterranean fauna biodiversity lies in preserving both the ecosystem function and intrinsic values. However, it is vulnerable to impacts due to limited distribution and specialised habitats of ancient evolutionary origin which has resulted in generally high rates of endemism. There are many motivations for human interest in conservation of biodiversity such as cultural, scientific and economic values. These can be broadly described as “use values”, i.e. interest in conservation is in retaining functions for direct use as well as “non-use values” such as ecological function (Boulton *et al.* 2008).

2.4 Geology and groundwater

The presence of subterranean fauna is strongly linked to underlying geology and hydrology, and the availability of suitable micro-habitats. Geology is influenced by chemical and physical processes occurring over time and shows evidence of past climatic conditions (Butt & Zeegers 1992). Schmidt *et al.* (2007) examined the influence of different types of groundwater exchange on faunal assemblages found in a Swan Coastal Plain catchment in WA. The hydrological exchange was largely governed by pore space (thus by geological formation) and different geological formations did not lead to hydrochemically distinct groundwater zones.

The geology of areas in which subterranean fauna are currently found provides clues about their evolutionary origins. Subterranean environments allow the avoidance of surface climatic conditions (Hancock *et al.* 2005) and therefore the fauna can be considered “time capsules” which offer a link to previous mesic climatic conditions. It is thought that subterranean fauna often occupy current palaeodrainage channels or underground interstitial spaces because these are the last remnants of mesic areas since the aridification of the Australian continent.

Subterranean fauna species usually have small distributions and do not move outside their specific habitats due to poor dispersal ability and the discontinuous nature of their habitats. Where underground geology allows the passage of fauna, movement is possible within habitats. Halse *et al.* (2002) suggested that subterranean aquatic fauna distributions ranged from directly under stream beds to groundwater, and species ranged from widespread to locally restricted. Subterranean fauna habitats also vary vertically, such as stratification in water columns or varying humidity levels with depth.

The relationship between hydrogeology and groundwater ecology has been established and the requirements and tolerance limits of subterranean species differ from those found in surface water species (Humphreys 2009). Aquifers have low concentrations of nutrients and carbon, limited dissolved oxygen and no light (Hancock *et al.* 2005; Humphreys 2009). Stygofauna assemblages have been found to be strongly linked to abiotic features including dissolved oxygen, land-use, and temperature (Schmidt *et al.* 2007). Water chemistry and ionic balances are important for stygofauna, particularly as many require the presence of appropriate pH and minerals (such as calcium for the formation of shells in ostracods) (Humphreys 2009). Subterranean terrestrial environments also tend to have very high humidity.

Subterranean ecosystems are thought to have reduced habitat diversity compared to terrestrial systems, mainly due to the absence of vegetation (Gibert *et al.* 1994). Physical heterogeneity exists as a consequence of geology and hydrology and community dynamics reflect the collective responses of organisms to their environmental conditions (Gibert *et al.* 1994). In some cases, there is separation of groups of organisms that occur close together as a result of different environmental conditions. For example, at Cape Range, it is likely that the perched fresh waters within Cape Range and the coastal aquifer do not connect and thus the subterranean fauna present appears to be restricted to the low salinity waters, although this may be an artifact of inaccessibility to sample marine waters (Knott 1993). Subterranean fauna assemblages have been found to occupy different niches defined by abiotic conditions (salinity, temperature, dissolved

oxygen, and precipitation rates) although some species displayed a range of tolerances (Schmidt *et al.* 2007).

Some groundwater-dependent ecosystems occur in the subterranean environment. These may be comprised of aquatic fauna or include troglodfauna which are dependent on humid conditions caused by proximity to groundwater (Tomlinson & Boulton 2008). Humphreys (2006) described the diverse subterranean faunas of karst, alluvial and fractured rock aquifers as the ultimate groundwater-dependent ecosystem because of their stability and reliance on hydrogeology.

Subterranean fauna is known from both karst and non-karst geologies, in areas where physical and chemical weathering over time has allowed formation of suitable habitats.

2.4.1 Karst

Karst geology results from weakly acidic water acting on weakly soluble bedrock, where the acidic water begins to dissolve the rock along fracture lines or at the bedding plane of bedrock. Over time the fractures increase in size and allow the underground drainage of water and accelerated formation of underground features. Karst geology extends above and below ground with features that include enclosed surface depressions (dolines), cave fissures, solution pipes, subterranean streams, and small interstitial spaces which provide habitat for fauna and ecological communities either above or below the watertable (EPA 2008a).

Areas of hard and soft rock karst geology (limestones) in WA include the Nullarbor Plain, Cape Range/Exmouth area, parts of the Kimberley, Swan Coastal Plain and Leeuwin–Naturaliste Ridge (EPA 2008a; Kiernan 2003). The great age of the ancient shield of which much of the Australian continent is comprised has contributed to the relative paucity of karst, and very significant erosion of surface features is evident (Kiernan 2003).

Subterranean fauna have traditionally been studied in limestone geologies where natural features such as caves have provided access to the subterranean environment. Anchialine systems are karst features which are not connected to the ocean but are influenced by tides, and tend to be stratified, showing a variety of salinity, temperature and biological gradients (Humphreys 2006; Humphreys 1999b). Anchialine systems are known from Cape Range, Barrow Island and the Pilbara coast (W.F. Humphreys pers. comm.).

Calcretes have been recognised as providing important habitats for subterranean fauna and in the Yilgarn calcrete aquifers some fauna assemblages may have been isolated between five and eight million years ago (Humphreys *et al.* 2009). These are areas of deposited calcium carbonate sedimentary rock that form by precipitation of shallow groundwater along the paleodrainage channel flow paths (Leys *et al.* 2003) immediately upstream of salt lakes (Humphreys 2009). The calcretes contain steep biogeochemical gradients (analogous to estuaries) which influence microbiological and invertebrate communities (Humphreys *et al.* 2009). Calcrete aquifers are effectively isolated from each other, which has resulted in the evolution of very diverse stygofauna assemblages (Cooper *et al.* 2007; Humphreys *et al.* 2009). Despite isolation and changes to climate and surface water, these assemblages have persisted in situ for very long periods of time (Guzik *et al.* 2011).

Karsts are particularly sensitive environments as they have a low capacity to cope with disturbance, and are difficult, if not impossible, to restore if degraded (Hamilton-Smith *et al.* 1998). The porous nature of the rock and movement of groundwater can easily transport contaminants or sediments from the surface to subterranean environments.

Locations of karst geologies in WA are shown in Figure 1 (limestones) and Figure 2 (calcretes).



Figure 1: Location of hard and soft rock karst geologies (limestones) in Western Australia (redrawn from Keirnan 2003)

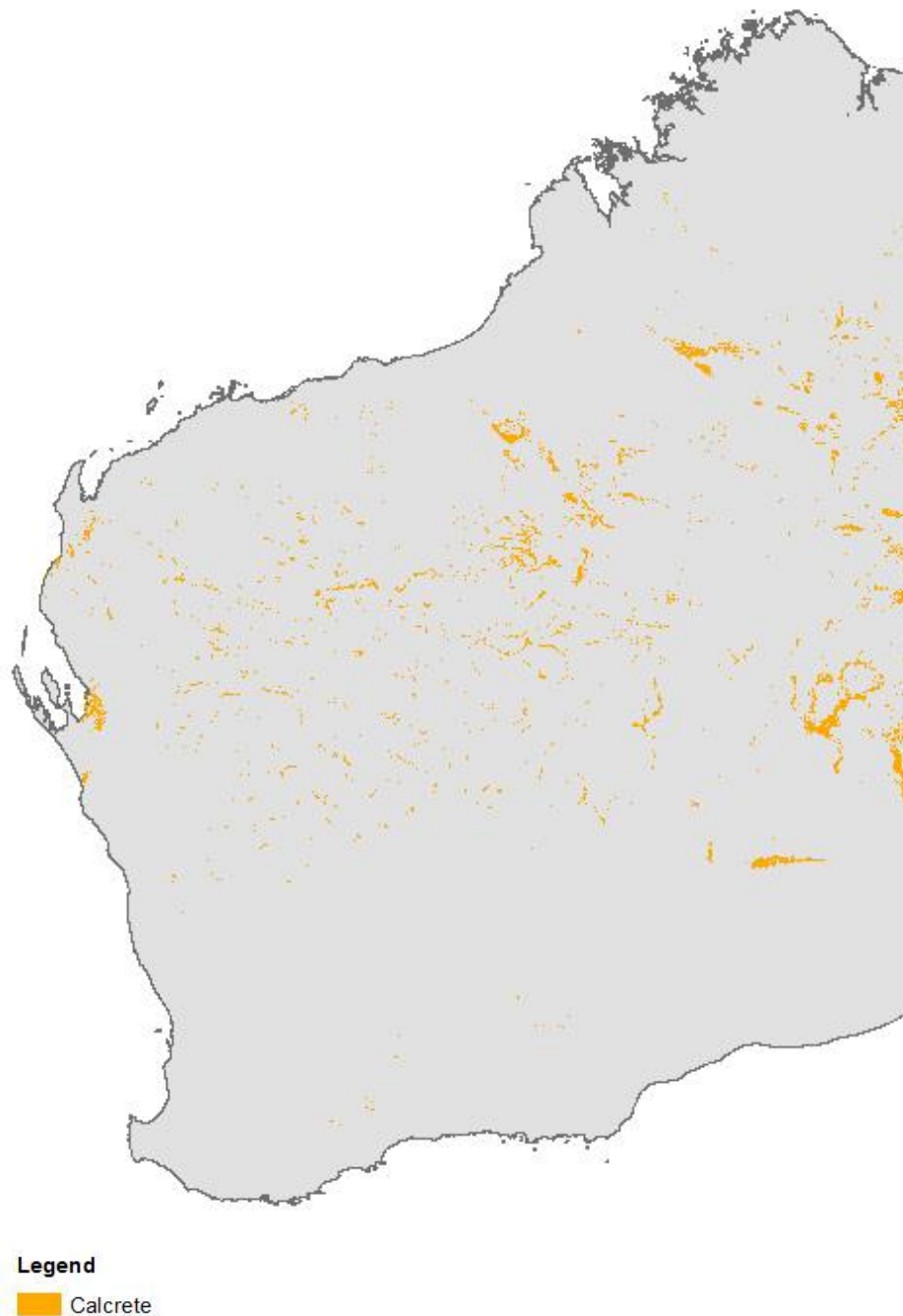


Figure 2: Locations of calcretes in Western Australia

2.4.2 Non-karst

Subterranean fauna also occur in non-karst environments, notably banded iron formations, alluvium and fractured rock aquifers.

Banded iron formations are thought to have originated in oceans where seawater high in dissolved iron and silica came into contact with water containing higher amounts of oxygen, which resulted in the precipitation of hematite and chert (microcrystalline quartz) (WA Museum, no date). Sediment laid down in alternate layers has resulted in bands of minerals. The Pilbara region (see also

section 2.9.3) contains the thickest and most extensive rocks of this type in the world, estimated to have been deposited about 2470 to 2450 million years ago. Banded iron formations are also found as more isolated outcrops throughout the Yilgarn region. Paleodrainage channels and vuggy geologies provide habitats for subterranean fauna.

Subterranean fauna have also been found in alluvial deposits such as the Robe and Fortescue deltas in the Pilbara and the Perth Basin and very high species richness has been recorded (up to 20 species in one bore) (Humphreys 2006; Eberhard 2005a). Fractured rock aquifers are also recognised as important habitats for subterranean fauna, and the use of bore holes for sampling has allowed more access to these systems (Humphreys 2006). Locations of banded iron formations in WA are included in Figure 3.

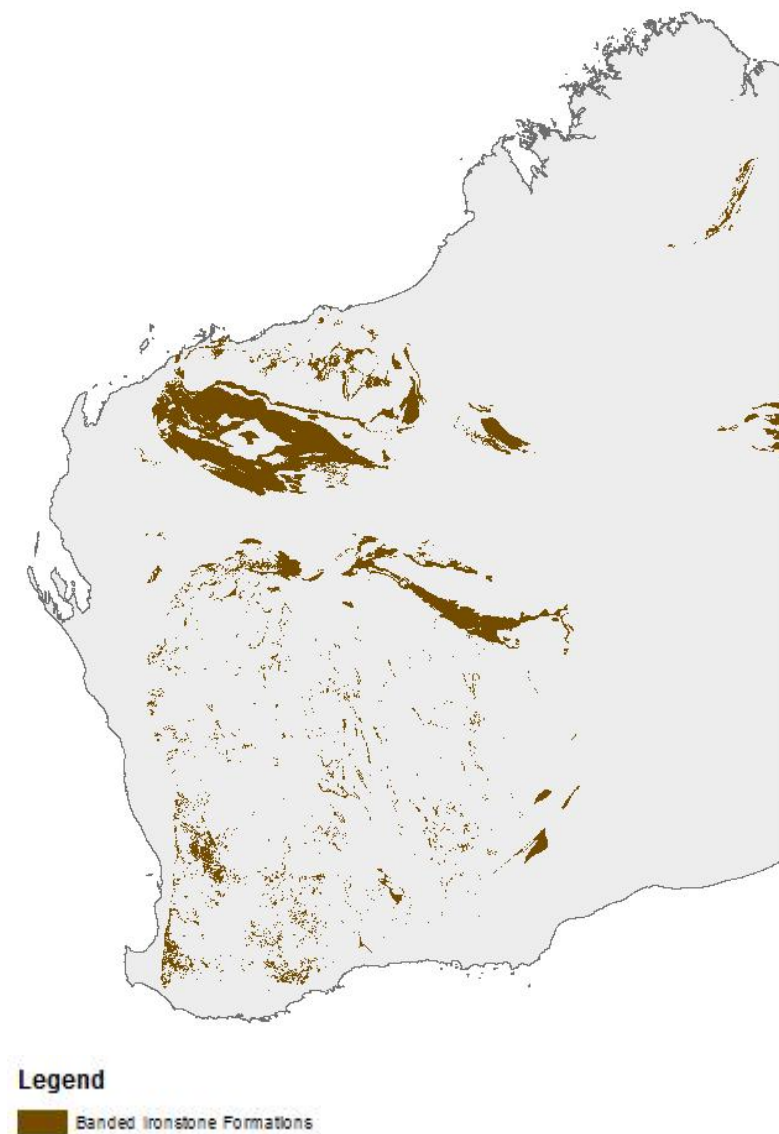


Figure 3: Locations of banded ironstone formation geologies in Western Australia

2.5 Origins of subterranean fauna

There are two main hypotheses regarding the origins of subterranean fauna which account for the observed species diversity and vicariant distributions. These hypotheses are not mutually exclusive:

1. Adaptive shift, where a surface species has pre-adaptations which allow it to expand into subterranean environments (such as in Buhay & Crandall 2005) thus inferring that subterranean species are descended from previous surface or aquatic fauna. Changed climatic conditions at the surface may cause significant changes to surface fauna.
2. Subterranean environments acting as below ground “islands” providing a mechanism for genetic isolation and evolutionary radiation.

Adaptive shift and evolutionary response can be seen in the following examples in WA:

- Troglifauna of the Nullarbor Plain have been described as survivors of evolutionary processes of genetic reorganisation that has preserved a tiny sample of the late Tertiary/Pleistocene surface fauna, which is now almost entirely absent from the region (Davey *et al.* 1992);
- Many examples of troglifauna at Cape Range (Humphreys 1993);
- Current distribution of schizomids across northern Australia, with some subterranean and some rainforest species indicating that although current subterranean species are now found in semi-arid areas, they are descendent from species similar to those occupying rainforest leaf litter (Harvey *et al.* 2008);
- Crangonyctoid and Chiltonid amphipods in the Yilgarn region calcretes, where changes to palaeodrainage channels over geological history appear to have prevented gene flow between calcretes and supports the hypothesis that colonisation originally occurred from surface waters, although further work is needed to show this conclusively (Cooper *et al.* 2007);
- Diving beetles in the Yilgarn region where most individual calcrete aquifers contain an assemblage of diving beetle species of distantly related lineages and/or a single pair of sister species that significantly differ in size and morphology indicating multiple independent origins (Leys *et al.* 2003). The climate and geology of the Pilbara region have remained relatively unchanged for 100 million years, and it is likely that ancient river systems would be the source of aquatic species now found in groundwater (Finston *et al.* 2007).

The alternative “island” hypothesis is supported in the following example:

- Stygofauna assemblages of two extensively sampled calcrete aquifers in the Yilgarn region found preferred pockets of habitat and complex connectivity such that there was evidence of genetic isolation over very short spatial scales, seemingly indicating diversification in situ (Guzik *et al.* 2011).

The current distributions of related subterranean fauna can be very disjunct on a world scale, indicating relationships from land masses and continental movements in geological history. For example, the Cape Range remipede is the only known example of the group in the southern hemisphere, with its closest relatives found around the Caribbean (Yager & Humphreys 1996; CALM undated a). An endemic WA subterranean shrimp (genus *Stygiocaris*) exhibits affinities (through nuclear and mitochondrial DNA analyses) with a sister genus found in Mexican caves, but is not related to numerous surface and cave atyids from Australia or the Indo-Pacific region (Page *et al.* 2008). These animals represent links to the time when Australia was part of Gondwanaland, bordered by the Tethys Sea (Humphreys 1999a), and was subsequently separated by plate tectonic movements (Page *et al.* 2008). In the Kimberley region, subterranean isopod species

present in limestone fossil reefs are thought to be relictual from freshwater species in the Devonian period (Wilson & Ponder 1992), while calcrete aquifers of the arid zone represent evolution within groups of surface fauna that became isolated with climate change (Humphreys *et al.* 2009).

Remnant fauna demonstrates remarkable persistence, and also shows that subterranean environments are likely to have been invaded and colonised many times, leading to the assemblages now observed.

2.6 Ecology of subterranean ecosystems

Invertebrates have been described as “the little things that run the world” (Wilson 1987), and this includes those living in subterranean environments. Recognition of their diversity, abundance, biomass and the ecological services they provide has increased over time but is still not well understood (Wilson 1987).

Research is increasingly showing that subterranean habitats contain many more species than previously recognised and are a significant proportion of global biodiversity (EPA 2007a; Gibert & Deharveng 2002). In recent years, understanding of subterranean groups has significantly increased in WA, mostly focused on the description of new species and determination of evolutionary relationships. However, many aspects of ecology, such as trophic, reproduction and dispersal systems are not well known for most subterranean groups. A summary of current information is presented below.

2.6.1 Trophic systems

The lack of light in subterranean ecosystems precludes primary producers, and food webs are usually simple with few trophic links – the fauna are either predators or detritivores (Gibert *et al.* 1994; Gibert & Deharveng 2002). Food resources may be scarce (in comparison to surface ecosystems) and reliant on organic material (such as dissolved or sedimentary organic carbon) and water flows from the surface environment (Gibert *et al.* 1994; Humphreys 2009) or in some cases on chemo-autotrophic generation (Boulton *et al.* 2008; Humphreys 2009). Aquifers tend to have low dissolved oxygen, and many stygofauna are known to tolerate low oxygen environments but not severe hypoxia (Gibert & Deharveng 2002), however some subterranean fauna in WA have been found in groundwater with dissolved oxygen concentrations close to anoxia (e.g. Schmidt *et al.* 2007). Groundwater may also be subject to high or low concentrations of other nutrients or dissolved salts or gasses dependent on local hydrogeology.

Bacteria are also present in many subterranean ecosystems and form biofilms at interfaces where water and geology meet, providing a food source for stygofauna (Boulton *et al.* 2008). Interaction and nutrient exchange occurs between stygofauna and bacteria through feeding and respiration.

Chemo-autotrophic systems are present at Bundera Sinkhole in Cape Range and at some Nullarbor caves (Humphreys 1999b; Eberhard & Moulds 2007) where anaerobic bacteria use alternative metabolic pathways (such as sulphur) to provide energy inputs. Detailed study of Bundera Sinkhole has shown stratification for dissolved oxygen, temperature, salinity (Humphreys 1999b) and microbial communities (Seymour *et al.* 2007) but stratification of groundwater/aquifers has not been well studied elsewhere.

Guano is known to provide a major energy input to cave systems, however caves containing guano are relatively rare in WA, although some do exist in the Nullarbor, Jurien Bay and Christmas Island (Moulds 2004). In WA caves, major contributors to guano deposits are birds, bats and crickets, and some invertebrate species are known to specialise in these habitats (Moulds 2004). Subterranean fauna can feed directly on guano or associated fungus or be predators.

Aquatic root mat communities are an exception to the generally low productivity of WA subterranean ecosystems. They are very diverse, with 41 species recorded in a 20 m length of cave stream in Yanchep, however most of the species are not considered to be obligate subterranean (Jasinska *et al.* 1996). The tree roots and associated mycorrhizal fungi provide habitat and a food source for subterranean fauna.

2.6.2 Reproduction

It is thought that stygofauna have slow metabolism, are long-lived and slow-growing, and have few young (Gibert & Deharveng 2002; Hancock *et al.* 2005). Subterranean fauna typically have no resting or dispersal stages (Humphreys 2009) but the life-histories of WA subterranean fauna have not been studied.

2.6.3 Dispersal

Vicariance and dispersal are both important in understanding the distributions and spatial patterns of species richness of subterranean fauna (Culver *et al.* 2007). Changes in sea level over time are thought to have led to current distributions of stygofauna (many with marine origins) around the Mediterranean, especially Slovenia (Culver *et al.* 2007). However, elsewhere (such as in the USA) the species richness cannot be explained by vicariance and it is likely that geologies favouring development of subterranean fauna over time provided opportunities for expansion into underground systems (Culver *et al.* 2007). Christman *et al.* (2005) found that, somewhat paradoxically, opportunities for migration measured by number of caves in an area increased the number of single-cave endemic troglotauna found. There may be an optimum level of cave/void density for speciation to occur (Christman *et al.* 2005).

Humphreys (1991) conducted an experiment in a cave at Cape Range to re-establish a depauperate terrestrial troglotauna community and examine succession in a pulse-driven environment. At Cape Range, the influx of water and organic matter is highly variable and there may be no inputs for many years. A cave was provided with an artificial water supply and organic matter (leaf litter) and monitored to determine the rate and process of colonisation. Areas that had both water and organic matter were rapidly colonised by cave fauna, compared to those areas without. The proportion of predator species in the cave community was very high and Humphreys (1991) concluded that the ability of fauna to colonise resource areas from within the same cave or adjacent caves was largely stochastic and took place through immigration of adults and sub-adults.

Trontelj *et al.* (2009) examined the ranges of European large stygofauna and cryptic diversity (i.e. morphologically similar animals which are genetically diverse). Many of the stygofauna studied were able to disperse (despite non-continuous habitats) but also others seem confined without obvious boundaries. More than 10% of the species examined occupied relatively large ranges from several hundred to over 2000 km in length but their dispersal and long-term gene flow mechanisms were unknown. Conversely, where the DNA analysis indicated cryptic lineages, 94% had ranges of less than 200 km in length, and half were recorded at single sites only.

2.6.4 Gene flow within subterranean habitats

There are two main methods for describing gene flow within a subterranean population (Gentile & Sbordoni 1998):

- Direct - attempts to estimate gene flow by measuring dispersal of individuals; and
- Indirect - estimate gene flow from the spatial distribution of gene frequencies, under the assumption that there is a balance between drift and gene flow.

Estimates of population sizes and distributions for subterranean animals are subject to many potential sources of error, such as difficulties with understanding movement patterns, sampling and ecological roles. Therefore, for subterranean species, indirect methods are preferred, even though they are based on some assumptions (for example, regarding the model of population structure, the action of selection, and the sampling strategy) (Gentile & Sbordoni 1998).

Troglofauna within a cave system may show very different levels of gene flow, and Caccone (1985) attributed this difference to both the habitat type (i.e. cave system) and dispersal abilities and behaviour. In general, subterranean species displayed less gene flow than epigeal species, however complex divisions below the species level confounded results for some species (Caccone 1985). Table 1 provides some examples of findings of studies examining gene flow in subterranean environments, particularly where examples of (relatively) widespread species of invertebrates have been used.

Table 1: Examples of studies of gene flow in subterranean invertebrates

Type of organism/s and location	Method of analysis	Major findings	Authors
Isopod woodlouse. Humid edaphic environments and natural and artificial caves across Central Europe, Great Britain, Italy and North Africa.	Two indices and the private alleles method, studied in central Italy	Expectation of high gene flow based on lack of morphological variation. However results show populations are isolated with high degree of genetic differentiation among populations independent of geographic distance. The absence of gene flow reveals an important role played by geographic isolation in determining evolutionary divergence between populations.	Gentile & Sbordoni 1998
Myriapods (millipedes) at Cape Range;	Allozyme analysis of 18 loci for allele frequencies	Three geographical separations were identified showing where one endemic species (<i>Stygiochiropus communis</i>) does not show evidence of gene flow between any of the three provinces and inferring that there is no subterranean connection between the provinces.	Humphreys and Adams 2001
Troglofauna at Cape Range – isopod, schizomid, millipede, amphipod, cave shrimp, fish	Allozyme characterization	Wide ranging levels of genetic divergence exhibited between populations, depending on predicted time of isolation, the potential for gene flow between localities and the number of cryptic species present in the sample.	Adams and Humphreys 1993
Two widespread endemic Pilbara subterranean amphipod genera <i>Pilbarus</i> and <i>Chydaekata</i>	Mitochondrial DNA used to examine the relationships between drainage patterns and genetic diversity.	No evidence of contemporary gene flow among populations of either genus, and each tributary (of three river basins) contained highly divergent lineages, which were not associated with similar morphological differentiation. Cryptic speciation is suggested,	Finston <i>et al.</i> 2007

Type of organism/s and location	Method of analysis	Major findings	Authors
		resulting in the lack of congruence between molecular diversity and morphology.	
Three taxa of large stygobiticray fishes, genus <i>Orconectes</i> inhabiting karst groundwaters of the southeastern United States	extensive geographic sampling and molecular data	Subterranean crayfish species have attained moderate to high levels of genetic diversity over their evolutionary histories with large population sizes and extensive gene flow among karst systems.	Buhay &Crandall 2005
Two species of cave-dwelling amphipods were examined for genetic relationships in a karst region in WA	Allozyme electrophoresis of surface water and cave-dwelling amphipods	<p>Contemporary populations of <i>Perthia</i> sp. 1, in geographically and hydrologically separated areas (Calgardup Cave, Strongs Cave, and the Jewel Cave karst system) are also genetically isolated from each other.</p> <p>The population in the Jewel Cave karst system was genetically isolated from populations in nearby springs and surface waters in adjacent catchments.</p> <p>Populations in the Jewel and Strongs cave systems displayed significantly reduced levels of genetic variability when compared to non-cave dwelling populations in nearby surface streams and springs, but the Calgardup Cave population did not display reduced levels of genetic variability (probably because the cave drainage system is less isolated from surface waters).</p>	Eberhard <i>et al.</i> 2005b
Stygofauna were sampled at three sites within the Laverton Downs Calcrete (Yilgarn region of WA)		<p>Connectivity within the aquifer was complex and likely to vary over time depending on the levels of groundwater and potential barriers.</p> <p>Different species assemblages were found at the three sites. Some species were found at all three, however there was clear potential for population genetic fragmentation within the calcrete. Below species-level genetic divergence was observed in some widespread species (notably isopods and amphipods), and different tolerances</p>	Guzik <i>et al.</i> 2011

Type of organism/s and location	Method of analysis	Major findings	Authors
		of physiochemical conditions were recorded.	

2.7 Ecosystem services

Extrapolation from the study of surface waters suggests that stygofauna have important ecosystem service functions, such as the maintenance of water quality in groundwater aquifers (EPA 2003a). Subsurface groundwater-dependent ecosystems provide four types of ecosystem services: provisioning, supporting (e.g. bioremediation, nutrient cycling, sustaining linked ecosystems, providing refugia), regulating (e.g. flood control and erosion prevention) and cultural (e.g. religious or scientific values, tourism) (National Water Commission 2008). In WA, groundwater is important for drinking water, irrigation, stock and industrial use (EPA 2003a).

There are few studies on the consequences of the loss of subterranean species on ecosystem function and services. However Boulton *et al.* (2008) indicated that species loss in terrestrial plant communities leads to a reduction in ecosystem function, and it is likely to be similar for subterranean systems.

2.8 The challenge of defining species

Species can be difficult to define where morphological characteristics are at variance with genetic information (EPA 2007a), and this issue is particularly pronounced for invertebrate subterranean fauna. Cryptic species (that look morphologically similar but are genetically distinct) can also contribute to taxonomic difficulty. EPA Guidance Statement 54a *Sampling methods and survey considerations for subterranean fauna in Western Australia* considered that the biological species concept as described by Paterson (1992) provided a useful framework for species conservation - a group of organisms that share the same mate recognition system and which, if occurring together, will interbreed. However, this concept of species definition is confounded for subterranean fauna as little specific life history and reproductive data are known, therefore it is hard to verify whether genetic and/or morphological species have the capacity to interbreed. Adaptation to the subterranean environment may lead to major modifications in morphology and convergent evolution can mask species differences or lead to problems in the classification of species (Bradford *et al.* 2010).

It may be a reasonable proposition that DNA analysis can use mutation rates and extent of variation to identify differences within and between species. An absence of gene flow strongly suggests that populations belong to different species (EPA 2007a). This situation can occur when populations are separated by long-term geological barriers (such as lack of suitable habitat for subterranean fauna) and genetic divergence is expected independent of whether speciation has occurred. However this approach leads to problems in understanding the differences in DNA sequences – the boundaries for inter- and intra- species variation may be complex. A combination of morphology and molecular analyses may be required to identify and discover many cryptic stygofauna (Bradford *et al.* 2010 and references cited therein).

The procedure of DNA barcoding has been investigated as a method of rapidly determining the species present in a sample and also differentiating any cryptic species (e.g. Bradford *et al.* 2010). In the Yilgarn region, a large number of unique calcrete communities have been described, however progress on understanding species differences in some of the groups (such as amphipods) has been impeded by their cryptic morphology (Bradford *et al.* 2008). A group of amphipod species (originally thought to comprise a single species based on morphology), has been subject to DNA analysis. Results showed there was reproductive isolation within the

amphipod group, with those found in WA's Yilgarn region more closely related to mound spring species from South Australia and species found at a distance of hundreds of kilometres than to amphipods of very similar appearance within the same or neighbouring calcrete system.

While DNA barcoding provides some promise for identifying species based on genetic material, it is likely that the EPA will continue to face challenges in understanding species-level diversity, especially in relation to extinction risks.

2.9 Survey and knowledge

Traditionally, arid and semi-arid areas have been considered poor potential habitat for subterranean fauna as organisms are moisture-dependent and the length of time since surface aridification occurred has been in the order of millions of years (Harvey *et al.* 2008). However the recent descriptions of subterranean fauna in the arid zone of WA have indicated the presence of a diverse fauna.

Guzik *et al.* (2010) posed the question “is the Australian subterranean fauna uniquely diverse?” and estimated that 4140 subterranean taxa are found in the western half of Australia, mostly in the arid and semi-arid regions. A total of 403 species are currently described and an additional 367 are known but not described. Based on this estimate, over 80% of the fauna likely to be present has not yet been documented (Guzik *et al.* 2010). While the potential scale for unique diversity in Australian subterranean fauna is not known, the summary (Table 2 below) is a collation of regional and continental scale counts and estimates of diversity taken from a series of publications. Thus the estimate provided by Guzik *et al.* (2010) seems to indicate that the Australian (and particularly WA) fauna is uniquely diverse. In addition, the rates of endemism and short ranges are high (Harvey 2002).

Table 2: Collation of counts and estimates for subterranean biodiversity

Region/Country	Number of taxa	Count/Estimate?	Authors
Australia (whole)	At least 750	count	Humphreys 2008
Australia - western half	4140 770	estimate count	Guzik <i>et al.</i> 2010
Australia - NSW	422 invertebrate subterranean fauna but only 83 are obligate subterranean	count	Thurgate <i>et al.</i> 2001
Australia – Pilbara region of WA	78 species of stygofauna known 350 species of stygofauna known after Pilbara Biological Survey 500 – 550 species groundwater fauna	count count estimate	Eberhard <i>et al.</i> 2005a DEC undated a Eberhard <i>et al.</i> 2009

Region/Country	Number of taxa	Count/Estimate?	Authors
Australia - Carnarvon Basin	Approximately 35 species in karst	count	Humphreys 2008
Australia - Christmas Island	6 troglofauna 12 stygofauna	count	Humphreys & Eberhard 2001
New Zealand	130 in ground water	count	Fenwick & Scarsbrook 2004
mainland USA	973 (673 terrestrial and 300 aquatic)	count	Culver <i>et al.</i> 2000
Balkan Peninsula (mostly Western region)	1625 (975 terrestrial, >650 aquatic - species only, subspecies excluded)	count	Sket <i>et al.</i> 2004
Portugal	110	count	Reboleira <i>et al.</i> 2011
Brazil	537 invertebrate taxa and 76 vertebrate taxa from caves (including troglobites, troglaphiles, and troglonexes)	count	Trajano 2000
Puerto Rico	78 species of invertebrates inhabit caves, 23 are endemic to Puerto Rico.	count	Peck 1974
Galapagos islands (Ecuador)	56 eyeless and reduced-eye macroscopic arthropods	count	Peck 1990

The first subterranean fauna described for Cape Range was between 1945 and 1960, however significant research attention has only been applied to the WA fauna since 1988 (Humphreys 1993). Recognition of the importance of subterranean fauna was largely the result of survey work carried out by the WA Museum, initially at Cape Range and then expanding to Barrow Island, the Pilbara and other areas of WA. More recently (since the mid-1990s), stygofauna of WA has been recognised as being of global significance (Humphreys 2008). Regional information is summarised below. Figure 4 shows the Interim Biogeographic Regionalisation of Australia (IBRA) boundaries.



Legend

IBRA Sub-Regions

Figure 4: Western Australian IBRA sub-region boundaries (version 6.1)

2.9.1 Nullarbor

The Nullarbor region is a vast area of tertiary limestone plain with low relief adjacent to the southern Australian coast (Davey *et al.* 1992; McKenzie *et al.* 2004). It is the world's largest contiguous karst area and the largest arid karst.

There has been interest in the natural heritage values of the Nullarbor region for many years. Some troglofauna survey was undertaken, as part of the nomination of the area for World Heritage status, which documented a diverse invertebrate fauna (Davey *et al.* 1992).

Eberhard & Moulds (2007) reviewed existing surveys and data for subterranean fauna on the Nullarbor and found 200 karst features with subterranean fauna records. Approximately 90% of the records were for invertebrates. Conservatively, 178 species of subterranean fauna were recorded, however species counts and analysis were confounded by records of epigeal species thought to have been washed in to cave systems, and many of the records did not identify specimens to genus or species level. The most diverse cave system was Cocklebidy (47 species), with five

caves having 30 or more species. However, fauna was only recorded from approximately 7% of the known karst features with a mean richness of five species per site.

Nullarbor stygofauna is depauperate, with only one species described (an amphipod), although several others are reported to be present (Humphreys 2008).

2.9.2 Cape Range and Barrow Island

Cape Range is a peninsula approx 80 km long and 20 km wide on the north western coastline of WA (Allen 1993). The geology of Cape Range is exposed Tertiary marine calcareous sediment and comprised of two main limestone types (underlying Mandu Calcarene which is friable and chalky and overlying Tulki which is hard and nodular) (Playford *et al.* 1975). A thin cap of Trealla limestone is evident on the western side of Cape Range and the drainage systems are deeply incised (Allen 1993). Groundwater is a lens of freshwater over sea water (Allen 1993). The climate is arid with occasional tropical cyclones (McKenzie *et al.* 2004).

The karst of Cape Range has been recently recognised by the inscription of the area on the World Heritage list for landscapes/seascapes and biological diversity values. The highly diverse subterranean fauna was noted for being comprised of rare, relictual, and taxonomically diverse species not found elsewhere (UNESCO 2011).

The significance of Cape Range subterranean fauna was first recognised in the early 1990s when significant survey effort was undertaken (especially by the WA Museum) and when a biogeography symposium and resulting publications publicised the high proportion of endemic species of both troglotauna and stygofauna (Humphreys 1993), the presence of subterranean fish, the only known troglobitic vertebrates in Australia (Humphreys & Adams 1991), and genetic and geographic separations of troglotauna and stygofauna (Knott 1993; Adams & Humphreys 1993; Humphreys & Adams 2001). Approximately 35 species of subterranean fauna have been recorded from karsts in the Carnarvon Basin (Humphreys 2008). Bundera Sinkhole and Cameron's Cave are significant karst features in Cape Range and contain distinctive and significant subterranean fauna (Kendrick & Mau 2004).

The first management plan for Cape Range National Park acknowledged troglotauna as one of the conservation and recreation values of the park and importance of maintaining water resources for subterranean fauna habitat (CALM 1987). However since then, knowledge of the very significant biodiversity values of the subterranean fauna has increased and the most recent management plan (2010) focuses on park management to maintain subterranean biodiversity (DEC 2010a).

Barrow Island is biogeographically linked with Cape Range (Kendrick & Mau 2004; Eberhard 2005a) and contains subterranean fauna communities of high conservation significance (Biota & RPS Bowman Bishaw Gorham 2005). At least 34 species of subterranean invertebrates have been recorded from Barrow Island, of which over 20 are endemic to the island (Biota & RPS Bowman Bishaw Gorham 2005; Moro and MacAuley undated). Subterranean vertebrates are also known from Barrow Island including; two subterranean fish species (also found at Cape Range) and potentially a reptile (blind snake). Investigations of subterranean ecosystems at Barrow Island have demonstrated chemo-autotrophic energy generation.

2.9.3 Pilbara

The Western Shield comprising weathered Precambrian rock underlies much of WA and is divided into the Pilbara and Yilgarn blocks (Trendall 1975a). The Pilbara block is comprised of ancient Archaean rock and the surface geology includes sandplain, extensive granitic rock and metamorphic rock (Blockley 1975). The region commonly referred to as the Pilbara also includes the Hamersley Basin and includes geologies rich in iron. The Pilbara has a semi-desert tropical climate, with active drainage from three river systems (McKenzie *et al.* 2004).

A regional biodiversity survey was undertaken for the Pilbara between 2002 and 2007, and included a comprehensive sampling and identification program for stygofauna (over 500 bore sites and 20 wetland springs were sampled) (DEC undated a). The survey sites were selected to represent a cross section of the Pilbara's major geological features and groundwater types (DEC undated a), with the aim of providing a regional context for smaller scale studies.

Prior to the Pilbara Regional Biodiversity survey, only about 40 species of stygofauna were known from the Pilbara, but after the survey, this rose to 350 species (DEC undated a). The estimated total number of stygofauna species for the Pilbara is between 500 and 550 (Eberhard *et al.* 2009). The Pilbara stands out as an area of globally significant stygofauna diversity, although the species-level taxonomy of most groups remains incomplete (see Table 2) (Eberhard *et al.* 2005a). Regional endemism also appears to be significant, including fauna from a variety of evolutionary origins.

A diverse schizomid troglofauna of the Pilbara has been discovered as a result of existing EPA requirements in environmental impact assessment (Harvey *et al.* 2011). This has brought considerable insight to a group of poorly known arachnids. The first WA schizomid species was described in 1988 (from Cape Range), and there are currently 12 described species for the Pilbara, with at least another 15 yet to be described. One schizomid has been removed from the threatened species (WC Act) as it was more widespread than initially thought, but other species which are often confined to individual mesas in the Pilbara are currently listed as threatened.

2.9.4 Yilgarn

The Yilgarn region is extensive, stretching from below the Pilbara, through the arid and semi-arid areas of the midwest, Gascoyne/Murchison and Goldfields. It is comprised of Archaean rocks, predominantly granitoids and the surface geology is gently undulating and deeply weathered (Anand & Paine 2002).

After the Pilbara, the central and northern Yilgarn region is the next best sampled for subterranean fauna and approximately 210 species have been recorded (records are predominantly of a family of predatory diving beetles) (Humphreys 2008).

Investigations of subterranean fauna in the Yilgarn region have focused on calcrete geology. Calcrete aquifers support diverse stygofauna (crustaceans and diving beetles) which are often endemic to the aquifer. Diving beetles (Dytiscidae) in the Yilgarn region display the world's highest known subterranean diversity with individual calcretes containing between one and five unique species (Leys *et al.* 2003). Humphreys *et al.* 2009 examined 107 discrete calcrete bodies from 15 palaeodrainage systems predominantly in the northern Yilgarn area. Stygofauna were found to have convergent characteristics and represent a wide variety of invertebrate families. One stygofauna taxon (genus *Haloniscus*, oniscidean isopods) was found to have an affinity with a species found in surface salt lakes (which has a widespread distribution across southern Australia) (Humphreys *et al.* 2009). The distribution of the surface salt lake species is remarkable because of the isolation of salt lakes and the lack of an aerial phase or resistant egg phase on the reproductive cycle, but numerous *Haloniscus* species occur within calcrete aquifers, with species restricted to single calcrete aquifers and some calcretes having sympatric species). Some calcretes contain marine and near-marine species alongside ancient freshwater lineages.

DNA barcoding has been used in the Yilgarn region to discern morphologically cryptic species (Bradford *et al.* 2010), and genetic information has been used to affirm the isolation of calcrete systems (Guzik *et al.* 2011).

2.9.5 Kimberley

The Kimberley region of Western Australia shows wide geological diversity and varied topography (Thom 1975). It includes the dissected plateau of the Kimberley Basin in the north, siliceous ranges and valleys of Proterozoic sedimentary rocks further south and alluvial plains to the east (McKenzie *et al.* 2004). Climates range from tropical to semi-arid.

The Kimberley region is poorly surveyed but sampling to date has shown that alluvium and karstic limestone, dolomite and sandstone systems, as well as offshore islands in the region, support stygofauna (EPA 2007a). The communities recorded are not as rich as in the Pilbara but this difference may be the result of less sampling effort. However, significant troglifauna communities are likely to occur.

Taxonomically interesting freshwater subterranean isopods were recorded from limestone fossil reefs (Wilson & Ponder 1992). When the isopods were described, the genus could not be assigned to any known isopod suborders or families because it displayed a unique combination of characters. Subsequent discovery of a related group found in deep bores in calcrete aquifers of the Fortescue River drainages in the Pilbara lead to the description of a new isopod family that is endemic to WA (Wilson 2003).

2.9.6 South West

The South West includes a wide range of geologies including coastal limestones, alluvial sand plain and dissected granite in inland areas. The climate ranges from Mediterranean in southern coastal areas to semi-arid inland (McKenzie *et al.* 2004).

Comprehensive surveys of subterranean fauna of the South West have not been conducted, however small areas (notably caves) have been targeted for scientific investigation. Detailed studies have been conducted on the hydrology and fauna of the Jewel Cave karst system (e.g. Eberhard *et al.* 2005b), caves at Yanchep National Park (Jasinska *et al.* 1996), and root mat Threatened Ecological Communities of the Leeuwin Naturaliste ridge and Swan Coastal Plain (DEC 2008; English *et al.* 2003). The root mat communities have been threatened by falling groundwater levels in the caves and bore and watering systems have been used to retain the Yanchep cave root mats (Durrant 2009).

Studies of the Gngangara Mound (underlying the northern part of Perth and forming its major water supply) have been conducted as a result of declining water levels, and have lead to concern about long term persistence of groundwater dependent ecosystems in the area. Biodiversity assessments conducted for the production of the Gngangara Sustainability Strategy included some subterranean fauna and habitats such as the Yanchep cave systems (Durrant 2009) and stygofauna of the Yarragadee and Leederville aquifers.

Stygofauna surveys of the Gngangara Mound have shown that stygofauna do occur within the unconfined aquifer, but species richness is low with 11 species recorded from a moderately extensive sampling program (Bennelongia Environmental Consultants 2008). Sampling of the Yanchep area has also shown low species richness in the area (Bennelongia Environmental Consultants 2008), with the exception of the aquatic root mat communities (threatened ecological community) from which an unusually rich cave fauna of 41 species was reported from a 20 m section of a shallow groundwater stream in a small limestone cave, Cabaret Cave (Jasinska *et al.* 1996).

The first stygofauna records for the Albany region were made during a survey conducted for environmental impact assessment for a magnetite project in 2005 (Rockwater 2006). The survey recorded 15 taxa, with between one and six taxa recorded for those sites where stygofauna were found. Some of those taxa found were known to be common and widespread in WA and two of the taxa were thought likely to have a restricted distribution.

3.0 Legislative and policy framework

A number of State and Commonwealth Acts are relevant to biodiversity conservation in WA and apply to subterranean fauna environmental impact assessment. They are listed and discussed below.

3.1 Legislation

3.1.1 *Environmental Protection Act 1986 (State)*

The *Environmental Protection Act 1986* (EP Act) is the legislation that provides for “the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with the foregoing”. It established the EPA as an independent authority, to make recommendations to the Minister for Environment on the environmental acceptability (or otherwise) of proposals. The Office of the EPA administers and operates under Part IV of the EP Act and its Regulations, and the Department of Environment and Conservation (DEC) has responsibilities under Part V.

If a proposal is likely to have a significant effect on the environment, it may be referred (under section 38 of the EP Act) to the EPA for a decision on whether or not it requires assessment (section 39). If an assessment is required (Assessment on Proponent Information or Public Environmental Review), the EPA takes a number of principles into account (section 4A). Under section 44, if the EPA assesses a proposal, it must prepare a report on the outcome of the assessment for the Minister, including the key environmental factors identified, recommendations on whether or not the proposal may be implemented, and any accompanying conditions. The EPA expects proponents to address impacts on fauna (including subterranean) during the scoping and assessment of the proposal where it is identified as a key environmental factor.

3.1.2 *Wildlife Conservation Act 1950 (State)*

The *Wildlife Conservation Act 1950* (WC Act) provides for the conservation and protection of wildlife, with DEC being responsible for its administration. Notices issued by the Minister for Environment are used to periodically update lists of species recognised under the WC Act, including specially protected fauna. Species appearing on the current list are collectively known as threatened species. The Minister takes recommendations from the Threatened Species Scientific Committee on species which should be listed. Although some fauna has special recognition, the WC Act wholly protects all fauna throughout WA at all times, except if the Minister declares otherwise by notice published in the *Government Gazette* (section 14(1)).

Section 15 of the WC Act provides that the Minister may issue a licence “to take” fauna, which within the context of the Act, means to kill or capture any fauna by any means or to disturb or molest any fauna by any means or to use any method whatsoever to hunt or kill any fauna whether this results in killing or capturing any fauna or not. This definition also includes attempts to take fauna and acts of assistance to others attempting to take fauna. The Minister may impose fines if fauna is taken without a licence. Although it is an offence “to take” fauna without a licence, the habitat for listed species is not protected.

Surveys, including trapping or collecting fauna, for all fauna (subterranean and epigeal) require a licence to take (see section 3.2) and personnel holding a current and applicable Regulation 17 *Licence to Take Fauna for Scientific Purposes* from DEC before beginning each fauna survey (EPA & DEC 2010). A condition on the issue of a licence is the appropriate vouchering of samples through lodgment with the WA Museum.

3.1.3 *Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a framework for protection of the Australian environment, including biodiversity. The EPBC Act includes a range of processes to help protect and promote the recovery of threatened species and ecological communities, and protect significant places from decline. The EPBC Act is administered by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities). Three species and five ecological communities of WA subterranean fauna are listed as threatened under the EPBC Act (and are also listed under the WC Act).

Threatened species and ecological communities are matters of national environmental significance and projects having impacts on these must be referred to the federal environment department, for assessment.

A proposed amendment to the EPBC Act (Protecting Australia's Water Resources bill), if passed, includes requirements for Commonwealth assessment and approval where mining operations would be likely to have a significant impact on Australia's water resources. This may have implications for subterranean fauna which is dependent on groundwater or recharge zones.

3.2 Threatened species and ecological communities

Forty subterranean fauna (two vertebrate and 38 invertebrate) of a total of 233 threatened fauna are currently listed under Schedule 1 of the WC Act (see Appendix 1). The first subterranean species listed under the WC Act were two fish (Blind Gudgeon and Blind Cave Eel) in 1990 and the first invertebrates to be listed for species-level protection under the WC Act were listed in 1994 (*Wildlife Conservation (Protected Invertebrate Fauna) Notice 1994*). No recorded species of subterranean fauna are known to have become extinct in WA.

Ecological communities are defined as naturally occurring biological assemblages that occur in a particular type of habitat (DEC undated b). They are the sum of species within an ecosystem and, as a whole, they provide many of the processes which support specific ecosystems and provide ecological services. As with species, ecological communities can be threatened with extinction. Nine of the 69 Threatened Ecological Communities (TECs) endorsed by the Minister for Environment are subterranean, including aquatic root mat, cave and stygofauna communities (see Appendix 2).

3.2.1 Blind Gudgeons and Cave Eel

The Blind Gudgeon (*Milyeringa veritas*), listed as Vulnerable under both the WC Act and the EPBC Act, is found in groundwaters of Cape Range, Barrow Island and the mainland Pilbara. However, there is almost a complete lack of basic biological information (Humphreys 1999b). The species appears to feed opportunistically, preying on stygofauna and invertebrates accidentally trapped in water.

Genetic studies indicated a different species was present in the southern-most part of the range of the Blind Gudgeon. Although the new species is morphologically similar to *M. veritas*, genetic analysis indicated it was a different species. A new species of Blind Gudgeon (*M. brooksii*) was described in 2010 (Chakrabarty 2010), however the current taxonomy is undergoing revision (W.F. Humphreys, pers. comm.). The conservation status of the newly described species has not yet been evaluated but is likely to be similar to that of *M. veritas*.

The Blind Cave Eel (*Ophisternon candidum*) is also listed as Vulnerable under both the WC Act and the EPBC Act. It is known from Cape Range and has also been anecdotally recorded from Bungaroo Creek near Pannawonica.

3.2.2 Cape Range Remipede Community and Camerons Cave TECs

The Cape Range Remipede Community found at Bundera Sinkhole (near Exmouth) is a unique fauna assemblage. The TEC is Critically Endangered in WA (but not listed under the EPBC Act). One of the species which makes up the community is the Cape Range Remipede (*Lasionectes exleyi*) which is listed as Critically Endangered under the WC Act and Vulnerable under the EPBC Act. It is a free-swimming, segmented crustacean. Bundera Sinkhole is the only known example of a remipede community in the southern hemisphere, with the only other members of its genus found in the Bahamas, Mexico and Cuba (Kendrick & Mau 2004; Yager & Humphreys 1996). The sinkhole provides habitat for a wide range of other crustaceans and two fish (Black *et al.* 2001a).

The Bundera Sinkhole is a water-filled anchialine cave found on the western side of the Cape Range peninsula about 1.7 km inland with subsurface connections to seawater. It contains water that is low in oxygen below a density-induced layer separating surface and deeper waters (Black *et al.* 2001a). Strata which differ in salt concentration, temperature, pH, dissolved oxygen, redox, dissolved inorganic nitrogen series and hydrogen sulphide (Humphreys 1999b) are easily disrupted. Threats to the community include disturbance of the chemico-physical attributes of the water body (for example, by diving), dumping of rubbish or toxic waste in the sinkhole, introduction of exotic species such as fish, and eutrophication or pollution of the water body (CALM undated a). In the longer term, a decline in groundwater quality and levels in the adjoining aquifer could also be a threat. An interim recovery plan has been written to progress the recovery of the TEC.

Camerons Cave is a cave system near the Exmouth townsite that contains a unique assemblage of troglafauna and stygofauna and the TEC is considered Critically Endangered in WA (Black *et al.* 2001a; DEC 2010b). The cave contains a number of endemic and threatened species, including Camerons Cave Millipede (*Stygiochiropus peculiaris*), Camerons Cave Pseudoscorpion (*Indohya gollum*), Blind Gudgeon, a schizomid (*Draculoides brooksi*) (Black *et al.* 2001a). The cave contains the most diverse subterranean fauna assemblage known from Cape Range (Kendrick & Mau 2004).

3.2.3 Aquatic root mat communities (Swan Coastal Plain and Leeuwin Naturaliste Ridge)

There are five different types of invertebrate communities defined as TECs and ranked as Critically Endangered as a result of highly restricted distributions. These communities were formed when living trees above the ground formed root mats within underground cave streams or pools which provide a source of food and habitat for aquatic fauna. The root mat communities have high species richness and abundance with 30-40 species of invertebrates, although many of these also occur in surface water (CALM undated b).

The caves vary greatly in species composition and abundance and in aspects of water quality (pH, temperature, electrical conductivity). The root mat communities are threatened by decline in groundwater levels as many of the species do not have drought-resistant stages and are unable to survive drying (CALM undated b). Causes of declining groundwater levels are likely to be a combination of a drying climate and increased abstraction. Additional threats include the loss of trees and pollution of groundwater. The Crystal Cave crangonyctoid (also separately listed as a threatened species) is one of the component fauna and is a Gondwanan relict (CALM undated b).

3.3 Recovery planning for conservation

Recovery plans (or interim recovery plans) are prepared as part of management of threatened species and communities, usually by DEC and often in conjunction with the establishment of recovery teams and consultation with stakeholders. There are four current interim recovery plans for subterranean TECs – two covering cave communities at Cape Range (Bundera Sinkhole and Camerons Cave) and two covering aquatic root mat communities (Swan Coastal Plain and Leeuwin Naturaliste Ridge) (see sections 3.2.2 and 3.2.3) (Black *et al.* 2001a; Black *et al.* 2001b; English *et al.* 2003; DEC 2008). Although no subterranean threatened fauna have full species recovery plans, some of the interim recovery plans for TECs also cover the threatened species in those communities – a pseudoscorpion and millipede are included in the interim recovery plan for Camerons Cave TEC; a remipede crustacean is included in the interim recovery plan for Cape Range Remipede Community (Bundera Sinkhole).

3.4 Priority species

Species that have yet to be adequately surveyed to be considered for listing as threatened species can be added to priority lists and ranked in order of priority for survey and evaluation of conservation status (priorities 1, 2 or 3), or are in need of regular monitoring (priority 4) or dependant on ongoing conservation actions (priority 5) (DEC 2010c). Two blind snakes known from Cape Range (*Ramphotyphlops* sp 'Cape Range') and Barrow Island (*Ramphotyphlops longissimus*) are listed as priority 1 and 2 respectively and the Cape Range Blind Cockroach (*Nocticola flabella*) is listed as priority 2 (DEC 2010d).

3.5 Priority ecological communities

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the priority ecological community list administered by DEC (DEC 2011). There are three categories in order of priority for survey and/or definition of the community and evaluation of conservation status, so that consideration can be given to their declaration as TECs. There are 83 priority ecological communities defined by assemblages of subterranean fauna, of a total of 284 defined community and sub-community types (DEC 2011). The majority of priority ecological communities are calcrete groundwater assemblages of the Yilgarn region, with 39 found in the Mid-west region and 34 in the Goldfields (DEC regions).

3.6 EPA policy context

The EPA develops various policy and guidance documents, ranging from statutory policy that carries the force of law to documents outlining the EPA's position on different environmental matters, and technical guidance to help proponents during the environmental impact assessment process. A number of EPA policy statements provide direct or indirect advice on subterranean fauna. The two guidance statements focusing on subterranean fauna are:

- *Consideration of subterranean fauna in groundwater and caves during environmental impact assessment in WA* (Guidance Statement 54, 2003) which provides information to proponents about how the EPA will assess proposals where the protection of troglafauna and stygofauna is a relevant environmental factor (EPA 2003a); and
- *Sampling methods and survey considerations for subterranean fauna in WA* (Guidance Statement 54a, 2007) which provides the detail on sampling efforts and methodologies that the EPA considers acceptable as well as reporting requirements (EPA 2007a).

Other policy statements which relate to subterranean fauna include:

- *Environmental guidance for planning and development* (Guidance Statement 33 2008) defined the EPA's expectations on a wide variety of planning issues, and included significant information about karst management and impacts on associated fauna (EPA 2008a); and
- Position Statement 1, *Environmental protection of Cape Range Province* (EPA 1999) identified the importance of the Cape Range area of WA and its significance largely as a result of the diversity of subterranean fauna.

Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (Guidance Statement 20) was produced in 2009 and describes methods for sampling and environmental impact assessment of short range endemic (SRE) invertebrate fauna. While this guidance specifically excludes subterranean fauna (because of the existing guidance statements) the approach used could have application for subterranean fauna, many of which meet the criteria for SREs (see section 4.7).

Figure 5 shows the timeline and context to assist understanding of events and evolution of thinking with respect to subterranean fauna assessment and policy.

The preparation of this discussion paper is the beginning of a process to update Guidance Statements 54 and 54a. Following stakeholder review of the discussion paper the guidance statements will be revised (see also section 5.0).

The major reports and policy documents identified in Figure 1 are summarised below. Case study examples of EPA assessments are summarised in section 4.2.

3.6.1 Karst Management Considerations for the Cape Range Karst Province of Western Australia (1998)

A number of development proposals requiring assessment in the Cape Range area during the late 1990s prompted the then Department of Environmental Protection to commission Hamilton-Smith, Kiernan and Spate to undertake an investigation of the significance of the Exmouth/Cape Range region for karst and karst management issues and prepare a report. The report was to contribute to the development of a policy to guide environmental management and the protection of karst in the context of current and anticipated development proposals. The report and recommendations to the EPA recognised the importance of the area and considered environmental protection and consistent conservation management; maintenance of water quality and quantity; and assessment of environmental impacts resulting from development along with social recommendations.

The importance and uniqueness of the Cape Range area on a world scale was identified (Hamilton-Smith *et al.* 1998). The types of geological features present were explained in detail, along with the movement of water through the karst. Biological values were also highlighted, with particular attention focused on the troglofauna of caves.

Concern was expressed by Hamilton-Smith *et al.* (1998) about the management of the aquifer beneath Cape Range, particularly pumping for human use and the potential for saline incursion under the lens of freshwater if over-extraction was to occur. They noted that there was some evidence over-extraction had already occurred. Management of waste water was also flagged as a particular problem in a karst environment, with high potential for contamination of groundwater but also extra difficulty in implementing solutions (e.g. sewerage). Hamilton-Smith *et al.* (1998) recognised the work that the Water Corporation was undertaking to better understand aquifer behaviour and stygofauna.

Current and proposed developments for Cape Range, notably for limestone quarries, a marina and canals and urban expansions were described by Hamilton-Smith *et al.* (1998). Engineering challenges associated with karst were identified, and potential impacts on subterranean fauna and

the aquifer were thought to be potentially significant. Concern was expressed that proponents had not adequately taken into account siting of quarries, potential for aquifer pollution, potential damage to caves known to contain important fauna, and the inadequacy of water management data (with respect to quarrying activities). The report emphasised the artificial nature of human boundaries in an environment where actions in one part of the landscape could affect the subterranean environment more widely.

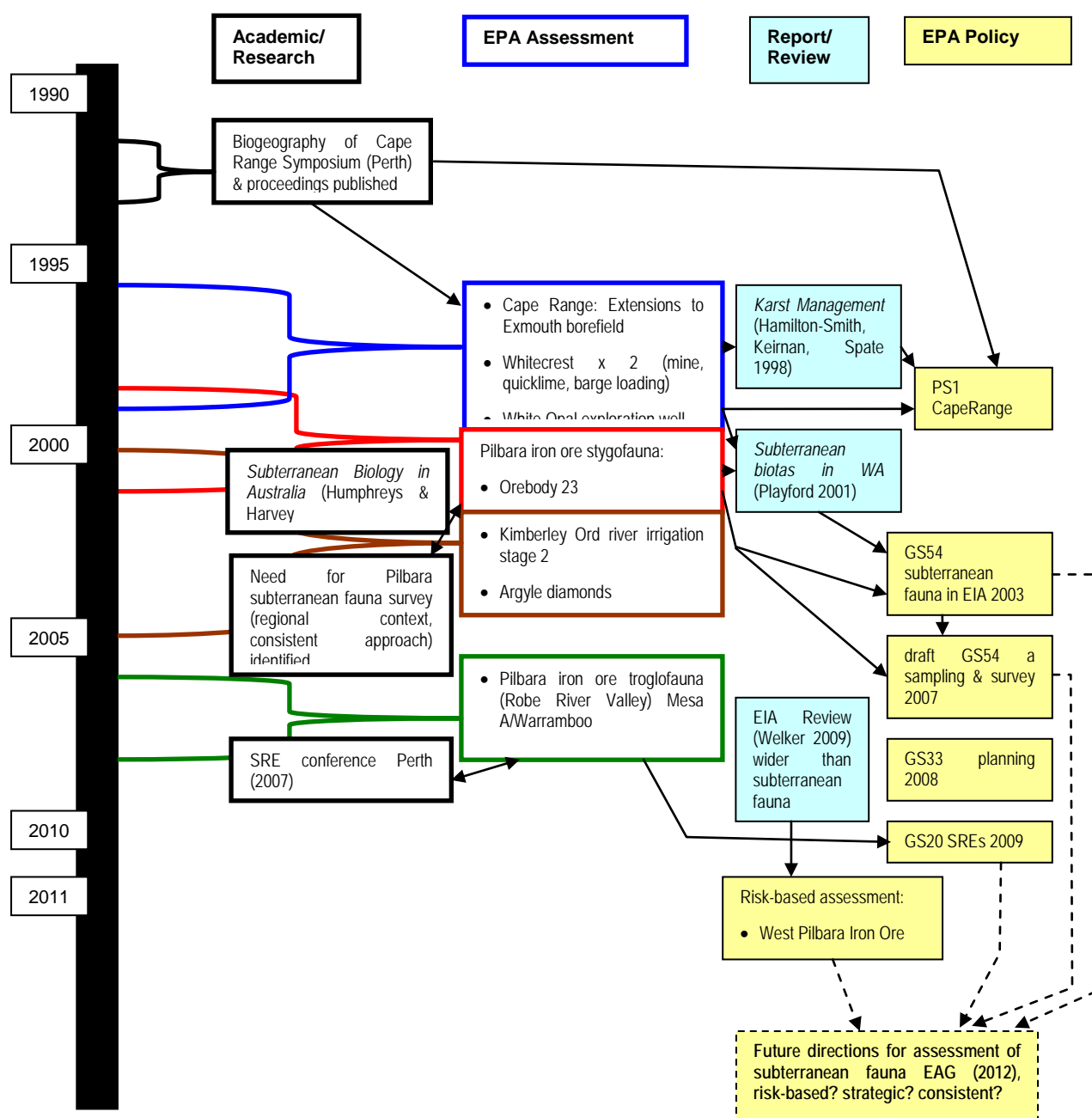


Figure 5: timeline of important dates, EPA assessments, reports and EPA guidance relevant to assessment of impacts of subterranean fauna

3.6.2 Environmental protection Cape Range Province (Position Statement 1) 1999

Following the release of the karst management report by Hamilton-Smith *et al.* (1998) the EPA published a position statement on environmental protection of Cape Range, which included recognition of the importance and diversity of subterranean fauna (EPA 1999). This position statement defined objectives to protect the environmental quality of all environmental systems to ensure that they are managed in accordance with principles of ecologically sustainable development and the National Strategy for the Conservation of Australia's Biological Diversity (ANZECC 1996). Some key constraints on development were identified and these included the availability of potable water and the need to maintain ecological processes and important subterranean fauna habitats.

3.6.3 Subterranean biotas in Western Australia (2001)

A report prepared for the EPA by Playford (2001), was largely the proceedings of a symposium attended by delegates of government agencies, private industry (mostly mining companies) and the EPA. Studies conducted in the Pilbara for a proposal to mine below the water table at Orebody 23 (near Newman) raised difficulties in understanding the distribution and impacts of dewatering on stygofauna (see case study 4.2.2) which had relevance for other projects in the Pilbara and more widely. Consequently, there was considerable interest in subterranean fauna, and proponent and agency frustration about the delays and uncertainties caused by assessment of subterranean fauna.

Playford (2001) reported considerable differences of scientific opinion, falling into two main views:

- largely endemic stygofauna across different types of paleodrainage; or
- genetic information to demonstrate that fauna displaying very different morphologies represented a small number of widespread variable species.

Also noted was the largely unknown nature of subterranean fauna (especially troglafauna) and the small number of specialists working in the field.

Playford (2001) identified three categories of conditions relating to subterranean fauna:

- identification of samples from the proposed minesite and sometimes further afield;
- identification of expected effects of mining operations on the fauna; and
- preparation of action/management plans to conserve fauna if the results show they are adversely affected by mining.

Playford (2001) included a number of recommendations on development of research programs, refining environmental conditions, developing guidelines on assessment requirements, use of a pilot project to study the effects of extensive dewatering on stygofauna, and the promotion of the importance of subterranean fauna.

3.6.4 Consideration of subterranean fauna in groundwater and caves during environmental impact assessment in Western Australia (Guidance Statement 54, 2003)

Playford (2001) and early assessments at Cape Range and in the Pilbara (Figure 1) demonstrated the need for guidance on how subterranean fauna are considered during environmental impact assessment (EIA). Guidance Statement 54 (EPA 2003a) was developed to meet this need and sets out the information that the EPA requires when assessing proposals where the protection of stygofauna or troglafauna is a relevant environmental factor. It takes into account:

- a) protection of the environment as defined by the EP Act with a focus on conservation of stygofauna and troglafauna, their habitats and the bio-physical processes that support them; and
- b) the conservation of stygofauna and troglafauna as required by the WC Act.

The focus of Guidance Statement 54 is to ensure that proposals do not potentially threaten the viability of any subterranean species in accordance with the WC Act (EPA 2003a). This has been done by suggesting that proponents:

- show that species within the potential impact zone also occur outside this area (i.e. no species is restricted to the impact zone);
- provide evidence that likely impacts will not significantly affect species within the potential impact zone; and
- produce a management plan for the potential impact zone and species to ensure the persistence of those species.

3.6.5 Sampling methods and survey considerations for subterranean fauna in Western Australia draft (Guidance statement 54a, 2007)

At the time that Guidance Statement 54 was released, relatively few surveys for subterranean fauna had been done and the distribution, conservation status and optimal survey techniques for most subterranean species were poorly known. Consequently, Guidance Statement 54a was developed to describe the sampling methods, survey considerations and reporting requirements for subterranean fauna, as a technical appendix to Guidance Statement 54. Guidance Statement 54a built on the previous guidance and reiterated the geographically restricted range of many subterranean species and their vulnerability to extinction if confined to highly restricted habitats or individual geological features.

The guidance addressed the risk of extinction using a matrix of probabilities to provide the basis for determining whether subterranean fauna would need formal consideration in an EIA. In addition, local geological setting, and other emerging information was used to indicate whether subterranean fauna surveys would be required. The guidance recommends the circumstances in which a desktop survey and/or a pilot study may be appropriate.

Guidance Statement 54a gives the EPA's expectations regarding adequate sampling effort and appropriate survey design and methodologies, detail for species level identifications, collection of other data, the public availability of survey documents and vouchering.

The EPA obtained comments on draft Guidance Statement 54a from several stakeholders regarding the prescriptiveness of the guidance and difficulties in understanding extinction risk in the context of poorly understood natural systems. The guidance statement remains a draft but is the most up-to-date guidance to proponents.

3.6.6 Environmental Guidance for Planning and Development (Guidance Statement 33) 2008

Guidance Statement 33 is a wide-ranging document which describes the EPA's approach to environmental protection and sets out what it considers as part of an assessment. It includes detailed advice on protecting a range of biophysical factors including fauna, and describes areas of high conservation significance and when the EPA is unlikely to recommend the approval of projects.

The EPA's recommended approach is an integrated natural resource management for karst and subterranean wetlands and fauna because of the inter-related nature of geology, hydrology and biology. The guidance supports the development of regional strategies for the protection of key fauna and biodiversity values, and the integration of land use planning with regional biodiversity protection measures.

3.6.7 EIA Review 2009

Subterranean fauna policy and practice has evolved over time and has been part of wider changes to EPA processes. A review of the EIA process made a total of 47 recommendations on improvements to the operation of EIA in WA (EPA 2009a). The reform program included the use of risk-based assessment where applicable, as well as other measures to improve the timeliness and effectiveness of the EPA's functions. The application of risk-based assessment to subterranean fauna is discussed in section 5.0. The EIA reforms were designed to achieve a thorough, clear, consistent and timely EIA process that meets the expectations of government, industry and the community.

The recommendations focused on the need to address the certainty and timeliness of EIA to deliver better environmental protection and to improve the efficiency and transparency of the EIA process (EPA 2009c). Some of the recommendations related to implementing more strategic environmental assessment, with the EPA subsequently developing detailed guidelines and toolkits to help responsible authorities and proponents. Changes have subsequently been made to EPA guidance, policy, and business process procedures. The EPA has since trialled the use of a risk-based approach for one assessment involving impacts of iron ore mining in the Pilbara (see 4.2.6). Section 5.0 suggests the use of a risk-based approach for assessment of subterranean fauna.

4.0 History of EIA

4.1 EIA process for subterranean fauna in WA

Identification of subterranean fauna as a key factor occurs in the scoping stage of the EIA process. This is currently conducted according to the geological and regional probabilities of subterranean fauna occurring as described in draft Guidance Statement 54a. Proponents are then responsible for designing a survey program to ensure the biodiversity of the site is adequately understood in the context of surrounding areas and the development proposal, and submitting appropriate documentation for public comment. Proponents must demonstrate how the EPA's objective for fauna (to maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge) will be met.

After receiving proponent responses to public submissions further information or proponent amendments to proposals may be requested. The EPA then reports to the Minister for Environment on the outcome of the assessment and its recommendations. The assessment report describes the key factors identified, and makes a recommendation regarding environmental acceptability of the proposal and recommend conditions as appropriate. The EPA's report and recommended conditions may be appealed, after which the Minister makes a decision as to whether the proposal can be implemented. A summary of the assessments in which subterranean fauna has been a key environmental factor is provided at Appendix 3.

4.2 Evolution of EPA assessment of subterranean fauna as a key environmental factor in WA

Between 1994 and 2011, the EPA provided reports and recommendations to the Minister for around 40 assessments for which subterranean fauna was a key environmental factor.

The first EPA assessment to include subterranean fauna as a key environmental factor was the extension to the Exmouth water supply borefield received in 1994. The proponent proposed to increase the number of bores and significantly increase the pumping capacity of the borefield. The potential impacts on stygofauna was a significant issue in the assessment and the Minister for Environment included endorsement of the proponent commitments of the need to document the assemblage and effects of pumping as a condition of approval (see 4.3.2 and Appendix 3 for further details). Subsequently, several other proposals in the Cape Range area, particularly for limestone mining, were assessed by the EPA and similar issues were encountered for troglafauna (see case study 4.2.1).

Advice to the EPA from the WA Museum and conservation and environmental protection agencies focused on the importance of conserving and documenting subterranean biodiversity and avoiding impacts that would potentially lead to the extinction of a species. A number of appeals on the EPA recommendations to the Minister raised the profile of subterranean fauna issues within the community, and prompted legal advice on the operations and interactions of the EP Act and the WC Act.

Since 2000, the Pilbara region has become the main focus of subterranean fauna assessment. This situation is primarily related to the significance of the fauna found in the region and the large number of resource developments that require assessment. Approximately 60% of proposals for which the EPA has made recommendations to the Minister (shown in Appendix 3) are located in the Pilbara, with smaller numbers of proposals for the Kimberley, Cape Range/Barrow Island and Yilgarn regions.

Since 2009, the EPA has received scoping documents for proposed uranium mining proposals in the Yilgarn for which subterranean fauna is a key environmental factor. Future assessments of uranium mining are likely to include subterranean fauna.

Where the EPA identified subterranean fauna as a key environmental factor, recommendations for conditions under which the proponents need to operate have usually been included. The Minister may accept the EPA recommended conditions or develop others as appropriate (for example to accommodate the outcome of appeals and/or consultation with decision-making authorities). The assessments which have resulted in a report and recommendations from the EPA to the Minister, associated appeals and Ministerial Statement conditions are summarised at Appendix 3. Some case studies are included below which show the evolution of the EPA's consideration of subterranean fauna over time.

4.2.1 Limestone mining at Cape Range

Two limestone projects were assessed by the EPA in the Shire of Exmouth, approximately eight kilometres south of Exmouth:

- a limestone mine, quicklime project and use of existing port facility (Point Murat), originally referred in 1992, EPA Bulletin 846; and
- Exmouth limestone project barge loading facility (Mowbra Creek) assessed in 1997, EPA Bulletin 871.

EPA assessment of the limestone mining and quicklime proposal raised considerable community and government agency discussion and came at a time when the importance of subterranean fauna at Cape Range was first being recognised. The EPA was satisfied that the proposal could be implemented in a manner which would not pose an unacceptable risk to the environment (EPA1997a). The potential impacts of the proposed mining were recognised, however the EPA concluded only a relatively small percentage of the karst landscape would be destroyed. Despite limited information available about the subterranean biodiversity available at that time, the EPA accepted that the research indicated a high degree of endemism and the high likelihood of finding undescribed species. The EPA considered the risk to species diversity to be acceptable, provided that Cape Range National Park was extended and a research program undertaken.

After the release of the report on the first limestone proposal (EPA 1997a), nine appeals were received, covering a wide range of subjects relating to social and environmental impacts (Appeals Convenor records, appeals 74, 75, 76, 79, 83, 84, 85 and 87 of 1997). The appeals relevant to impacts on subterranean fauna included:

- concern regarding the lack of consideration of the report by Hamilton-Smith *et al.* (1998);
- risk of reduction in genetic diversity of troglodfauna;
- destruction of caves;
- potential for pollution of groundwater; and
- the inappropriateness of giving approval before the release of an environmental policy and integrated approach to development (Position Statement 1).

The Minister allowed in part those appeals which addressed subterranean fauna and environmental management plan issues and agreed with the appeal comments that a survey of the site should be conducted before mining, and that sampling should be extended to outside the area of impact. The Minister did allow implementation of the proposal with conditions for a public review of the management plan before implementation (Minister for the Environment 1997a).

The proponent decided to change the way in which the limestone was exported and submitted a second proposal for a barge loading facility at Point Murat (EPA 1997b). Ministerial approval was given for the facility in 1998 (Minister for the Environment 1997b).

Ongoing monitoring in accordance with approval conditions at the mine site has recorded 18 troglofauna species from the overall study area including mined and non-mined areas (unpublished data submitted to the EPA 2011). Half of the species recorded were singletons, five have been collected from other areas of Cape Range and an additional two were thought to correspond to species now known from elsewhere. The proponent considered that the species were probably more widely distributed than the data demonstrated and that their apparent restriction was due to chance, stochastic processes and other ecological sampling effects.

Summary:

- Proposal to mine limestone in an important area of subterranean fauna diversity.
- EPA recommended implementation could proceed with conditions, and the decision was appealed.
- Minister allowed implementation of the proposal with conditions.
- Ministerial Statement conditions required a site survey before mining (inside and outside the area of impact) to identify and document the subterranean fauna, notification of voids encountered during mining operations, public review of the management plan.
- Ongoing monitoring has detected a total of 18 subterranean fauna species at the site.

4.2.2 Iron ore mining below the watertable in the Pilbara

A proposal to mine below the water table at the Orebody 23 iron ore deposit (13 km northeast of Newman), was referred to the EPA in July 1997. Mining commenced at the site in 1992, and the proposal would extend the life of the mine (EPA 1998). The planned approach required significant dewatering and drawdown of the unconfined aquifer was predicted.

The impacts of the mine dewatering on aquifer habitat of stygofauna was identified as a relevant environmental factor. The proponent prepared a Consultative Environmental Review, and the WA Museum made a submission regarding the importance of stygofauna in the calcretes in the vicinity of Ethel Gorge and the upper Fortescue River system. Groundwater investigations of the area surrounding the mine site confirmed there was hydraulic connection between the aquifers.

The EPA's objective was to maintain the abundance, species diversity and geographical distribution of the subterranean fauna, and it advised the Minister that the proposal could meet the objective (as long as management and research conditions were met). The EPA was satisfied that, provided the area of impact was small and of short duration, the impact to various species of stygofauna may be negligible as stygofauna could move between habitats.

The proponent agreed to undertake further work with the WA Museum and the then CALM, and also to identify stygofauna species already sampled, assess the conservation significance, map local distributions for species, and undertake further sampling in the Ophthalmia region to further identify stygofauna distribution. The Minister allowed implementation of the proposal (Minister for the Environment 1998) with conditions that the proponent implement the agreed environmental management commitments which include conditions relating to stygofauna.

At the time of Ministerial approval for implementation of the proposal, the stygofauna at site had not been identified. The species found were new to science and required scientific description, including descriptions of the genera (Bradbury 2000). Amphipods (a type of crustacean) comprise a significant proportion of the subterranean fauna of Orebody 23 and Ethel Gorge, and Bradbury (2000) described two new genera and sixteen new species of amphipods from the Orebody 23 site.

During 2001, mining activity was stopped at Orebody 23 due to the discovery of a locally endemic stygofauna community. Bradbury (2000) described fifteen species of the new genus *Chydaekata* and one of the new genus *Molina*. The *Chydaekata* species were found with extremely restricted

ranges (single bore locations) over a distance of approximately 35 km along the Fortescue River catchment north of Newman (with one found about 100 km downstream) (Finston & Johnson 2004). Three bores were present in the project footprint area (subject to dewatering), one of which contained six of the newly described species.

The findings were critical for compliance with Ministerial conditions, particularly the requirement to assess the conservation significance of the stygofauna (Finston & Johnson 2004), which required an understanding of the current and projected (as a result of dewatering) distributions of species. The Ethel Gorge region was described as a hotspot of stygofauna biodiversity by Boulton *et al.* (2003) and listed as an Endangered TEC (Ethel Gorge Aquifer Stygobiont Community) in WA.

Finston & Johnsons study (2004) was not able to identify all specimens using the Bradbury (2000) key because many specimens appeared to possess mixtures of morphological characteristics of more than one species and the extreme morphological diversity made species identifications difficult. However, eight species could be tentatively identified on morphology and these were found to have broader distributions than were indicated by the initial survey. The Finston & Johnson (2004) study concluded that only one species (*C. transversa*) appeared to be restricted to the dewatering zone.

Finston & Johnson (2004) found that the patterns of variation produced by genetic analysis differed from those described on morphology and that the original taxonomy was based on a limited amount of material. Many of the specimens were juveniles, for which character variation was not feasible. Additional sampling increased the number of specimens examined and revealed greater morphological complexity, including new combinations of characters. However the most important finding was that genetic analyses indicated the presence of one apparently common, widespread species which directly contradicted the identifications based on morphology. The study found that the stygofauna was not highly restricted (such as to individual boreholes), with the exception of one individual found at bore W245 which was significantly different from all other fauna sampled.

After the study by Finston & Johnson (2004), the then CALM advised the EPA that dewatering at the site would not lead to the extinction of a species, based on three criteria:

1. most species previously thought to be restricted to the dewatering zone were found to have broader distributions beyond the area of impact;
2. morphological boundaries between species were ambiguous; and
3. the DNA evidence did not support distinct species.

The EPA advised the Minister that mining could be resumed at Orebody 23, with a condition to continue regular stygofauna monitoring. The case study highlights the difficulties in decision-making where sampling is inadequate but only shown to be so after the fact, and that the interruption to operations resulted in a significant cost to mine operators. Monitoring data submitted to the EPA since 2004 indicates that dewatering does not appear to have impacted the stygofauna community. However, DEC remained concerned about the long term cumulative impacts of dewatering (from Orebodies 23, 24 and 25) and dewatering discharges on the Ethel Gorge Aquifer Stygobiont TEC. In 2010 a two-year extension to the life of the mine was approved by the EPA under section 45c of the EP Act.

Summary:

- First proposal to include assessment of subterranean fauna in the Pilbara.
- Main impact was effect of dewatering on stygofauna communities.
- Minister allowed implementation of the proposal but with conditions to undertake sampling and identification of stygofauna and describe distributions.

- Initial identification based on morphology described two genera and sixteen species of amphipods, many of which were thought to be confined to the area of impact. A key to identification was produced.
- Uncertainty regarding impacts stopped mining activities at the Orebody 23 site in 2001.
- Later analysis showed the key based on morphology was inconsistent (extreme variability in characteristics used to define species) and genetic analysis indicated one widespread and common species was present. As of 2010, dewatering does not appear to have had an effect on the stygofauna community.

4.2.3 Iron ore mining in the Robe River Valley

Mesa A

In 2005 the EPA received a proposal to develop an iron ore mine at Mesa A and Warrambo 43 km west of Pannawonica, including mine pits, a processing plant, mine infrastructure and a rail line to an existing mining operation (EPA2007b). The mesas of the Robe Valley were amongst the first areas of the Pilbara from which troglofauna fauna had been collected, and this fauna was deemed a key environmental factor in assessment of the proposal.

The proposed mining was to remove the majority of the ore body (approx 570 ha), but to retain 87 ha of mining exclusion zone of between 50 m and 200 m width (effectively the rim of the mesa) (EPA2007b). Stygofauna sampling at bore holes in the area revealed only one contained species (oligochaete worms) which were considered to be widespread. Eleven species of troglofauna were identified from Mesa A, five of which were only recorded in the proposed pit area. However, interpretation of the species accumulation curves presented indicated that the total troglofauna species richness for Mesa A could range from 18 to 25 species. The species found at Mesa A were not identified anywhere else in the Robe Valley region, and it was possible that the species were restricted to micro-habitats within the orebody (EPA 2007c). There was also concern that even if the mining exclusion zone allowed for the retention of existing species, its shape (long and narrow) may cause desiccation of the orebody and thus become unsuitable for troglofauna over time.

The EPA considered that there would be impacts on the troglofauna and that the proposed mining exclusion zone was inadequate to conserve the troglofauna. Based on the information available the EPA concluded that the proposal as a whole was environmentally unacceptable and should not be implemented (EPA 2007b).

Three appeals were made against the EPA's decision, including one by the proponent. Additional geotechnical and subterranean fauna survey information was presented during the appeals. The Minister for the Environment allowed the appeals in part as the additional information showed that there was an acceptable risk to troglofauna populations as long as conditions were set regarding retention of habitats and that monitoring took place (Minister for the Environment 2007). The Minister then re-submitted the proposal so that the EPA could re-examine it with the additional information provided by the proponent (EPA 2007c).

In the second assessment, the proponent addressed the EPA's key concern regarding troglofauna by providing greater surety that all fauna species would be protected through provision of further information (evidence that subterranean fauna occur in sub-grade ore that was proposed to be retained as habitat and that it persisted at Mesa K in the Robe Valley after mining) and modifications to the mining exclusion zone (EPA 2007c). The EPA considered that the sampling effort undertaken by the proponents was significant, and considered that although additional survey would record more species it would be unreasonable to require further survey. The Minister for the Environment gave approval for the modified proposal with conditions for monitoring and

investigating the effects of blasting and recreating habitat on subterranean fauna (Minister for the Environment).

In 2008 the proponent applied (under section 45c of the EP Act) to remove an extra 60 m of the mining exclusion zone. This was approved by the EPA as it did not consider there would be an effect on subterranean fauna (unpublished data submitted to the EPA). The proponent studied the effects of vibration on subterranean fauna and temperature and humidity conditions in subterranean environments at Mesa A (unpublished data submitted to the EPA). Sampling after Ministerial approval has found the continued presence of troglotauna at Mesa A during mining operations, including three taxa not previously collected (unpublished data submitted to the EPA). No increased risks to troglotauna were identified as a result of mining operations.

Summary:

- First troglotauna collected in pisolite iron ore formations in WA.
- Troglotauna sampling recorded 11 species, five of which were only found in the proposed pit area.
- Mesa fauna assemblages are different from each other and endemic.
- Initial proposal was found by the EPA to be environmentally unacceptable.
- Changes were made to the mining exclusion zone and additional information satisfied the EPA that troglotauna continued to persist at Mesa A.
- The proponent attempted to provide troglotauna habitat using waste rock and undertook a monitoring program.
- Monitoring has shown the continued presence of troglotauna at Mesa A.

Mesa K

In 2007 a proposal was referred to the EPA to mine the remnant of a previously mined deposit at Mesa K in the Robe River Valley, 11 km southwest of Pannawonica (EPA 2008b). Approximately 90 ha of the 254 ha Mesa K formation was proposed to be disturbed including a small area to be newly mined. Surveys conducted during the assessment indicated that considerably more troglotauna were collected from historically disturbed areas than from relatively undisturbed areas. However, because there were no baseline surveys available prior to the original mining it could not be determined whether all species previously present had survived post mining. Despite the fact that all taxa recorded at Mesa K were considered to be endemic to the mesa, the EPA considered that because of the number of troglotauna species found at Mesa K, even in areas where there has not been any active rehabilitation, there was greater confidence regarding the resilience and persistence of troglotauna (EPA 2008b). The proponent also proposed to minimise new disturbance and retain some habitats.

The EPA found that the proposal could be managed to meet the environmental objectives for the factor, provided that conditions were imposed. The EPA report (EPA 2008b) recommended that a 50 m buffer around the locations of five singleton species would be adequate to address the risk of species extinction (based on information proponent from Mesa A). The EPA also requested that the proponent undertake investigations of environmental conditions within the orebody to attempt to define troglotauna habitat during and post mining. Rehabilitation using native plant species was also required to provide optimal conditions for long-term survival of troglotauna.

One appeal was received relating to the level of knowledge and understanding of the troglotauna communities. However the Minister for the Environment found that the EPA was justified in concluding that the implementation of this proposal was not likely to result in extinction of a species and potential impacts could be managed through the implementation of mining exclusion zones (Minister for the Environment 2008). Although the species present at Mesa A were different from those found at Mesa K, the use of mining exclusion zones around key species/habitats and

providing linkages with larger areas of habitat was considered an acceptable strategy for minimising the risks to troglofauna species.

Summary:

- Proposal was to mine the remnant of a previously mined deposit.
- No baseline surveys were conducted before the first mining operations thus the previous subterranean fauna assemblage was unknown.
- A high proportion of the mesa was proposed to be retained.
- Sampling showed that subterranean fauna was present in previously mined areas.
- Mining disturbance was excluded from areas where troglofauna were represented by single records of species, and a monitoring program implemented.

4.2.4 LNG development on Barrow Island

Barrow Island was made a flora and fauna reserve in 1908 and upgraded to a Class A Nature Reserve in 1910 because of its very high conservation values. A petroleum lease was established in 1966, which lead to the development of an oil field.

In 2003, the WA Government provided in-principle agreement for restricted access to the island for gas processing facilities. The EPA conducted an assessment of the Gorgon Gas Development proposal for construction of a liquefied natural gas (LNG) plant and associated pipeline infrastructure (EPA 2006). The EPA identified subterranean fauna was one of the key environmental factors due to the endemicity and diversity of species, of which twelve are listed as threatened under the WC Act (see Appendix 1). Clearing, earthworks, construction activities, waste water discharges and spills of fuel or hazardous materials, and groundwater extraction were identified as potential impacts on subterranean fauna. Surveys showed that seven taxa were found only in the project footprint and a proposed new accommodation area had not been adequately sampled.

The proponent committed to carrying out management measures to minimise the impacts, however, the EPA assessment showed that the risk of extinction of subterranean fauna was high (EPA 2006). The Barrow Island *Draculoides* exhibited substantial genetic differentiation across the island, which suggested that there was limited underground movement of fauna and there were significant knowledge gaps regarding the distribution and taxonomy of undescribed taxa. The EPA considered the risk of significant environmental impacts on subterranean fauna were not acceptable.

There were eleven appeals against the EPA report and the Minister for the Environment appointed an Appeals Committee to investigate the matters raised and to make recommendations (Appeals Committee 2006). The appeals raised concerns about aspects of the EPA's report including subterranean fauna (Minister for the Environment 2006). In response, the proponent presented advice to the Appeals Committee that further surveys identified some species previously thought to be restricted to the footprint were now recorded outside (Appeals Committee 2006). The proponent contended that further sampling was likely to record all taxa in other parts of the island. However, the Appeals Committee noted that there was no certainty that the species would be found elsewhere and recommended to the Minister that the proposal be remitted to the EPA for further assessment or subject to further survey the proponent's appeal be allowed.

The Minister allowed the proponent's appeal on the basis that subterranean fauna surveys typically experience considerable species accumulation over time; that the hydrogeological environment showed no physical impediment to dispersal; and that with further survey it was likely that the remaining subterranean taxa would be found elsewhere on Barrow Island with only a small risk they would not be found outside the project footprint (Minister for the Environment 2006).

The Minister approved the proposal and required terrestrial and subterranean fauna baseline survey, environmental impact report, environmental protection plan, environment monitoring program and a groundwater abstraction management plan. Ministerial conditions required further surveys until the species were located outside the footprint area (Minister for the Environment 2007, Ministerial Statement 748).

In 2008, the EPA received a new proposal (Gorgon Gas Development Revised and Expanded Proposal) to increase production from 10 to 15 million tonnes per annum by the addition of a third gas processing train (EPA 2009d). This required significant revisions to the layout, size and orientation of infrastructure. The EPA assessed the revised proposal and determined that subterranean fauna was a key environmental factor. The proposal included a 20% increase in clearing with a proportional reduction in subterranean habitat, and increased risks for spills and contamination of subterranean habitats. In addition to the four taxa not recorded outside the footprint area, from the previous assessment, additional surveys showed another three subterranean taxa were also not found outside. The EPA concluded that the risk of extinction of subterranean fauna was unacceptable and could not be managed to meet its objective (EPA 2009d, Bulletin 1323).

Construction of the first proposal had not commenced at the time of assessment of the new proposal, and therefore the EPA could not evaluate the effectiveness of Ministerial conditions for the first proposal (EPA 2009d). The EPA concluded that the proposal could only meet its objectives if stringent conditions were applied. The EPA examined the conditions associated with the first proposal and suggested ways in which conditions could be modified to meet the EPA's objectives for the new proposal (Appendix 3 of EPA 2009d). For subterranean fauna, these additional conditions included further survey to address concerns of extinction risk. The EPA's recommendations to the Minister in Bulletin 1323 were appealed (Appeals Convenor 2009).

As part of their appeal the proponent stated that an extensive and ongoing field monitoring and taxonomic research program was in place to establish the presence of the species outside the footprint area, as required by conditions in Ministerial Statement 748, and the expectation that future sampling would meet the EPA's objectives. The EPA disagreed that conditions in Ministerial Statement 748 required ongoing survey (hence the recommendation for additional surveys). The Minister found that there was a sound basis for the EPA's recommendation and this ground of appeal was dismissed (Minister for Environment 2009). The Minister allowed the proposal to be implemented with new conditions (Ministerial Statement 800).

Summary:

- Barrow Island is a Class A Nature Reserve and highly significant for subterranean fauna.
- The EPA assessed the first proposal for construction of an LNG plant and associated infrastructure for which subterranean fauna was a key factor.
- Seven of the species identified within the project footprint were not located elsewhere on the island.
- The EPA concluded that the overall impacts of the proposal would be environmentally unacceptable.
- The EPA report was subject to appeal, the Minister partly upheld the appeals and issued Ministerial Statement 748 which allowed the proposal to be implemented.
- The EPA received a new proposal and conducted a second assessment.
- Additional surveys reduced the number of subterranean taxa were known only from the footprint in the first proposal but located another three.
- The EPA remained concerned about the risks of species extinction for subterranean fauna, however overall found that overall the proposal could only meet its objectives if stringent conditions were applied.

- Ministerial Statement 800 allowed implementation of the new proposal with conditions.

4.2.5 Change to dewatering rate at Pilbara Iron Ore and Infrastructure Project - Christmas Creek

The EPA assessed the development of iron ore mines north of Newman at Christmas Creek and Mindy Mindy (as well as a borefield, railway system and accommodation village) in 2005 (EPA 2005). The EPA found that it was unlikely that its objectives would be compromised provided there was satisfactory implementation by the proponent of their commitments and the recommended conditions. Ministerial Statement 707 was issued so that the proposal could be implemented (Minister for the Environment 2005). Stygofauna sampling was conducted as part of the assessment, but identifications had not been completed. The proponent prepared a subterranean fauna management plan to continue monitoring (EPA 2005). The management plan only addressed stygofauna and the lack of likely troglifauna habitats in the project area was noted (FMG 2004).

In 2011, the EPA assessed the Christmas Creek Water Management Scheme proposal which involved the dewatering and injection of groundwater within the Christmas Creek project area to enable mining of iron ore below the water table (EPA 2011a). This significantly increased the dewatering rate (from 11.4 to up to 50 gigalitres per annum). Six stygofauna species were recorded within the proposal area but all were considered widespread as they were all recorded outside the area of impact and therefore impact to stygofauna from the proposal was unlikely to be significant (EPA 2011a).

Desktop survey for troglifauna concluded that it was likely that species occurred within the project area and mounding of groundwater was predicted to reduce the total volume of potential troglifauna habitat (up to 19%), but there were difficulties in predicting the impact of dewatering on soil humidity within potential troglifauna habitat (EPA 2011a). Field surveys for troglifauna had been undertaken by the proponent but results were not available at the time of assessment. However the connectivity of the geology and size of habitat volume along the Fortescue valley and footslopes of the Chichester range made it unlikely that any troglifauna species was restricted to the impact area and therefore the EPA concluded that the risk to troglifauna species was low.

No conditions relevant to subterranean fauna survey or management were recommended, by the EPA, however conditions to address groundwater mounding and potential effects of dewatering and mounding on vegetation were included. Ministerial Statement 871 was issued so that the proposal could be implemented (Minister for Environment 2011).

Summary:

- An area not thought to contain troglifauna habitat in 2005 but considered very likely to contain species in 2011.
- Assessment of a dewatering and reinjection proposal was based on desktop survey (not field survey).
- Mounding of groundwater was predicted to reduce the volume of troglifauna habitat by up to 19%, however geological connectivity and habitat volume satisfied the EPA that the risk to troglifauna species was low.

4.2.6 Risk-based assessment - West Pilbara Iron Ore

A proposal to develop eight iron ore deposits at five locations south of Pannawonica was referred to the EPA in 2008 and a PER level of assessment set (EPA 2011b). In addition, the proposal included a 285 km heavy-haulage railway from the iron ore deposits to a port to be constructed at Anketell Point (25 km north-east of Karratha). The large-scale proposal included mining below the

watertable at two orebodies (with associated dewatering), a central ore processing facility, rail transport, bridges, sidings, a power station and port facilities.

Subterranean fauna was one of four key environmental factors identified. During the assessment, a regional survey was conducted and a total of 24 species were found in pisolite ore formations. Of these, 13 species were only recorded from the proposed mining impact areas. With the exception of one pseudoscorpion, all those collected during surveys were undescribed or had not been previously collected. Some were likely to warrant listing under the WC Act (EPA 2011).

The proponent undertook geological sampling and was able to show the underground extent of orebodies, however the degree and distribution of interconnected voids within channel iron formations could not be quantified (EPA2011). The extent of orebodies provided the basis for mapping the potential troglofauna habitat.

The proponent considered that singleton records were not representative of true distributions, but reflected sampling bias. Genetic analyses demonstrated apparent subterranean habitat connectivity (EPA 2011):

- molecular data for the best sampled group (schizomids) indicated that in general there was gene flow and interbreeding throughout each mesa landform;
- parallel molecular results were recorded from cockroaches; and
- other members of the same genera occur more widely.

A strong correlation was detected between the distribution of well-collected species and the geomorphology of the palaeodrainage systems, and five habitat units (with associated fauna assemblages) were described by the proponent. Using precedents from other cases (iron ore mining at Mesa K and limestone mining at Cape Range) the proponent argued that troglofauna continued to exist at sites subject to mining (for many generations). The proponent considered that the retention of at least 50% of troglofauna habitat for each palaeodrainage habitat unit constituted a significant amount and was consistent with a precautionary approach, despite not demonstrating the presence of all species found within the mining impact areas occurring beyond mining areas.

The proponent suggested that a minimum of 50% of the channel iron deposits (potential troglofauna habitat) in all palaeodrainage systems impacted by mining would be retained, and other impact minimisation actions would be conducted (e.g. type of blasting, backfilling and rehabilitation).

The EPA accepted the proponent's view that the palaeodrainage habitat for the majority of species extended to large areas outside the area of impact and that gene flow within two widespread species suggested connectivity (EPA 2011). The EPA recommended a condition requiring further sampling of the potential troglofauna habitat outside of areas proposed to be mined.

Mining activities at two of the locations would require dewatering and the subsequent loss of stygofauna habitat. Twenty-one of the 37 taxa recorded in the stygofauna surveys were represented in the groundwater drawdown area at Ken's Bore and Cardo Bore East (EPA 2011). Nineteen of the 21 taxa recorded from the impacted sites have been recorded elsewhere in the region. Most of these have been shown to be widespread or at the outer limits of the drawdown area (within the seasonal variation for water tables). The EPA accepted the proponent's calculations that superficial aquifer stygofauna habitat and the large number of stygofauna species found both within and outside the impact zone indicated that distributions are likely to be regional, and therefore impacts on stygofauna were unlikely to be significant.

Summary:

- Large proposal to develop eight iron ore deposits at five locations near Pannawonica.
- Regional scale surveys conducted.

- 24 troglotauna species found at ore formations to be mined.
- 37 stygofauna species found within the water drawdown area.
- Troglotauna were strongly associated with palaeodrainage systems and widespread species were used to describe habitat units.
- Molecular data from schizomids indicated that there was gene flow and interbreeding throughout each mesa landform.
- A minimum of 50% of the channel iron deposits was retained as troglotauna habitat.
- 19 of the 21 stygal taxa recorded from the impact sites have been recorded elsewhere in the region.
- The EPA accepted the use of widespread species to define palaeodrainage habitat units.
- Effects of water drawdown on superficial aquifer stygofauna habitats were unlikely to be significant.

4.3 Lessons learned from case studies of EPA assessments so far

The relatively recent increase in profile of subterranean fauna as a factor in environmental impact assessment has led to an evolution in thinking and assessment procedures. The learning curve is evident with developments in policy and changes in assessment practices and conditions over time. The case studies (4.2.1 to 4.2.6) also demonstrate increase in knowledge over time and how the amount and quality of information available can provide a greater understanding of the potential for subterranean fauna to occur and whether that subterranean fauna is likely to be restricted in distribution and thus more vulnerable to impacts.

4.3.1 Vulnerability to impacts

The observed persistence of subterranean fauna during and after mining operations indicates that species are often likely to have distributions larger than the small areas from which they have been recorded. The post-mining sampling undertaken at Mesa K in the Pilbara demonstrated that subterranean fauna was present despite previous mining activities. The results from Mesa A also show that subterranean fauna persists in areas which are subject to disturbance from mining. Monitoring of subterranean fauna populations at Cape Range have also shown persistence of species recorded prior to mining. Additional species were recorded over time than were recorded in initial surveys.

However, their resilience to impacts remains largely unknown, and many subterranean fauna have small recorded distributions. Those subterranean fauna which have limited ranges and poor dispersal abilities may be vulnerable to localised impacts. Use of groundwater resources has not traditionally taken into account any effects on subterranean fauna in criteria to determine over-exploitation, and little information is available on changes to stygofauna as a result of groundwater abstraction or variations in flow rates (Humphreys 2009). Understanding the effects of disturbance on subterranean fauna remains challenging because sampling may not detect all the species that are present which makes determining change overtime difficult.

4.3.2 Conditions as part of Ministerial Statements

Where impacts on subterranean fauna are identified as part of an environmental impact assessment process, conditions may be imposed by the Minister to reduce or mitigate the impacts. A summary of the assessments in which subterranean fauna was a key environmental factor is provided in Appendix 3. This includes conditions that were recommended by the EPA, any appeals and relevant Ministerial Statements.

The earliest examples of Ministerial approvals subject to subterranean fauna conditions (notably at the limestone mine at Cape Range for troglotauna and Orebody 23 iron ore mine in the Pilbara for

stygo fauna) included requirements to complete inventory surveys and management plans post-approval. This resulted in significant difficulties for proponents who experienced delays to commencement of operations while survey work and identification of samples was undertaken. In the case of Orebody 23, significant concern about the very small ranges of stygo fauna and potential for dewatering to cause extinction of species resulted in cessation of mining activities following post approval survey. Early Ministerial Statements often included conditions relating to identification or management of subterranean fauna in supplementary table of proponent commitments, with the condition to implement those commitments.

During the late 1990s to early 2000s, requirements for survey and monitoring as part of Ministerial conditions were often very extensive (for example for West Angelas Iron Ore Project, Hope Downs and Orebody 24/25, Appendix 3) and included either proponent commitments or conditions on the Ministerial Statement to increase scientific knowledge of subterranean fauna; and often required the use of management plans to address potential threats (especially by dewatering). During this time there was a general trend away from the use of proponent commitments towards inclusion of requirements for survey as part of the Ministerial Statement. The release of Guidance Statement 54 in 2003 resulted in conditions which had a stated purpose of maintaining abundance and diversity and avoiding impacts. Conditions common to many proposals included requirements to: survey areas affected by operations; survey outside the footprint to assist with determining conservation significance (i.e. not found elsewhere) of the species inside the project area; ongoing monitoring of species present; and planning to address adverse issues should they arise (i.e. if monitoring shows a decline in abundance or diversity).

More recently, conditions of Ministerial Statements where much of the survey work was done as part of the assessment have required less detail post approval. EPA reports and Ministerial Statements issued since 2009 commonly do not include any specific conditions relating to subterranean fauna where the EPA has been satisfied by comprehensive information presented regarding species present, extent of habitats and potential threats, for example Western Turner Syncline, Marillana Iron Ore Mine, Balmoral South Iron Ore Project.

The use of subterranean fauna habitat mapping to infer continuous or unimpeded movement has increasingly been used. Ministerial conditions for some projects have required further definition of habitats or validation of assumptions regarding habitat connectivity (e.g. Carina Iron Ore Mine, Balmoral South, Cundaline and Callawa Mining Operations Solomon Project, Appendix 3). West Pilbara Iron Ore (2011) was the first project to use a combination of habitat and genetic analysis to indicate likely habitat connectivity.

New information can result in a condition being removed. During the assessment of Pardoo Direct Shipping Ore Project at Port Hedland a pseudoscorpion was only found within the mining footprint (Bulletin 1289; Report 1320). As a result a condition requiring demonstration of the presence of the species outside the mining footprint was imposed. However, despite substantial survey work the species could not be located again either inside or outside the footprint. Subsequently the proponent applied under s46 of the EP Act to have the condition removed. The Minister sought advice from the EPA who recognised that the condition could not be met and the condition was removed.

4.4 Comparison of WA approach with other jurisdictions

Much of the research on subterranean fauna in Australia has been conducted in WA, where understanding and knowledge of subterranean fauna has increased significantly since its recognition as an environmental factor in EIA. Outside WA, the understanding of subterranean fauna diversity is also increasing and key areas of karst have been identified in Eastern Australia, with rich fauna now known in NSW (at Jenolan, Wombeyan, Wee Jasper and Stockyard Creek)

and Tasmania, with some diversity also known in central Queensland and arid South Australia (Thurgate *et al.* 2001).

Consideration of subterranean fauna in the EIA of development proposals is only formalised in WA (National Water Commission 2008). Assessment of subterranean fauna is integrated into the EIA process in WA in a manner that is not evident in other states. A summary of environmental protection legislation, EIA process, relevant policy documents and numbers of threatened species of subterranean fauna are included in Table 3.

Table 3: Subterranean fauna summary of legislation, inclusion in impact assessment, relevant policy documents and numbers of threatened species

Jurisdiction	Agency	Legislation	Subterranean fauna included in impact assessment?	Policy documents	Number of subterranean threatened species
Commonwealth	SEWPaC	EPBC Act	Yes but not comprehensive - where subterranean fauna are covered by other listings such as Ramsar, threatened species and ecological communities or on Commonwealth land these are matters of national environmental significance.	Recovery outline for Blind Cave Eel in Action Plan for Australian Freshwater Fishes. IRP for Aquatic Root Mat Community of Caves of the Swan Coastal Plain.	3 (all WA)
WA	EPA, Office of the EPA. Advice requested from WA Museum and DEC	EP Act 1986, WC Act	Yes – subterranean fauna can be a key environmental factor in assessment (separate to other fauna and SREs).	GS 54, draft GS 54a, GS 33, GS 20.	40 species, 9 ecological communities.
NSW	Office of Environment and Heritage (OEH), Department of Planning and Infrastructure (DPI)	Protection of the Environment Operations (General) Regulation 2009; <i>Environmental Planning Assessment Act 1979</i> ; <i>Threatened Species Conservation Act 1995</i> .	OEHS is an environmental regulator and manages parks. Management of karst areas is done by reservation. EIA is conducted under the <i>Environmental Planning Assessment Act 1979</i> which includes assessment of impacts on biodiversity but subterranean fauna is not specifically included as a factor. However Environmental Impact Statements for some	Guidelines on fauna survey do not include subterranean fauna. WA EPA Guidance Statements referred to in some environmental impact statements.	None (however listed species include surface fauna that utilise caves)

Jurisdiction	Agency	Legislation	Subterranean fauna included in impact assessment?	Policy documents	Number of subterranean threatened species
			proponents require inclusion of subterranean fauna		
Vic	EPA Victoria & Department of Planning and Community Development	<i>Environment Protection Act 1970</i> ; <i>Environment Protection (Amendment) Act 2006</i> ; <i>Environment Effects Act 1978</i> ; <i>Flora and Fauna Guarantee Act 1988</i>	Proponent prepares Environmental Effects Statement (after scoping and public consultation), submitted to the Minister for Planning. Ecological impact statement and licences may also be necessary (from EPA).	State Environment Protection Policy (Groundwaters of Victoria) No. S160	Some invertebrates listed but more information required to determine if any are subterranean. No vertebrates of TECs are subterranean. No current Actions for Biodiversity Conservation statements apply to subterranean species.
Tas	EPA Division Department of Primary Industries, Parks, Water and Environment	Environmental Management and Pollution Control Act 1994 (EMPCA), Land Use Planning and Approvals Act 1993 (LUPAA), State Policies and Projects Act 1993 (SPPA), and Resource Management and Planning Appeals Tribunal Act 1993	Yes, as for impacts on other fauna (Natural Values Assessments).	No but proponent identifies all flora and fauna requiring management in a Proposal and Environmental Management Plan	At least 10 species (not all have listing statements), no ecological communities listed.
SA	Environment Protection Authority SA & Department of Environment and Natural Resources	<i>Development Act 1993</i> ; <i>National Parks and Wildlife Act 1972</i>	Minister for Urban Development and Planning can declare a proposed development a Major Development where the proposal is considered to be of major economic, social or environmental importance. This triggers a	EPA Guidelines Regulatory monitoring and testing Groundwater sampling June 2007 – includes stygofauna but sampling method not defined.	No invertebrate species or ecological communities listed.

Jurisdiction	Agency	Legislation	Subterranean fauna included in impact assessment?	Policy documents	Number of subterranean threatened species
			thorough environmental impact assessment process with multiple opportunities for public comment.	No guidelines for troglofauna or invertebrates.	
NT	Environment and Heritage Division of the Northern Territory Department of Natural Resources, Environment The Arts and Sport; and NT EPA	Environmental Assessment Act (EEA); <i>Environment Protection Authority Act</i>	Actions in the Northern Territory that are likely to have significant impacts require environmental impact assessment. Proponent prepares an Environmental Impact Statement or a Public Environment Report (including identification of relevant environmental issues). No specific guidance on identification of impacts on subterranean species.	NRETAS does not have any specific expertise. If an assessment indicated that subterranean fauna was an issue, agency seeks external advice.	No subterranean species or ecological communities listed.
Qld	EPA agency - Dept of Environment and Resource Management (DERM)	<i>Environmental Protection Act 1994</i> ; <i>Integrated Planning Act 1997</i> <i>Environmental Protection Act 1994</i> ; <i>Nature Conservation Act 1992</i> .	Assessment occurs under <i>Integrated Planning Act 1997</i> for development projects other than mining; under the <i>Environmental Protection Act 1994</i> for some mining and petroleum activities; under the <i>State Development and Public Works Organisation Act 1971</i> .	Subterranean groundwater systems are recognised as wetlands. A series of criteria are used in assessment and impacts on biological factors are included but this is general.	No subterranean species or ecological communities listed.
ACT	ACT EPA; Department of the Environment, Climate Change, Energy and Water	<i>Environment Protection Act 1997</i> ; Part 4 of the <i>Land (Planning and Environment) Act 1991</i> and Territory Plan (plan for land-use); <i>Nature Conservation Act 1980</i> . ¹	Use of environmental impact statements to identify impacts and develop management actions, including for fauna.	General policies on preparation of an environmental impact statement and process.	No subterranean species or ecological communities listed

4.5 Limitations of current approach

The EPA's approach to assessment of impacts on subterranean fauna has been to define ways of addressing uncertainty in relation to the organisms that may occur in an area and the effects that implementing a proposal may have on them. The uncertainty primarily results from:

- difficulties in understanding morphology;
- difficulties in defining and identifying species;
- artifacts of sampling, especially singletons;
- lack of understanding of ecological function; and
- inconsistencies between current EPA policies and application over time.

Currently, Guidance Statements 54 and 54a require proponents to show that species within the potential impact zone also occur outside the area, provide evidence that likely impacts will not significantly affect species within the potential impact zone, and include operational conditions that ensure appropriate management and monitoring of subterranean species.

This approach has resulted in proponents undertaking (sometimes extensive) survey work and genetic analyses in isolation of surrounding developments, with results that are not necessarily useful in informing decision-making and management.

4.5.1 Defining and identifying species

Studies of subterranean fauna have highlighted considerable challenges to the traditional understanding of species - whether a species is defined by morphological or genetic similarity (see also section 2.8). The traditional approach to invertebrate systematics is based on displayed characteristics (such as shape and placement of body segments, protrusions, mouth parts or sexual organs). Traditional dichotomous keys distinguish species using these characteristics, however, this can be problematic if:

- the key relies on adult or sex-related characteristics where there is a lack of specimens of the appropriate life stages or gender;
- the specimens show significant variation in body appearance; and
- there is a lack of taxonomic expertise to prepare keys and descriptions.

In a contemporary approach, morphological characteristics alone are often not considered sufficient evidence to deduce lineages and evolutionary relationships, and genetic techniques are increasingly being used to understand the evolutionary relationships between species. A comparison of genomes can give an indication of the degree of similarity, difference and genetic distance. However, the degree of similarity or difference can vary between taxonomic groups (i.e. plasticity in the genome appears to be naturally higher in some groups than others), so there may be difficulty in distinguishing within and between species variation. Guidance Statement 20 on short range invertebrate endemics cautions against species descriptions which are based only on genetic studies (molecular taxonomy) as this may not correspond with more robustly defined species that also incorporate morphological features, distribution and habitat parameters (EPA 2009b).

DNA sequence studies on the schizomids found in different mesas of the Robe Valley concluded there was less than 12% divergence between populations (indicating that the animals found on different mesas may be quite similar) (Harvey *et al.* 2008). However, comparison of specimens has shown that there is enough morphological differentiation between the mesas that the schizomids can be regarded as separate species. This was consistent with the observed genetic divergence between species at Cape Range.

In contrast, geographically isolated amphipods in the Pilbara and Yilgarn displayed divergence of 10% to 35% between populations but show no morphological differences (Finston *et al.* 2007; Cooper *et al.* 2007), which may indicate the presence of more than one cryptic species. In other examples, significant morphological diversity occurs within the same species, for example the amphipods of Orebody 23 (case study 4.2.2), where specimens with significantly different morphologies were identified as being genetically the same species (Finston & Johnson 2004).

Identifying reproductively isolated species may be difficult in cases where the potential for within-species variation for less-vagile invertebrates is high. This then contributes to difficulty in understanding the evolutionary relationships between groups (EPA 2009b).

4.5.2 Artifacts of sampling

Sampling of subterranean fauna has similar issues as for epigeal species, but sampling limitations may be harder to overcome.

While the representativeness of sampling may be argued, the absence of records during a survey does not necessarily mean a species is not present (false negative). Detection requires appropriate sampling techniques and some species may not be trapped, even if they are present. This may be due to low numbers, size of animals in relation to traps, placement of traps/bores, trap/net design, or seasonal or other movements of the fauna. A species can be found in one location in one sampling effort and then never re-sampled at the same location although nothing in

the management or land-use of surrounding areas or groundwater appears to have changed. Lack of survey records can lead to underestimations of range and overestimations of probability of extinction (Eberhard *et al.* 2009). There is little information available about the factors affecting species detectability or whether there is any relationship between detectability and conservation status (Eberhard *et al.* 2009).

Eberhard *et al.* (2005a) found that sampling coverage of stygofauna in the Pilbara region was skewed in terms of both areal coverage (not uniform across the region) and the different types of groundwater habitats represented. In addition, logistical constraints have directed sampling towards water supply borefields and mine dewatering areas (access to many bores within a small area) and bores and wells are concentrated in high-yield aquifers with comparatively few bores or wells in low-yielding aquifers. Sampling of springs, or the benthic and interstitial zones of springs, brooks and rivers has been too limited to draw general conclusions about the degree of faunal overlap and importance of groundwater-surface water ecotones, however stygofauna has been found in these habitats.

Eberhard *et al.* (2009) found that some short range endemism was probably an artifact of low sampling effort, however a high proportion of the known groundwater species in the Pilbara appeared to be SREs, as around 55% of the species examined had ranges of less than 10,000 km² and very few species were collected at more than three sites in a regional survey (see section 4.5.4).

Comparability of survey technique over time and geography may be affected by survey effort/intensity, mesh size, number of runs, whether or not the sediments are included in the sample or if sediments are agitated (EPA 2007a). The number of species collected from any habitat containing subterranean fauna is likely to increase with sampling effort and time. In addition, some species are not abundant or not frequently caught or may be only collected after significant repeated sampling effort and it is hard to distinguish whether records of species are the result of them moving into a habitat from a surrounding area. The results of monitoring can initiate a management trigger, for example, if a sampling program fails to detect a species then a proponent may be required to implement management or mitigation measures or potentially risk contravening a ministerial condition.

Species accumulation curves measure the relationship between sampling effort and species detection (Eberhard *et al.* 2009). Guidance Statement 56 *Terrestrial Fauna surveys for environmental impact assessment in Western Australia* states the importance of appropriate sampling effort (duration and spatial scale) for fauna (EPA 2004). The use of species accumulation curves to define the trapping effort required to adequately sample fauna has been suggested for vertebrates (e.g. Thompson *et al.* 2007). This is a recommendation in Guidance Statement 54a which suggests aiming to collect 95% of species predicted to be present (EPA 2007). However despite this aim Guidance Statement 54a allows flexibility provided agreement is sought from the OEPA in advance.

Sampling to record a high proportion of the predicted number of species is impractical due to the time constraints of survey, and is not required for the purposes of EIA. The Eberhard *et al.* (2009) analysis of regional survey data from the Pilbara concluded that two rounds of sampling was usually sufficient to identify sites rich in groundwater species but additional sampling was required to document the full richness of the sites.

The use of indices or predictors for presence of subterranean fauna may represent an alternative approach to determining suitable habitat for subterranean fauna. An index to overcome “bad predictability” of presence of stygofauna was developed in Germany (Hahn 2006). Environmental conditions were quantitatively measured and variables (oxygen concentration, the relative amount of detritus, and the standard deviation of temperature) were used with stygofauna abundance data

to determine whether environmental variables could adequately predict stygofauna habitat. Three groundwater habitat types were characterised, but the results were considered preliminary and further investigations were necessary.

Guidance Statement 54a recognised that there are some inherent issues with sampling and survey. For example, introduction of a bore hole to an aquifer creates an artificial environment which may be favoured by some species and not others, therefore the species sampled may not be representative of those in the aquifer. Evidence from elsewhere in the world suggests that bores contain all species found in the aquifer, although sometimes in different proportions (EPA 2007a; Hahn & Matzke 2005). The guidance statement also prescribes survey techniques (mesh size, number of runs, whether or not the sediments are included in the sample or sediments are agitated) to allow comparison between projects and over time.

Lodgement of adequately documented vouchers of samples is a licence condition under the WC Act (see section 3.2) for undertaking a survey. The licensing (and therefore vouchering) process is administered by DEC.

Creation of drill holes has the potential to significantly change the subterranean environment by creating areas where the above-ground environment is connected with it (such as through drill cores and bores). This may have implications of sampling for small non-mobile populations.

4.5.3 Difficulty of understanding ecological function

Despite recent significant taxonomic study, fundamental questions remain about the ecology and behaviour of many subterranean fauna species. For example:

- the relative importance of stratification of stygofauna within the water column or an aquifer is not known;
- understanding of distribution/range and ecosystem requirements can be distorted by survey artifacts;
- are singleton records representative of rare or restricted species or the result of sampling methodology; and
- behaviour may be particularly pertinent for subterranean species and may impact on sampling results.

For stygofauna, the trapping methodology (involving netting or pumping) makes it very difficult to determine whether there is stratification within the water body or if there is movement of fauna according to climatic or other conditions. Thus, distinguishing any impacts caused by implementing a proposal from natural environmental variation is a challenge, especially against a background of poorly understood biology and ecology (see section 4.6.1 for an example). If conditions of an approval are reliant on results from survey or monitoring and impacts caused by development cannot be determined, it may be difficult for proponents to comply with conditions or for enforcement action to be taken in cases of non-compliance.

4.5.4 Inconsistency

The EPA's requirements in relation to information where subterranean fauna is a key environmental factor have changed over time. While to some extent this is to be expected inconsistency between guidance and practice is now an issue. For example, Guidance 54 advises that proponents should show that species within the potential impact zone also occur outside. However in a number of recent assessments the EPA has not required this. Instead the EPA has accepted geological information indicating continuity between the impact zone and areas outside to indicate that species are unlikely to be confined within the impact zone. It has also accepted genetic data for widespread species.

4.6 Condition setting and compliance

As discussed in section 4.5, limitations can contribute to difficulties in meeting approval conditions (recommendations by the EPA or included in the Ministerial Statements). The following section provides a case study of the challenges in design of monitoring programs, understanding results, ability to detect environmental change caused by implementing a proposal from natural variation and ability to understand compliance.

4.6.1 Extensions to the Exmouth water supply borefield

This proposal was the first to be assessed where subterranean fauna was a key environmental factor. At the time little was known about the stygofauna assemblages and their ecological requirements and there was limited understanding of the aquifer at Exmouth. However, the importance of subterranean fauna at Cape Range region had been highlighted. There was concern about salt water intrusion as a result of fresh water pumping at unsustainable rates and the impact that would have on the aquifer and stygofauna assemblages (EPA 1997c).

High salinity was thought to impact stygofauna habitat (EPA 1997c) and proponent commitments to report salinity levels and implement management actions if they increased were made (see Appendix 3). Groundwater salinity profiles were collected and submitted to the EPA (1999 to 2007), but limitations in the data and a lack of knowledge of natural variation within the groundwater system meant that key questions regarding changes in salinity or impacts on stygofauna could not be answered (Goater 2009). Data collection methods (especially the location of monitoring equipment relative to the fresh/saline interface), definition of an 'increase' in salinity sufficient to trigger management actions, differences in salinity trend evident in shallow and deeper bores, other aspects of aquifer hydrology (major rain events, high tides, storm surges) and the frequency and timing of data collection in relation to pumping peaks meant that detection of upwelling of underlying saline waters could not be determined and the ecological tolerances of stygofauna for salinity are unknown.

4.7 Comparison with short range endemic invertebrates

It has been questioned whether an undue level of significance is ascribed to the assessment of subterranean fauna in contrast to terrestrial, aquatic or marine fauna. In examining the impacts of proposed development on the environment, the EIA process has focused special attention on aspects of biodiversity that are restricted in distribution as it has been considered that there are fewer opportunities for them to be conserved outside the area of development.

The most comparable environmental factor to subterranean fauna is SREs. Guidance Statement 20, guides assessment of SRE's, advocates the use of a risk-based approach where the likelihood of SRE fauna occurring is inferred from the occurrence of geographic boundaries, landform changes or habitat isolates, results of previous surveys, or advice from the WA Museum or DEC. If vegetation or geological units are restricted to the potential impact area, and are especially different from adjoining units, there is the potential for some SREs to be similarly confined. In contrast, if similar vegetation units are contiguous and broadly distributed outside the proposed impact area, the likelihood of SREs being confined to the impact area is reduced.

There are parallels between the issues raised in assessment of of subterranean fauna and SREs, particularly where species are represented by a low number of records located with the a proposal footprint (EPA 2009b). Guidance Statement 20 advises that the EPA expects reasonable efforts to be made in attempting to place single SRE records from impact areas into context, although it is recognised that in some cases this may not yield any further records in a reasonable timeframe.. Guidance Statement 20 uses a risk-based approach where the likelihood of SRE fauna occurring is inferred from the occurrence or otherwise of geographic boundaries, landform changes or

habitat isolates, results of previous surveys, and advice from State government agencies. Guidance Statement 20 used vegetation and/or geological units and their degree of landscape connectedness to infer risks to SREs. Guidance Statement 20 is not prescriptive for survey technique (compared to Guidance Statement 54a) and does not advocate additional sampling to record a high proportion of the predicted number of species.

The limitations of the use of surrogates were recognised in the guidance statement. However it provides the only practicable method of undertaking an informed assessment where small-scale distributions are involved (EPA 2009b).

5.0 Options for future direction in subterranean fauna assessment

At a meeting on 14 April 2011 the EPA agreed to pursue a more risk-based approach to assessing subterranean fauna as a factor in environmental impact assessment. This would use, for example, information on the distribution and population structure of surrogate species and the extent of relevant habitat. Such an approach would be consistent with the recommendations of the 2009 EIA review, and would make subterranean fauna assessment more consistent with other faunal assessments such as the requirements in Guidance Statement 20 for SRE terrestrial invertebrates. Information provided in this discussion paper indicates that it is clear that some change in the way that the EPA considers subterranean fauna is not only desirable but necessary.

This discussion paper has reviewed current knowledge about subterranean fauna in WA, provides comment on the history of how subterranean fauna has been considered in EIA, the legal and policy drivers that dictate how subterranean fauna is currently surveyed for EIA, and what has been learned through the practice of EIA. While significant knowledge gaps still remain, it must be acknowledged that our understanding of the diversity of subterranean fauna has developed rapidly from information provided as part of the EIA process and compliance monitoring as a part of Ministerial conditions, as well as survey and study outside the EPA's processes. The discussion paper has highlighted the lack of consistency in the way that surveys are conducted for EIA and in the way that data are analysed and reported. Current knowledge needs to be used better to inform assessment and to ensure more consistency of assessment between different proposals.

This discussion paper will form the basis of a new Environmental Assessment Guideline (EAG) about specific procedures, methodologies and the minimum requirements for environmental assessment that the EPA would expect where subterranean fauna is likely to be an environmental factor. Such an EAG would provide certainty to proponents on how the EPA will conduct assessments to protect the extraordinary richness and diversity of subterranean fauna. In preparation of an EAG on assessment of subterranean fauna the EPA is mindful of the EP Act which stipulates that the objective of the EPA is to "use its best endeavours to protect the environment" and that recommending approval of a proposal does not result in species extinction or pose a high risk of species extinction.

Current guidance statements 54 and 54a require proponents to demonstrate that all species found within the impact zone also occur outside the area. This approach is not always possible for a number of reasons including lack of accessibility to adjacent areas if they are part of other company leases and impracticability of sampling if sample bores are not available. An alternative to this requirement can be provided by a risk-based approach where it can be demonstrated that there is connectedness between habitats occupied by particular subterranean fauna. Focusing on the degree of connectedness or isolation in a landscape allows inferences to be drawn about the potential of species or assemblages to have a widespread or restricted range. The EPA has already assessed one project that used a combination of geological and genetic information to conclude that the habitat for the assemblage within the project footprint also occurred outside. Thus it was reasonable to infer from the amount of subterranean habitat that would be removed if the project was implemented that no species was likely to face a high risk of extinction. The key to this approach was to use data for widespread species rather than that for those recorded only once or a relatively few times.

Moving to a risk-based approach will require acceptance of the view that it is scientifically defensible to use data from widespread species which show gene flow together with habitat mapping to predict potential habitats. The EPA will also require multiple lines of evidence, such as from genetic studies and habitat assessments, to ensure there is consistent information. A caution

to this approach is uncertainty regarding within-assemblage distribution and diversity, i.e. some species may be restricted, while some may be widespread. Adoption of this assessment procedure generally would require significant changes in survey design and analysis. Significant investigation of use of geology (and likely other factors) to predict habitat would be required, along with addressing questions of accuracy, on-ground verification and rigour.

If there is consistency within regional subterranean fauna assemblages, a strategic approach for that region may be adopted. Implementing this approach will require new policy development to define which regions are appropriate for a regional approach because some areas lack adequate background information. Some geologies and groundwater types have reasonable information available on their subterranean assemblage. However, there are examples of substrates or geologies which were not thought to contain subterranean fauna, but subsequent sampling has revealed the presence of fauna.

There is a need to define areas for which there is reasonable information available to indicate whether the likelihood of finding subterranean fauna is high or low. Ideally, where the location and geology show that subterranean fauna is unlikely to occur, the need for survey may be minor or nil. However the information available does not allow this kind of decision-making yet, although it can be investigated for the future. In general, it is reasonable to presume that geological types that are well-known to support subterranean fauna will require adequate survey before impacts of proposals can be determined. If the potential for subterranean fauna to be present has been identified but proponents have information which indicates it is not a key environmental factor for their proposal area, the EPA will examine this information before requesting detailed survey information.

Processes that act on the substrate occupied by subterranean fauna are quite different for stygofauna and troglifauna, so it may be appropriate to take a different approach to risk assessment for the two groups of organisms. There is strong evidence to show that species distribution within calcretes is patchy and that within species there may be limited gene flow. It would appear from this evidence that using a risk-based approach for stygofauna in calcretes may be problematic.

The most analogous example of assessment of a similar factor is that of SREs where Guidance Statement 20 suggests the use of geographic boundaries, landform changes or habitat isolates together with advice from the WA Museum and DEC to determine the likelihood of SRE fauna occurring. However this is dependent on the time and resourcing of these agencies to allow capacity to provide advice. Proponents are able to use a risk-based approach and use a process to determine the level of survey effort required for EIA.

At present, the survey and monitoring reports submitted by proponents as requirements of EPA assessment and approval conditions, are now usually publicly available, but may not be in the form or detail that would be useful to other proponents or government agencies. At present, there is no requirement to enable data to be incorporated into a consolidated database. Much of this information, (i.e. environmental and species data as well as the interpretation) although important for building biodiversity understanding and which ideally should be used to support industry and government planning, decision-making and management, is inadequately used.

There is an imperative for information to be better shared, to be better defined so that targets can be audited and validated, and to be subjected to value-adding, data derivatives and interpretation to ensure the information can be accessed and used effectively. While recognising the importance of intellectual property and ensuring that it is appropriately protected, the EPA is progressing solutions for the sharing and better use of environmental information (including full disclosure of methods, data and analysis) gathered during assessment, condition compliance or other

monitoring. A data management system would require appropriate data capture to ensure the system is able to support clear and consistent decision-making and record-keeping into the future.

Sufficient flexibility must be allowed to enable the use of new or advanced cost-effective monitoring technologies as they develop or evolve. Best practice is expected.

In summary, it is anticipated that an EAG on assessment of subterranean fauna will cover issues such as risk assessment, regional context, when a strategic approach is appropriate and how to manage uncertainty. A review of survey requirements and analysis will be required to accommodate policy changes. Pivotal to changes in approach will be the development of standard procedures for adoption of a prescriptive system for all subterranean fauna data to ensure that it becomes part of a coordinated Statewide data system.

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Appendix 1 - Threatened subterranean fauna listed under Schedule 1 of the Wildlife Conservation Act 1950 and/or Environment Protection Biodiversity Conservation Act 1999

Scientific name	Common name	Type of fauna	Region	Threat category	
				EPBC 1999	WC Act (notice 2012) & date of first listing
<i>Milyeringa veritas</i>	Blind Gudgeon	fish	Cape Range & Barrow Island	VU	VU (16-11-1990)
<i>Ophisternon candidum</i>	Blind Cave Eel	fish	Cape Range & Pilbara	VU	VU (16-11-1990)
<i>Abebaiaoscia troglodytes</i>	Pannikin Plain Cave Isopod	isopod	Nullarbor		VU (30-4-1996)
<i>Bamazomus subsolanus</i>	Eastern Cape Range Bamazomus	pseudoscorpion	Cape Range		EN (14-8-2001)
<i>Bamazomus vespertinus</i>	Western Cape Range Bamazomus	pseudoscorpion	Cape Range		EN (14-7-1998)
<i>Bogidomma australis</i>	Barrow Island Bogidomma	amphipod	Barrow Island		VU (14-7-1998)
<i>Bunderia misophaga</i>		copepod	Cape Range		CR (9-4-2002)
<i>Danielopolina kornickeri</i>		ostracod	Cape Range		CR (9-4-2002)
<i>Draculoides bramstokeri</i>	Barrow Island Draculoides	schizomid	Barrow Island		VU (30-4-1996)
<i>Draculoides brooksi</i>	Northern Cape Range Draculoides	schizomid	Cape Range		EN (14-8-2001)
<i>Draculoides julianneae</i>	Western Cape Range Draculoides	schizomid	Cape Range		EN (14-7-1998)
<i>Draculoides mesozeirus</i>	Middle Robe Draculoides	schizomid	Pilbara		VU (22-1-2008)
<i>Hurleya</i> sp. (WAM 642-97)	Crystal Cave Crangonyctoid	amphipod	South West		CR (14-7-1998)
<i>Indohya damocles</i>	Cameron's Cave Pseudoscorpion	pseudoscorpion	Cape Range		CR (5-8-2008)
<i>Lasionectes exleyi</i>	Cape Range Remipede	aquatic crustacean	Cape Range	VU	CR (30-4-1996)
<i>Liagoceradocus branchialis</i>	Cape Range Liagoceradocus	amphipod	Cape Range		EN (14-7-1998)
<i>Liagoceradocus subthalassicus</i>	Barrow Island Liagoceradocus	amphipod	Cape Range		VU (14-7-1998)

Scientific name	Common name	Type of fauna	Region	Threat category	
				EPBC 1999	WC Act (notice 2012) & date of first listing
<i>Nedsia fragilis</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia humphreysi</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia hurlberti</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia macrosculptilis</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia sculptilis</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia straskraba</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Nedsia urifimbriata</i>		amphipod	Barrow Island		VU (14-7-1998)
<i>Paradraculoides anachoretus</i>	Mesa A Paradraculoides		Pilbara		VU (22-1-2008)
<i>Paradraculoides bythius</i>	Mesa B/C Paradraculoides		Pilbara		VU (22-1-2008)
<i>Paradraculoides gnophicola</i>	Mesa G Paradraculoides		Pilbara		VU (22-1-2008)
<i>Paradraculoides kryptus</i>	Mesa K Paradraculoides		Pilbara		VU (22-1-2008)
<i>Speleophria bunderae</i>		copepod	Cape Range		CR (9-4-2002)
<i>Speleostrophus nesiotese</i>	Barrow Island Millipede	millipede	Barrow Island		VU (14-7-1998)
<i>Stygiocaris lancifera</i>	Lance-Beaked Cave Shrimp		Cape Range		VU (8-4-1994)
<i>Stygiochiropus isolatus</i>		millipede	Cape Range		VU (30-4-1996)
<i>Stygiochiropus peculiaris</i>	Cameron's Cave Millipede	millipede	Cape Range		CR (28-11-1997)
<i>Stygiochiropus sympatricus</i>		millipede	Cape Range		VU (30-4-1996)
<i>Stygiocylopia australis</i>					CR (9-4-2002)
<i>Tartarus mullamullangensis</i>	Mullamullalang Cave Spider	spider	Nullarbor		VU (8-4-1994)
<i>Tartarus murdochensis</i>	Murdoch Sink Cave spider	spider	Nullarbor		VU (14-8-2001)
<i>Tartarus nurinensis</i>	Nurina Cave Spider	spider	Nullarbor		VU (14-8-2001)
<i>Tartarus thampannensis</i>	Thampanna Cave Spider	spider	Nullarbor		VU (14-8-2001)
<i>Troglodiplura lowryi</i>	Nullarbor Cave Trapdoor Spider	spider	Nullarbor		VU (8-4-1994)

Appendix 2 – Subterranean Threatened Ecological Communities of WA

Community	Threat category		Region
	EPBC 1999	Endorsed by Minister for Environment (current at August 2010)	
Aquatic Root Mat Community Number 1 of Caves of the Swan Coastal Plain	EN	CR	South West
Aquatic Root Mat Community Number 1 of Caves of the Leeuwin Naturaliste Ridge	EN	CR	South West
Aquatic Root Mat Community Number 2 of Caves of the Leeuwin Naturaliste Ridge	EN	CR	South West
Aquatic Root Mat Community Number 3 of Caves of the Leeuwin Naturaliste Ridge	EN	CR	South West
Aquatic Root Mat Community Number 4 of Caves of the Leeuwin Naturaliste Ridge	EN	CR	South West
Camerons Cave Troglobitic Community		CR	Cape Range
Cape Range Remipede Community		CR	Cape Range
Ethel Gorge Aquifer Stygobiont Community		EN	Pilbara
Depot Springs Stygofauna Community		VU	Yilgarn

Appendix 3 - Summary of major EPA decisions, Ministerial decisions and conditions where subterranean fauna is a relevant environmental factor

	Name, location and bulletin number	EPA decision/ recommendation to Minister	EPA conditions ¹	Appeal details ²	Ministerial Statement ¹
1	Extensions to the Exmouth water supply borefield (a'mnt 921), Bull 843, Mar 1997	Proposal can be implemented if subject to conditions.	<ul style="list-style-type: none"> • Proponent's commitments to be made enforceable. • Proponent should be required to implement an environmental management plan. • Proponent should be required to implement an environmental management system. 	Appeal 86 of 1997 had 5 grounds relevant to subterranean fauna ³ . Dismissed.	Ministerial Statement 459. Proposal may be implemented. Conditions: 1-1 Proponent shall fulfil commitments in Consultative Environmental Review: 1. Finalise detailed stygofauna and aquifer monitoring program; 2. Submit data on stygofauna species composition and numbers; 3. Implement actions to protect stygofauna populations and habitat to EPA requirements; If monitoring reveals that salinity of production or monitoring wells is increasing, the proponent will 4. Immediately reduce the rate of pumping; 5. Reduce the local production from the group of bores in the area; and 6. If the salinity levels do not improve, cease groundwater production from the bores involved. 5-1 to 5-4 – general conditions relating to due care and diligence, implementing a management plan and manage the environmental factors to ensure environmental objectives are met.
2	Limestone mine, quicklime and use of existing port facility (Whitecrest) (Point Murat),	Project can be managed to reasonably meet EPA objective, provided: • Cape Range	<ul style="list-style-type: none"> • Proponent's conditions should be made enforceable • Proponent is required to address a number of specified issues in the environmental management plan. 	Appeals 74, 75, 76, 78 and 79, 83, 84, 86 and 87 of 1997. Two main appeal grounds ⁴ are relevant	Ministerial Statement 461. Proposal may be implemented. Conditions: 1-1 Proponent to fulfil commitments made in PER (37 Ongoing program of sampling identification and documentation of troglotic fauna; 38 Prior to commencement of mining, proponent to develop a practicable protocol for the notification, documentation and management of any large or significant caverns encountered)

¹ Text in these columns has been abbreviated where possible and does not represent legal wording of the conditions. Please refer to original documents for more information.

² Includes appeals related to the EPA report and recommendations to the Minister only, not appeals/decisions relating to levels of assessment.

³ Grounds were the loss of stygofauna, lack of survey and analysis for decision-making, potential for watertable drawdown in the absence of a wider development policy for Cape Range (Hamilton-Smith *et al.* 1998 was in preparation but had not been released).

⁴ Risk of reduction in genetic diversity of troglotauna with the mining activities and destruction of caves. Other issues were also widely applicable - lack of consideration for the karst management report (Hamilton-Smith *et al.* 1998); unsuitability of developing an environmental management plan after the proposal has been given approval; and inappropriateness of giving approval before the release of an environmental policy and integrated approach to development. The Minister allowed the appeals in part and required the proponent to undertake subterranean fauna survey and release the environmental management plan for public comment prior to finalisation.

	Shire of Exmouth (a'mnt 715) Bull 846, Mar 1997.	National Park is extended to include comparable areas of troglofauna habitat; and •proponent is required to contribute to research to increase the understanding of subterranean fauna.		to subterranean fauna Allowed in part.	4-1 Prior to construction proponent to prepare environmental management plan 4-2 Management plan to be available for public review and comment prior to finalization and 4-3 Subjects for inclusion. 6-1 Prior to commencement of mining, proponent in liaison with agencies shall prepare a subterranean fauna program to address stratified sampling; Mining to only proceed in areas where the EPA is satisfied that there is no significant risk of any species becoming extinct as a result.
3	Exmouth limestone project barge loading facility (Whitecrest) Mowbowra Creek Exmouth Gulf (a'mnt 1107) Bull 871 Nov 1997.	Proposal does not impose an unacceptable impact on the environment, provided that conditions are imposed and the proposal can conform to the WC Act.	<ul style="list-style-type: none"> •proponent shall fulfil commitments (further investigate occurrences of karst features; report to agencies and investigate options to modify the proposal to conserve features; if cannot be avoided, proponent to discuss with agencies regarding the need for investigation of karst values) •proponent to prepare and implement an environmental management plan to address karst features and subterranean fauna (and other subjects) 	Appeal 217 of 1997 was recorded but not relevant to subterranean fauna.	Ministerial Statement 465. Proposal may be implemented. Conditions: 1-1 Proponent shall fulfil commitments (further investigate occurrences of karst features; report to agencies and investigate options to modify the proposal to conserve features; if cannot be avoided, proponent to discuss with agencies regarding the need for investigation of karst values) 5-1 Prior to construction, the proponent shall prepare an environmental management plan (including for karst features and subterranean fauna).
4	Newman Satellite Development, Mining of Orebody 23 below the water table (a'mnt 1142) Bull 888 Apr 1998. Ethel Gorge An s45c amendment was approved to extend the life and maximum disturbance boundary of Orebody 23 Mine in Sept 2010.	Proposal can be managed to meet EPA objectives provided conditions are imposed.	<ul style="list-style-type: none"> •Within 2 years following commencement of mining below the water table, the proponent shall submit a performance review on: 1. environmental objectives reported in Bulletin 888 (maintain the abundance, species diversity and geographical distribution of subterranean fauna) and 2. proponents consolidated environmental management commitments (Identify stygofauna species collected in the vicinity of OB 23; Assess conservation significance; Map the local distribution of species sampled; and undertake sampling in the Ophthalmia region if species found to be at significant conservation risk). 	No appeal recorded	Ministerial Statement 478. Proposal may be implemented. Conditions: 2-1 Proponent shall implement proponents consolidated environmental management commitments (Identify stygofauna species collected in the vicinity of OB 23; Assess conservation significance; Map the local distribution of species sampled; and undertake sampling in the Ophthalmia region if species found to be at significant conservation risk) 4-1 Within 2 years following commencement of mining below the water table, the proponent shall submit a performance review on: 1. environmental objectives reported in Bulletin 888 (maintain the abundance, species diversity and geographical distribution of subterranean fauna).
5	White Opal-1	Proposal can be	•the proponent shall fulfil the commitments in the	No appeal recorded.	Ministerial Statement 488. Proposal may be implemented. Conditions:

	Exploration Well Cape Range Peninsula Exmouth, a'mnt 1167, Bull 905 Oct 1997.	managed in a manner such that the proposal does not impose an unacceptable impact on the environment, provided that the recommended conditions are imposed.	consolidated commitments statement (4. Operational methods to prevent spillage; 5. Use of non-toxic drilling fluids for exploration well; 6. Operational methods to prevent seepage of harmful pollutants; 7. Take action to restore groundwater quality in the event of leakage or spillage).		2-1 implement the consolidated environmental management commitments (4. Operational methods to prevent spillage; 5. Use of non-toxic drilling fluids for exploration well; 6. Operational methods to prevent seepage of harmful pollutants; 7. Take action to restore groundwater quality in the event of leakage or spillage). 2-2 proponent shall implement subsequent environmental management commitments.
6	West Angelas Iron Ore Project – East Pilbara, Ashburton, Roebourne (a'mnt 1144) Bull 924 Jan 1999	Proposal is largely able to meet the EPA's environmental objectives, some portions of the proposed rail line are unable to do so ⁵ .	<ul style="list-style-type: none"> • Prior to commencement of ground-disturbing activities, proponent shall prepare an environmental management program (including 2. Report on the assessment of subterranean fauna as proposed in the proponents commitments; 8. Assist WA Museum to minimise and manage impacts to stygofauna around the minesite and borefield; 9. Use standby bores if further research indicates that stygofauna species present are of significant conservation value; 10. Bores to provide water for construction phase if no stygofauna found; 11. Monitor production and dewatering bores for stygofauna abundance and water levels; 12. Drawdown and fauna abundance monitoring; 13. Pumping rates to be re-assessed or stopped to ensure conditions for the protection of stygofauna are met; 14. Alternative bores to be utilised; 15. Workshops, stores and fuel depots to prevent pollution to groundwater; 16. Monitoring of abundance and water table levels; 17. Further survey and monitoring for production bores; 18. Monitoring programme for expanded borefield; 19. Mine staff briefed). 	Appeals 15 and 16 of 1999 were made against the EPA's report and recommendations but not relevant to subterranean fauna.	Ministerial Statement 514. Proposal may be implemented. Conditions: 4-1 Prior to commencement of ground-disturbing activities, proponent shall prepare, an environmental management program (including 2. Report on the assessment of subterranean fauna as proposed in the proponents commitments; 8. Assist WA Museum to minimise and manage impacts to stygofauna around the minesite and borefield; 9. Use standby bores if further research indicates that stygofauna species present are of significant conservation value; 10. Bores to provide water for construction phase if no stygofauna found; 11. Monitor production and dewatering bores for stygofauna abundance and water levels; 12. Drawdown and fauna abundance monitoring; 13. Pumping rates to be re-assessed or stopped to ensure conditions for the protection of stygofauna are met; 14. Alternative bores to be utilised; 15. Workshops, stores and fuel depots to prevent pollution to groundwater; 16. Monitoring of abundance and water table levels; 17. Further survey and monitoring for production bores; 18. Monitoring programme for expanded borefield; 19. Mine staff briefed).

⁵ This was because the railway line traversed sections of conservation estate, and inability to meet EPA objectives was not caused by impacts on subterranean fauna.

7	Murrin Murrin Nickel-Cobalt Project Stage 2 Expansion, 60 km east of Leonora (a'mnt 1229) Bull 931 Mar 1999.	Proposal can be managed in an environmentally acceptable manner such that it is unlikely that the EPA's objectives would be compromised, provided there is satisfactory implementation of the recommended conditions.	<ul style="list-style-type: none"> • Prior to quarrying either calcrete deposit, the proponent shall develop a subterranean fauna management plan to conserve and protect subterranean fauna species. Plan shall address: 1. Subterranean fauna surveys of the calcrete areas, and possibly outside, to establish the conservation significance; 2. Mapping of the local and regional distribution; and 3. measures to limit the impacts on any localised species. • Implement the plan. • Make the plan publicly available. 	Appeal 56 of 1999 included impacts on subterranean fauna as one of the grounds. Dismissed.	Ministerial Statement 506. Proposal may be implemented. Conditions: 4-1 Prior to quarrying either calcrete deposit, the proponent shall develop a subterranean fauna management plan to conserve and protect subterranean fauna species. Plan shall address: 1. Subterranean fauna surveys of the calcrete areas, and possibly outside, to establish the conservation significance; 2. Mapping of the local and regional distribution; and 3. measures to limit the impacts on any localised species. 4-2 Implement the plan. 4-3 Make the plan publicly available.
8	Industrial subdivision Lot 51 Murat Road Exmouth (a'mnt 1269) Bull 972 Mar 2000.	Proposal could be readily managed to meet the EPA's environmental objectives.	<ul style="list-style-type: none"> • Prior to the commencement of subdivision works, the proponent shall prepare an environmental management programme, including: 3. preparation of a karst management plan which a) incorporates a ground survey using ground probing radar; and b) includes recommendations for further detailed geotechnical investigations of areas of high risk karst; 4. Environmental requirements to be addressed by prospective occupiers/purchasers: a) follow-up geotechnical investigations, if necessary; b) management of the storage, handling and disposal of environmentally sensitive materials; d) volume and management of wastewater. e) management of stormwater; f) the volume of effluent and management of on-site disposal systems. 	No appeal recorded.	Ministerial Statement 545. Proposal may be implemented. Conditions: 5-1 Prior to the commencement of subdivision works, the proponent shall prepare an environmental management programme, including: 3. preparation of a karst management plan which a) incorporates a ground survey using ground probing radar; and b) includes recommendations for further detailed geotechnical investigations of areas of high risk karst; 4. Environmental requirements to be addressed by prospective occupiers/purchasers: a) follow-up geotechnical investigations, if necessary; b) management of the storage, handling and disposal of environmentally sensitive materials; d) volume and management of wastewater. e) management of stormwater; f) the volume of effluent and management of on-site disposal systems.
9	Ord River irrigation area Stage 2 Kununurra (revised proposal) (a'mnt	Proposal can be managed to meet the EPA's objectives, subject to conditions and	<ul style="list-style-type: none"> • Prior to finalisation of detailed design and ground disturbing activities, the proponent shall prepare a flora and fauna survey plan to conserve and protect listed and subterranean fauna species. Plan shall address: 1. Identification and protection of subterranean 	Appeal 126 of 2000 ⁶ appealed the provisions for additional survey of subterranean fauna	Ministerial Statement 585. Proposal may be implemented. Conditions: 9-1 Prior to finalisation of detailed design and ground disturbing activities, the proponent shall prepare a flora and fauna survey plan to conserve and protect listed and subterranean fauna species. Plan shall address: 1. Identification and protection of subterranean fauna.

⁶ Appeals 124, 125, 127, 128 and 131 of 2000 were not relevant to subterranean fauna.

	1240), Bull 988 Aug 2000.	commitments.	fauna.	was dismissed.	
	Ord River irrigation area Stage 2, M2 Supply Channel), Kununurra, (a'mnt 1240 and 1828), Bull 1016, May 2010.	Proposal is capable of being managed to meet the EPA's objectives related to management.	<ul style="list-style-type: none"> • Prior to the preparation of the final project design layout, proponent shall prepare a flora and fauna protection plan for the project area, as part of the environmental management programme, to conserve and protect listed and subterranean species. The Plan shall address: 4 the identification and protection of subterranean fauna. 	Appeal 61 of 2001 ⁷ appealed the provisions for additional survey of subterranean fauna, was dismissed.	Ministerial Statement 830. Proposal may be implemented. Conditions: 9-1 Prior to the preparation of the final project design layout, proponent shall prepare a flora and fauna protection plan for the project area, as part of the environmental management programme, to conserve and protect listed and subterranean species. The Plan shall address: 4 the identification and protection of subterranean fauna.
	Ord River irrigation area Stage 2 (M2 Supply Channel) proposal under S46 to make changes. Rep1354, Apr 2010.	The proponents made a s46 request to change the timing of formation of the environmental management entity, update the titles of the Minister and government departments and remove the need for the EPA to approve a number of management plans. No change to conditions relevant to subterranean fauna.		No appeal recorded	Ministerial Statement wording as above
10	Hope Downs Iron Ore Mine 75 km north-west of Newman Pilbara Region, a'mnt 1308, Bulletin 1024 Aug 2001. Other a'mnts for the same proponent (eg Bull 1066) do not include subterranean	Proposal is capable of being managed in an environmentally acceptable manner such that it is most unlikely that the EPA's objectives would be compromised, provided there is satisfactory implementation by the proponent of the recommended	<ul style="list-style-type: none"> • The proponent shall implement the environmental management commitments (3 Prepare and implement a Water Management Plan; 10 Undertake a comprehensive stygofauna sampling programme within the project area). • Prior to commencing dewatering operations, the proponent shall develop a subterranean fauna sampling plan for the respective area. The objective of the plan is to increase scientific knowledge about subterranean fauna to assist in the conservation of this element of the environment. Plan shall address: 1. subterranean fauna surveys of the areas to be affected by dewatering; 2. characterisation of subterranean fauna habitats to be affected by dewatering and 	Appeal 86 of 2001 made against the EPA's report and recommendations but not relevant to subterranean.	Ministerial Statement 584. Proposal may be implemented. Conditions: 2-1 The proponent shall implement the environmental management commitments (3 Prepare and implement a Water Management Plan; 10 Undertake a comprehensive stygofauna sampling programme within the project area) 6-1 At least 12 months prior to commencing dewatering operations, the proponent shall develop subterranean fauna sampling plan for the respective area. The objective of the plan is to increase scientific knowledge about subterranean fauna to assist in the conservation of this element of the environment. Plan shall address: 1. subterranean fauna surveys of the areas to be affected by dewatering; 2. characterisation of subterranean fauna habitats to be affected by dewatering and identification of similar subterranean fauna habitats outside the affected areas; 3 surveys of similar habitats to assist in

⁷ Appeals 63, 64, 54, 66 and 67 of 2001 were not relevant to subterranean fauna.

	fauna. Weeli Wolli	conditions, including the proponent's commitments.	identification of similar subterranean fauna habitats outside the affected areas; 3 surveys of similar habitats to assist in establishing the conservation significance of fauna within the areas to be affected; and 4. specific measures to record and preserve biological information on any species collected in the project area). • Implement the plan. • Make the plan publicly available. • Submit results from the plan to the EPA, CALM and WAM. • In the event that the EPA consider, based on the results of plan, that its objective would be compromised, the proponent shall develop an action plan.		establishing the conservation significance of fauna within the areas to be affected; and 4. specific measures to record and preserve biological information on any species collected in the project area) 6-2 Implement the plan. 6-3 Make the plan publicly available. 6-4 Submit results from the plan to the EPA, CALM and WAM. 6-5 In the event that the EPA consider, based on the results of plan, that its objective would be compromised, the proponent shall develop an action plan.
	Hope Downs 4 Iron Ore Mine approximately 30 km north-west of Newman (a'mnt 1738) Bull 1374, Dec 2010.	Unlikely that the EPA's objectives would be compromised provided there is satisfactory implementation by the proponent of the recommended conditions.	• No conditions or proponent commitments relevant to subterranean fauna recommended. • Surveys were conducted to identify stygofauna and troglofauna and were not considered to be restricted to the site. Therefore subterranean fauna was not considered to be significant and no further assessment was required.	No appeals recorded.	Ministerial Statement 854. Proposal may be implemented. No conditions or proponent commitments relevant to subterranean fauna.
11	Pilbara Iron Ore & Infrastructure Project: East-West Railway and Mine sites (Stage B) (a'mnt 1520) Bull 1202 Oct 2005, FMG Christmas Creek	Unlikely that the EPA's objectives would be compromised provided there is satisfactory implementation by the proponent of their commitments and the recommended conditions.	• Within six months the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey plan. Plan shall set out procedures and measures to: 1. survey areas likely to be affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations. • In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, proponent shall institute management measures in accordance with a subterranean fauna management plan which shall set out	Appeal 231 of 2005 ⁸ was against the EPA report and recommendations on the grounds the proposal had been allowed to proceed when the stygofauna taxonomy was not complete and survey was inadequate. Upheld in part and required amendments	Ministerial Statement 707. Proposal may be implemented. Conditions: 10-1 Within six months the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey plan. Plan shall set out procedures and measures to: 1. survey areas likely to be affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations. 10-2 The proponent shall review and revise the subterranean fauna survey plan at intervals not exceeding five years. 10-3 In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, proponent shall institute management measures in

⁸ Appeal 232 of 2005 was also made against the EPA's report and recommendations but was not relevant to subterranean fauna.

			<p>procedures and measures to: 1. avoid and/or manage impacts on fauna and/or communities and their habitats where the long-term survival may be at risk; 2. monitor the distribution and abundance of species and/or communities, groundwater levels, groundwater quality and other relevant aspects to ensure that the long-term survival is not compromised; 3. Take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival.</p> <ul style="list-style-type: none"> • Prior to the commencement of dewatering the proponent shall, if applicable, implement the subterranean fauna management plan. • Make the plan publicly available. 	to the EPA's recommended conditions.	<p>accordance with a subterranean fauna management plan which shall set out procedures and measures to: 1. avoid and/or manage impacts on fauna and/or communities and their habitats where the long-term survival may be at risk; 2. monitor the distribution and abundance of species and/or communities, groundwater levels, groundwater quality and other relevant aspects to ensure that the long-term survival is not compromised; 3. Take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival.</p> <p>10-4 Prior to the commencement of dewatering the proponent shall, if applicable, implement the subterranean fauna management plan.</p> <p>10-5 Make the plan publicly available.</p>
12	Christmas Creek Water Management Scheme (a'mnt 1873) Rep 1402, June 2011	Proposal can be managed to meet the EPA's environmental objectives, provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • No conditions relevant to subterranean fauna survey or management were recommended, however conditions to address groundwater mounding and potential effects of dewatering and mounding on vegetation were included. • Six stygofauna species were recorded within the proposal area but all of these species are considered widespread as they were all recorded outside the area of impact and therefore the impact is unlikely to be significant. • Desktop survey concluded that it was very likely that troglifauna species occur and field surveys had been undertaken but were results were not available at the time of assessment. Mounding of groundwater was predicted to reduce the total volume of potential troglifauna habitat (up to 19%), but there are difficulties in prediction of the impact of dewatering on soil humidity within potential troglifauna habitat. Connectivity and size of habitat volume along the Fortescue valley and footslopes of the Chichester range make it unlikely that any troglifauna species is restricted to the area and therefore the EPA concluded that the risk to troglifauna species was low. 	No appeals recorded	<p>Ministerial Statement 871. Proposal may be implemented.</p> <p>No conditions relevant to subterranean fauna survey or management were recommended, however conditions to address groundwater mounding and potential effects of dewatering and mounding on vegetation were included.</p>

13	Ellendale 4 Diamond Project West Kimberley (a'mnt 1571) Bull 1181, Jun 2005.	Proposal can be managed in an acceptable manner subject to the EPA's recommended conditions and the proponent's commitments being made legally binding.	<ul style="list-style-type: none"> No conditions or proponent commitments relevant to subterranean fauna recommended. Stygofauna studies showed that species were widespread and not restricted to the area of dewatering impact and connectivity between aquifers, and results from similar limestone geology in the West Kimberley showed that stygofauna can recolonise areas of historic dewatering. 	Appeals 110, 111 and 112 of 2005 against the EPA report and recommendations included grounds that insufficient information was in the report and potential impacts on stygofauna. Dismissed.	No conditions or proponent commitments relevant to subterranean fauna recommended.
14	Argyle Diamond Mine - underground project 110km south of Kununurra East Kimberley (a'mnt 1606), Bull 1205, Nov 2005.	Proposal can be managed in an acceptable manner subject to the commitments to the proposal being legally binding.	<ul style="list-style-type: none"> The proponent shall review and update, if necessary, the subterranean fauna management plan which forms part of the <i>Argyle Underground Environmental Management Plan</i> (September 2005). Implement plan. Make the plan publicly available. 	No appeal recorded	Ministerial Statement 711. Proposal may be implemented. Conditions: 12-1 The proponent shall review and update, if necessary, the subterranean fauna management plan which forms part of the <i>Argyle Underground Environmental Management Plan</i> (September 2005). 12-2 Implement the plan. 12-3 Make the plan, monitoring and associated subterranean fauna reports publicly available.
15	Orebody 25 Extension 8 km north east of Newman Pilbara Region, Bull 1210, Nov 2005. See also Orebody 23 and 24/25 (Bull 888; Bull 1356)	Proposal described can be managed in an acceptable manner subject to the commitments to the proposal being legally binding.	<ul style="list-style-type: none"> Within six months, the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey plan. The plan shall set out procedures and measures to: 1. survey areas affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish conservation significance. In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan which sets out procedures and measures to: 1. avoid and/or manage impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of may be at risk as a result of 	No appeal recorded	Ministerial Statement 712. The proposal may be implemented. Conditions: 9-1 Within six months, the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey plan. The plan shall set out procedures and measures to: 1. survey areas affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish conservation significance. 9-2 In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan which sets out procedures and measures to: 1. avoid and/or manage impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of may be at risk as a result of project operations; 2. monitor the distribution and abundance of species and/or communities, groundwater levels, groundwater quality and other relevant

			<p>project operations; 2. monitor the distribution and abundance of species and/or communities, groundwater levels, groundwater quality and other relevant aspects of subterranean fauna habitat to ensure that the long-term survival is not compromised as a result of project operations; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival of subterranean fauna and / or communities.</p> <ul style="list-style-type: none"> • Prior to the commencement of dewatering activities at Cattle Gorge or Nimingarra I, proponent shall implement the subterranean fauna management plan. • Make the plan publicly available. 		<p>aspects of subterranean fauna habitat to ensure that the long-term survival is not compromised as a result of project operations; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival of subterranean fauna and / or communities.</p> <p>9-3 Prior to commencement of dewatering activities at Orebody 25, proponent shall implement the subterranean fauna management plan.</p> <p>9-4 Make the plan publicly available.</p>
16	Orebody 24/25 Upgrade project (a'mnt 1833) Rep 1356, Apr 2010.	Proposal can be managed in an acceptable manner subject to the commitments to the proposal being legally binding.	<ul style="list-style-type: none"> • No conditions relevant to subterranean fauna recommended by the EPA. 	Appeal 56 of 2010 was received but the grounds were not relevant to subterranean fauna.	<p>Ministerial Statement 834. The proposal may be implemented.</p> <p>No conditions relevant to subterranean fauna recommended by the Minister.</p>
17	Wheelarra Hill iron ore mine extension project Jimblebar Newman (a'mnt 1558) Bull 1168, Apr 2005.	Proposal could be carried out in an environmentally acceptable manner provided that the recommended conditions, which address all the main issues, together with the proponent's commitments, are implemented.	<ul style="list-style-type: none"> • Within 12 months, the proponent shall prepare a stygofauna investigation plan to maintain the abundance, diversity, geographic distribution and productivity of stygofauna at species and ecosystem levels through the avoidance or management of adverse impacts and through improvements in knowledge. plan shall include: 1. subterranean fauna surveys in areas affected by project operations; 2. subterranean fauna surveys in areas with similar habitats outside the areas to be affected by project operations to assist in establishing the conservation significance of fauna within the areas to be affected; 3. records of biological information on any species collected in the project area; 4. effects that climate change may have on stygofauna in the wellfield; 5. a stygofauna management plan where surveys indicate that species and/or communities of 	Appeal 61 of 2005 was received but the grounds were not relevant to subterranean fauna.	<p>Ministerial Statement 683. The proposal may be implemented. Conditions:</p> <p>7-1 Within 12 months, the proponent shall prepare a stygofauna investigation Plan to maintain the abundance, diversity, geographic distribution and productivity of stygofauna at species and ecosystem levels through the avoidance or management of adverse impacts and through improvements in knowledge. plan shall include: 1. subterranean fauna surveys in areas affected by project operations; 2. subterranean fauna surveys in areas with similar habitats outside the areas to be affected by project operations to assist in establishing the conservation significance of fauna within the areas to be affected; 3. records of biological information on any species collected in the project area; 4. effects that climate change may have on stygofauna in the wellfield; 5. a stygofauna management plan where surveys indicate that species and/or communities of conservation significance exist within the impact areas (including monitoring for species and/or communities of conservation significance and details of management measures); 6. reporting procedures and schedule; and 7. the timeframe for implementation of the</p>

			<p>conservation significance exist within the impact areas (including monitoring for species and/or communities of conservation significance and details of management measures); and 6. reporting procedures and schedule.</p> <ul style="list-style-type: none"> • Within 12 months, the proponent shall implement the stygofauna investigation plan. • Make the plan publicly available. 		<p>plan.</p> <p>7-2 Implement the plan.</p> <p>7-3 Make the plan publicly available.</p>
18	<p>Goldsworthy Iron Ore Mines Extension Project Northern Pilbara, Bull 1171, May 2005</p>	<p>Proposal can be managed in an acceptable manner subject to the recommended conditions and commitments to the proposal being legally binding.</p>	<ul style="list-style-type: none"> • Within 6 months, the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey programme which sets out procedures and measures to: 1. survey areas affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish the conservation significance. • If results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan including procedures and measures to: 1. avoid and/or manage impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of those species and/or communities may be at risk as a result of project operations; 2. monitor the distribution and abundance of species and/or communities of subterranean fauna, groundwater levels, groundwater quality and other relevant aspects of subterranean fauna habitat to ensure that the long-term survival of subterranean fauna species and communities; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival. • Prior to the commencement of dewatering activities at Cattle Gorge or Nimingarra I, the proponent shall implement the plan. • Make the plan publicly available. 	<p>Appeal 95 of 2005 was received but the grounds were not relevant to subterranean fauna.</p>	<p>Ministerial Statement 682. The proposal may be implemented. Conditions:</p> <p>8-1 Within 6 months, the proponent shall commence surveys for subterranean fauna in accordance with a subterranean fauna survey programme which sets out procedures and measures to: 1. survey areas affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish the conservation significance.</p> <p>8-2 If results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan including procedures and measures to: 1. avoid and/or manage impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of those species and/or communities may be at risk as a result of project operations; 2. monitor the distribution and abundance of species and/or communities of subterranean fauna, groundwater levels, groundwater quality and other relevant aspects of subterranean fauna habitat to ensure that the long-term survival of subterranean fauna species and communities; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival</p> <p>8-3 Prior to the commencement of dewatering activities at Cattle Gorge or Nimingarra I, the proponent shall implement the plan.</p> <p>8-4 Make the plan publicly available.</p>

19	Mesa A/ Warrambo Iron Ore Project (a'mnt 1574) Bull 1251, March 2007.	Proposal is environmentally unacceptable because it cannot be managed to meet the EPA's objectives in relation to subterranean fauna (also landforms, closure planning & rehabilitation).	<ul style="list-style-type: none"> The EPA did not include conditions & procedures to which the proposal should be subject in the bulletin because it held the view that the proposal should not be implemented. 	Two appeals were received (32 & 33 of 2007) during which new information was introduced by the proponent to address the EPA's concerns.	The Minister remitted the proposal to the EPA for reassessment on two factors (one of which was subterranean fauna) (see Bulletin 1264. Ministerial Statement 756).
20	Mesa A/ Warrambo Iron Ore Mine 43 km West of Pannawonica Shire of Ashburton (a'mnt 1574) Bull 1264, Sept 2007.	Proposal can be managed to meet its environmental objectives provided that conditions are imposed.	<p>After the publication of Bulletin 1251 (during the appeals process), the proponent provided the results of further investigations into troglobitic fauna & also a geotechnical assessment. The Minister for Environment remitted the proposal to the EPA for reassessment & the proponent changed the project design to enlarge the mining exclusion zone (MEZ).</p> <p>The EPA recommended the following conditions:</p> <ul style="list-style-type: none"> Prior to the commencement of productive mining, the proponent shall submit a troglobitic fauna monitoring program for approval with the objective to gather information about the response of troglobitic fauna species & populations to direct & indirect impacts of mining, both during the mining process & after mining has ceased. The monitoring program shall incorporate periodic sampling of: 1. troglobitic fauna species & populations; 2. key habitat parameters including humidity within the underground spaces; & shall provide for studies on: 3. the impacts of blasting & mining on the integrity of the troglobitic fauna habitat; & 4. the effectiveness of re-creating troglobitic fauna habitat through such measures as replacement of waste rock. 	Appeals 79, 80 & 81 of 2007 were received. The minister allowed the appeals in part and made changes to the suggested conditions in the Ministerial Statement.	<p>Ministerial Statement 756. The proposal may be implemented. Conditions:</p> <p>5-1 Prior to the commencement of productive mining, the proponent shall submit a troglobitic fauna monitoring program for approval with the objective to gather information about the response of troglobitic fauna species and populations to direct and indirect impacts of mining, both during the mining process and after mining has ceased.</p> <p>5-2 The monitoring program shall incorporate periodic sampling of: 1. troglobitic fauna species and populations; 2. key habitat parameters including humidity within the underground spaces; and shall provide for studies on: 3. the impacts of blasting and mining on the integrity of the troglobitic fauna habitat; and 4. the effectiveness of re-creating troglobitic fauna habitat through such measures as replacement of waste rock.</p> <p>5-3 Proponent shall implement the troglobitic fauna sampling program before the start of ground disturbing activity and shall continue through the active mining phase of the project and into the post-mining phase, until the CEO determines that monitoring may be discontinued.</p> <p>5-4 Make the sampling program publicly available.</p> <p>5-5 Proponent shall report annually to the CEO: 1. the results of the monitoring program, and 2. assessment of the risk to the survival of remaining populations of troglobitic fauna.</p> <p>5-6 Should the monitoring show that the risk to these populations is increasing, the proponent is required to develop and implement</p>

			<ul style="list-style-type: none"> • Proponent shall implement the troglobitic fauna sampling program before the start of ground disturbing activity & shall continue through the active mining phase of the project & into the post-mining phase, until the CEO determines that monitoring may be discontinued. • Make the sampling program publicly available. 	<p>mitigation measures to reduce that risk to.</p> <p>6-1 Prior to commencement of productive mining, the proponent shall provide to DEC an accurate 3-dimensional plan of the proposed final contours of the mine pit following mining and rehabilitation that would ensure the depth of material suitable for troglobitic fauna habitat that would be retained under the pit floor after mining.</p> <p>6-2 Proponent is required to carry out works consistent with the plan unless otherwise authorised.</p> <p>6-3 12 months after commencement of productive mining and every 12 months after that the proponent is to carry out an annual audit to determine the actual pit shell contours for the area of the project where mining and rehabilitation has been completed and compare that to the plan. In locations where the actual pit shell is deeper than the plan (operational error), the proponent is to carry out remedial works.</p> <p>6-4 Any operational error is to be no more than 2m and the total area of mining that is subject to operation error in any one year should not exceed 5% of the actual area mined in any one year.</p> <p>6-5 Within 15 months of commencement of productive mining and every 12 months after that the proponent is to report to DEC on: 1. how the actual pit shell contours for the area of the project where mining and rehabilitation has been completed and any remediation required has been carried out compares with the planned pit shell; and 2. extent of any operations errors that occurred in the reporting period.</p> <p>6-6 The CEO may agree to minor changes to the plan if proponent can demonstrate that such a change is consistent with, or provides more troglobitic fauna habitat</p> <p>9-1 Prior to productive mining, the proponent is to lodge data, including in an appropriate GIS format, which accurately depicts the MEZ.</p> <p>9-2 Proponent shall ensure that the mining activities are carried out so that the MEZ is not mined and not affected by mining activities</p> <p>9-3 Any minor unintended operational errors shall be less than 5m and in any one year should not exceed 5% of the MEZ isolated because of mining.</p> <p>9-4 In locations where the MEZ is less wide than required the proponent is to carry out remedial works.</p> <p>9-5 Proponent shall report annually the geographic extent of the MEZ isolated because of mining in that year and how that compares with the</p>
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					data provide.
21	Pilbara Iron Ore and Infrastructure Project: Cloud Break (no beneficiation) (a'mnt 1577) Bull 1216, Jan 2007	Unlikely that the EPA's objectives would be compromised provided there is satisfactory implementation by the proponent of their commitments and the recommended conditions.	<ul style="list-style-type: none"> • Requirement to prepare a groundwater and bore management plan. • Within six months following, the proponent shall commence surveys in accordance with a subterranean fauna survey plan which shall set out procedures and measures to: 1. survey areas likely to be affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish the conservation significance of fauna. • In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan which will include: 1. avoid and/or demonstrate management of impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of those species and/or communities may be at risk as a result of project operations; 2. monitor the distribution and abundance of species and/or communities of subterranean fauna, groundwater levels, groundwater quality and other relevant aspects of subterranean fauna habitat to ensure that the long-term survival is not compromised; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival of subterranean fauna and / or communities. • Prior to the commencement of dewatering activities, proponent shall, implement the subterranean fauna management plan. • The proponent shall make the subterranean fauna management plan publicly available. 	No appeals recorded.	<p>Ministerial Statement 721. Proposal may be implemented. Conditions:</p> <p>9-1 to 9-3 relate to preparation of a groundwater and bore management plan.</p> <p>10-1 Within six months following, the proponent shall commence surveys in accordance with a subterranean fauna survey plan which shall set out procedures and measures to: 1. survey areas likely to be affected by project operations; and 2. survey areas with similar habitats outside the areas to be affected by project operations to establish the conservation significance of fauna.</p> <p>10-2 In the event that the results of the surveys indicate that there is a risk of loss of subterranean species or communities as a result of project operations, the proponent shall institute management measures in accordance with a subterranean fauna management plan which will include: 1. avoid and/or demonstrate management of impacts on subterranean fauna species and/or communities and their habitats where the long-term survival of those species and/or communities may be at risk as a result of project operations; 2. monitor the distribution and abundance of species and/or communities of subterranean fauna, groundwater levels, groundwater quality and other relevant aspects of subterranean fauna habitat to ensure that the long-term survival is not compromised; and 3. take timely remedial action in the event that monitoring indicates that project operations may compromise the long-term survival of subterranean fauna and / or communities.</p> <p>10-3 Prior to the commencement of dewatering activities, proponent shall, implement the subterranean fauna management plan.</p> <p>10-4 The proponent shall make the subterranean fauna management plan publicly available.</p>
22	Cloud Break Life of Mine Project, 120kms north of	It is likely that the EPA's objectives would be achieved provided	<ul style="list-style-type: none"> • Subterranean fauna was not a key factor in the assessment. • Stygofauna surveys were conducted for the assessment of the expansion, and two stygofauna 	Appeal period closed 22 February 2012	The appeal period was still open at the time of writing. The EPA did not recommend any conditions related to management of subterranean fauna.

	Newman Pilbara (a'mnt 1848) Rep 1429 Feb 2012	there is satisfactory implementation by the proponent of the recommended conditions.	<p>species were sampled only within the project footprint area, however the predicted impacts were 1m drawdown and 1 m mounding and this was considered to be within the natural variation of groundwater and therefore not significant. Other stygofauna species were found outside the area of impact.</p> <ul style="list-style-type: none"> • Two species of troglifauna were found during stygofauna sampling but these were located outside the project footprint. The EPA considered that the potential impacts to troglifauna were not significant given that the habitat within the impact area is likely to be well connected with other habitat outside the impact area for more than 100 km, therefore the factor did not require further evaluation. • No conditions relating to management of subterranean fauna were recommended by the EPA. 		
23	Gorgon Gas Development, Barrow Island Nature Reserve (a'mnt 1496) Bull 1221, Jun 2006.	<p>Overall impacts of the proposal would be environmentally unacceptable.</p> <p>The extent of predicted impacts and degree of residual uncertainty and risks posed by the proposal remain unacceptably high; EPA did not believe that the proposal could be made</p> <p>environmentally acceptable and recommended against implementation of</p>	<ul style="list-style-type: none"> • The EPA did not consider that its environmental objectives could be met, therefore did not included recommended environmental conditions for the management of the proposal in this report. • If Government was to decide that the proposal may proceed for other than environmental reasons, a set of strict conditions and governance arrangements would be required, along with implementation of the proponent's commitments. A draft framework to guide the necessary content of environmental conditions is included. • If the proposal were to be allowed to proceed, it would be incumbent on the proponent to promptly undertake studies to locate the taxa so far known only from the project • footprint in similar environments elsewhere on the island or demonstrate convincingly why it is likely that they do occur elsewhere and hence would not be driven to extinction. Depending on the results, this work could lower the level of risk but there is currently no certainty that that would be the case. Short of finding these taxa elsewhere, 	11 appeals total (Appeals 229 to 239 of 2006) but the Appeals Committee report does not detail how many appellants raised subterranean fauna issues.	<p>Ministerial Statement 748. The proposal may be implemented. Conditions:</p> <p>6.1. Prior to commencement of construction of terrestrial facilities on Barrow Island, proponent shall submit to the Minister a terrestrial and subterranean baseline state and environmental impact report that meets the purposes determined by the Minister. The report shall cover the following ecological elements: i. flora; ii. vegetation; iii. fauna (including subterranean fauna and short range endemics); iv. habitat; v. ecological communities; vi. groundwater; vii. surface water landforms; and viii. other significant landforms.</p> <p>6.2. The Proponent shall consult with DEC in the preparation of the report, including the methodology to be used to survey, collect and collate the baseline data and information for all ecological elements.</p> <p>6.3. The terrestrial facilities are: i. Gas Treatment Plant; ii. Carbon Dioxide Injection System; iii. Associated Terrestrial Infrastructure; iv. Areas impacted for seismic data acquisition; and v. Onshore Feed-gas Pipeline System and terrestrial component of the Shore Crossing</p> <p>6.4. The purposes of the report are to: i. Define and map the pre-development baseline state for the ecological elements within the areas that are expected to, or may be at risk of Material or Serious Environmental Harm due to any works associated with the terrestrial</p>

		the proposal.	or at least demonstrating that there is a high likelihood that they occur elsewhere, a real risk exists that they would become extinct as a result of the proposal.	<p>facilities; ii. Define and map the ecological elements within the Terrestrial Disturbance Footprint; and iii. Define and map the ecological elements which are at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities; iv. Define and map the ecological elements of reference sites, which are not at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities.</p> <p>6.5. The report shall include: i. A review of the results of the existing qualitative ecological risk assessments of the likelihood and consequence of Proposal impacts on the ecological elements identified; ii. Details of the methodology that was used to survey, collect and collate the baseline data and information for all ecological elements; iii. A description and map of the ecological elements within the Terrestrial Disturbance Footprint; iv. A description and map of the ecological elements which are at risk of Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint due to construction and operation of the terrestrial facilities; v. A review of the results to include existing areas of disturbance, including clearing, existing non indigenous species (including weeds) and disturbed landscapes; vi. Spatially accurate (e.g. rectified and geographically referenced) maps showing the baseline data and information for the ecological elements; vii. Discussion of the data on the baseline biological, physical and chemical variables including any significant relationships, for the ecological elements; viii. Significant ecological elements to be protected in areas of risk - e.g. DRF, TECs, Threatened Species under the EPBC Act, habitats of rare fauna; ix. An analysis of, and procedures to address reasonable data and information gaps associated with the baseline data for the areas identified in iv. above for the ecological elements and associated relationships; and x. A description and map of the ecological elements of reference sites in locations which are not at risk of Material or Serious Environmental harm due to construction and operation of the terrestrial facilities.</p> <p>6.6. The Proponent shall not cause or allow Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint.</p> <p>7.1. Prior to commencement of construction of any of the terrestrial facilities, the Proponent shall submit a terrestrial and subterranean environment protection plan (the plan) that meets the objectives and the requirements determined by the Minister, unless otherwise allowed.</p> <p>7.2. In the event that any portions of the plan related to specific elements or subelements (Schedule 1) is not submitted, the proponent shall submit</p>
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					<p>the portions of the plan relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the Plan shall meet the objectives and requirements as determined by the Minister.</p> <p>7.3. The Proponent shall consult with DEC in the preparation of the plan.</p> <p>7.4. The objectives of the Plan are: i. To reduce the adverse impacts from the construction and operation of the Terrestrial Disturbance Footprint as far as practicable; ii. To ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside and below the Terrestrial Disturbance Footprint.</p> <p>7.5. The plan shall include the following: i. Management measures to reduce the adverse impacts from the construction and operation on the Terrestrial Disturbance Footprint as far as practicable; and ii. Management measures to ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside and below the Terrestrial Disturbance Footprint.</p> <p>7.6. The measures required by 7.5.i. and ii. shall address but not be limited to: i. Vegetation Clearing Audit Procedures to determine the extent of clearing and rehabilitation on an annual basis; ii. Procedures in relation to and protocols for capturing, relocating, handling, housing and caring for significant fauna found within the Terrestrial Disturbance Footprint that are not required by DEC for translocation to other islands; iii. Procedures to avoid secondary impacts to fauna as a consequence of risks such as animals being trapped in construction trenches or subject to vehicle strike; iv. Measures including detailed drainage and containment designs for all works and infrastructure that control stormwater run-off outside the Terrestrial Disturbance Footprint with the aim of ensuring that runoff is consistent with the pre-development runoff regime as far as practicable, and any recharge does not cause pollution; and v. Measurable limits which specify the performance standards to be met when undertaking actions controlled by the plan.</p> <p>7.7. The Proponent shall report any Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint to DEC within 48 hours of their detection.</p> <p>7.8. The Proponent shall implement the plan.</p> <p>8.1. Prior to commencement of construction of the terrestrial facilities the proponent shall prepare and submit a terrestrial and subterranean environment monitoring program (the program) to the Minister that meets</p>
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					<p>the aim and the requirements as determined by the Minister, unless otherwise allowed.</p> <p>7.2. In the event that any portion of the program related to specific elements or subelements (Schedule 1) is not submitted as required, the proponent shall submit the portion of the program relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or subelement. All portions of the Plan shall meet the objectives identified and the requirements as determined by the Minister.</p> <p>7.3. The objective of this program is to establish a statistically valid ecological monitoring program to detect any Material or Serious Environmental Harm to the ecological elements outside the Terrestrial Disturbance Footprint.</p> <p>7.4. The program shall include: i. Indicators, parameters and /or criteria to be used in measuring changes on the ecological elements that are at risk of Material or Serious Environmental Harm. ii. Protocols for on-going reporting of adverse changes to the ecological elements identified; iii. Protocols for identifying additional areas not originally identified that are at risk of sustaining Material or Serious Environmental Harm from the proposal, and for adding monitoring sites to include these additional locations if required; iv. Establishing an ecological monitoring program with the ability to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, any environmental harm to the ecological elements; v. Location of monitoring sites in areas that are at risk of Material or Serious Environmental Harm due to construction and operation of terrestrial facilities; and vi. Location of reference sites.</p> <p>7.5. The proponent shall implement the program.</p> <p>11.1. Prior to commencement of construction of the Gas Treatment Plant, the proponent shall prepare and submit to the Minister, a short range endemics and subterranean fauna monitoring plan (the plan) for the further survey and identification of those short range endemics and subterranean fauna species which have previously only been located on the Gas Treatment Plant site. The Plan shall address the following: i. survey methods; ii. survey sites; iii. frequency of surveys; and iv. indicators for cessation of surveys, as determined by the Minister.</p> <p>11.2. The proponent shall implement the plan.</p>
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24	<p>Gorgon Gas Development, revised and expanded proposal, Barrow Island Nature reserve (a'mnt 1727) Rep 1323 Apr 2009.</p>	<p>EPA reiterates its original view that any development on Barrow Island A class nature reserve should not be implemented, particularly given the very high and unique conservation and environmental values of the island.</p> <p>However, the EPA recognises that an LNG processing and export project has been granted environmental approval on Barrow Island, following an appeals process, undertakings by the proponent to provide a number of offsets and the imposition of environmental conditions by the then Minister for the Environment.</p> <p>The EPA considers that the current proposal could only meet the EPA's environmental</p>	<ul style="list-style-type: none"> • The EPA's assessment of the revised and expanded proposal has lead it to a different view. The EPA considers that there is an increased likelihood of additional impacts and risks (for marine turtles and coral dominated habitat of the Lowendal Shelf), beyond those assessed as likely from the approved project. 	<p>3 appeals in total, only one which related to subterranean fauna.</p>	<p>Ministerial Statement 800. The proposal may be implemented. Conditions:</p> <p>5.1 The proponent shall submit annually to the Minister an environmental performance report covering the topics listed, and the specific details shown in Schedule 3, covering the previous 12 month period as determined by the Minister. The date of the first environmental performance report (the report) shall be 15 months from the date this Statement with each subsequent report 12 months from the date of the previous report.</p> <p>5.2 The report shall cover the following topics: i. Terrestrial and subterranean environment state; ii. Terrestrial and marine quarantine (including weed management); iii. Marine turtles (including light and noise management); iv. Short range endemics and subterranean fauna; v. Fire management; vi. Carbon Dioxide Injection System; vii. Air quality; viii. Coastal stability; ix. Terrestrial rehabilitation; and x. Greenhouse gas abatement.</p> <p>5.3 Every five years from the date of the first annual environmental performance report the proponent shall submit to the Minister an environmental performance report for review by the Minister, covering the previous five year period, comprising: i. The topics listed in Condition 5.2; ii. Specific details shown in Schedule 3; iii. A five year overview of environmental performance; iv. Proposed environmental management improvements; and v. A review of whether there are any reasonably practicable management measures, operating controls or design features that can be implemented to reduce or eliminate the alteration of the light horizon on the east coast beaches of Barrow Island as a result of the implementation of the proposal.</p> <p>5.4 The proponent shall, if required by the Minister, update management plans, programs, systems or reports to include any reasonably practicable improvements identified as part of the environmental performance report.</p> <p>6.1 Prior to commencement of construction of terrestrial facilities on Barrow Island, the proponent shall submit to the Minister a terrestrial and subterranean baseline state and environmental impact report (the report) that meets the purposes as determined by the Minister, unless otherwise allowed. The report shall cover the following ecological elements: i. flora; ii. vegetation; iii. fauna (including subterranean fauna and short range endemics); iv. habitat; v. ecological communities; vi. groundwater; vii. surface water landforms; and viii. physical landforms.</p>
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		objectives if, and only if, stringent conditions were applied to it.		<p>6.2 The proponent shall consult with DEC in the preparation of the report required by Condition 6.1, including the methodology to be used to survey, collect and collate the baseline data and information for the ecological elements.</p> <p>6.3 The terrestrial facilities referred to are: i. Gas Treatment Plant; ii. Carbon Dioxide Injection System; iii. Associated Terrestrial Infrastructure forming part of the Proposal; iv. Areas impacted for seismic data acquisition; and v. Onshore Feed Gas Pipeline System.</p> <p>6.3 A In the event that any portions of the Report related to specific elements or sub-elements are not submitted as required, the proponent shall submit the portions of the Report relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the report shall meet the purposes identified and the requirements as determined by the Minister.</p> <p>6.4 The purposes of the report are to: i. Define and map the pre-development baseline state for the ecological elements within the areas that are expected to, or may be at risk of Material or Serious Environmental Harm due to any works associated with the terrestrial facilities; ii. Define and map the ecological elements within the Terrestrial Disturbance Footprint; and</p> <p>iii. Define and map the ecological elements of reference sites, which are not at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities.</p> <p>6.5 The report shall include: i. A review of the results of the qualitative ecological risk assessments of the likelihood and consequence of proposal impacts on the ecological elements identified; ii. Details of the methodology that was used to survey, collect and collate the baselinedata and information for all ecological elements identified; iii. A description and map of the ecological elements within the Terrestrial Disturbance Footprint; iv. A description and map of the ecological elements which are at risk of Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint due to construction and operation of the terrestrial facilities; v. A review of the results to include existing areas of disturbance, including clearing, existing non-indigenous species (including weeds) and disturbed landscapes; vi. Spatially accurate (i.e. rectified and geographically referenced) maps showing the baseline data and information for the ecological elements; vii. Discussion of the data on the baseline biological, physical and chemical variables including any significant relationships, for the ecological elements identified; viii. Significant ecological elements to be protected - e.g. DRF,</p>
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					<p>TECs, Threatened Species under the EPBC Act, habitats of rare fauna; ix. An analysis of, and procedures to address data and information gaps associated with the baseline data for the areas identified for the ecological</p> <p>elements; and x. A description and map of the ecological elements of reference sites in locations which are not at risk of Material or Serious Environmental harm due to construction and operation of the terrestrial facilities.</p> <p>6.6 The Proponent shall not cause or allow Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint.</p> <p>7.1 Prior to commencement of construction of any of the terrestrial facilities, the proponent shall submit a terrestrial and subterranean environment protection plan (the plan) that meets the objectives identified and requirements as determined by the Minister, unless otherwise allowed.</p> <p>7.2 In the event that any portions of the Plan related to specific elements or sub-elements (Schedule 1) is not submitted, the proponent shall submit the portions of the plan relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the plan shall meet the objectives identified and requirements as determined by the Minister.</p> <p>7.3 The Proponent shall consult with DEC and DEWHA in the preparation of the plan.</p> <p>7.4 The objectives of the Plan are: i. To reduce the adverse impacts from the construction and operation of the terrestrial facilities as far as practicable; and ii. To ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint, including below the surface of the land.</p> <p>7.5 The Plan shall include the following: i. Management measures to reduce the adverse impacts (including from light and noise) from the construction and operation of the terrestrial facilities as far as practicable; and ii. Management measures to ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint, including below the surface of the land.</p> <p>7.6 The measures required by 7.5.i. and ii. shall address but not be limited to: i. Vegetation Clearing Audit Procedures to determine the</p>
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					<p>extent of clearing and rehabilitation on an annual basis; ii. Procedures in relation to and protocols for capturing, relocating, handling, housing, caring for and reporting to DEC threatened or listed fauna found within the Terrestrial Disturbance Footprint that are not required by DEC for translocation; iii. Procedures to avoid secondary impacts to fauna as a consequence of risks such as animals being trapped in construction trenches or subject to vehicle strike; iv. Measures including detailed drainage and containment designs for all works and infrastructure that control stormwater run-off outside the Terrestrial Disturbance Footprint with the aim of ensuring that runoff is consistent with the pre-development runoff regime as far as practicable, and any recharge does not cause pollution; and v. Performance Standards against which achievement of the objectives of this condition can be determined.</p> <p>7.7 The proponent shall report any Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint to DEC and DEWHA within 48 hours of detection.</p> <p>7.8 The proponent shall implement the plan.</p> <p>8.1 Prior to commencement of construction of the terrestrial facilities the proponent shall prepare and submit a terrestrial and subterranean environment monitoring program (the program) to the Minister that meets the objective and requirements as determined by the Minister, unless otherwise allowed.</p> <p>8.2 In the event that any portion of the program related to specific elements or sub-elements (Schedule 1) is not submitted as required, the proponent shall submit the portion of the program relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the program shall meet the objective identified and the requirements determined by the Minister.</p> <p>8.3 The objective of this Program is to establish a statistically valid ecological monitoring program to detect any Material or Serious Environmental Harm to the ecological elements outside the Terrestrial Disturbance Footprint.</p> <p>8.4 The Program shall include: i. Indicators, parameters and criteria to be used in measuring changes on the ecological elements identified that are at risk of Material or Serious Environmental Harm due to construction and operation of terrestrial facilities. ii. Protocols for on-going reporting of adverse changes to the ecological elements listed; iii. Management Triggers; iv. Protocols for identifying additional areas not originally</p>
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					<p>identified that are at risk of sustaining Material or Serious Environmental Harm from the Proposal, and for adding monitoring sites to include these additional locations, if required; v. Establishing an ecological monitoring program with the ability to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, any environmental harm to the ecological elements listed; vi. Location of monitoring sites in areas that are at risk of Material or Serious Environmental Harm due to construction and operation of terrestrial facilities listed; and vii. Location of reference sites.</p> <p>8.5 The proponent shall implement the program.</p> <p>11.1 Prior to commencement of construction of the Gas Treatment Plant, the proponent shall prepare and submit to the Minister, a short range endemics and subterranean fauna monitoring plan (the plan) for the further survey and identification of those short range endemics and subterranean fauna species which have previously only been located on the Gas Treatment Plant site. The plan shall address the following: i. survey methods; ii. survey sites; iii. frequency of surveys; and iv. in respect of any species that has only been found on the Gas Treatment Plant site as at the date of this Statement, the continuation of surveys for that species until it is found elsewhere, as determined by the Minister.</p> <p>11.2 The proponent shall implement the plan.</p> <p>13.1 Prior to the commencement of construction of facilities to abstract groundwater for water supply purposes, the Proponent shall submit a groundwater abstraction management plan to the Minister that meets the objective and as determined by the Minister unless otherwise.</p> <p>13.2 In preparing this plan the proponent shall consult with DEWHA, DoW and DEC.</p> <p>13.2A In the event that any portions of the plan related to specific elements or sub-elements (Schedule 1) of the Proposal are not submitted, the proponent shall submit the portion of the plan relevant to that element or sub-element to the Minister prior to the planned commencement of construction of that element or sub-element. All portions of the Plan shall meet the objective identified and the requirements as determined by the Minister.</p> <p>13.3 The objective of the plan is to ensure that groundwater abstraction does not cause Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island.</p>
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					<p>13.4 The plan shall include: i. Practicable environmental triggers for contingency plans to avoid Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island (this may include separate triggers for within and outside the Terrestrial Disturbance Footprint); ii. Actions (including an immediate reduction in the rate of or cessation of groundwater abstraction) which will be taken to avoid Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island; iii. Reporting procedures; and iv. Performance standards against which achievement of the objective of this condition can be determined.</p> <p>13.5 The proponent shall implement the plan.</p>
25	<p>Roy Hill Iron Ore Project Stage 1, approximately 100 km north of Newman, Bull 1342, Nov 2009</p> <p>A s45c amendment occurred to February 2012 such that access to Stage 1 and Stage 2 areas can occur for the life of the mine.</p>	<p>EPA has concluded that it is unlikely that the EPA's objectives would be compromised provided there is satisfactory implementation by the proponent of the recommended conditions.</p> <p>EPA considers that the project will not have a significant impact on subterranean fauna.</p>	<ul style="list-style-type: none"> • A three phase subterranean survey was undertaken for the project area in accordance with draft EPA Guidance statement 54a and although an adequate sampling effort was performed the results gained were lower in yield than is usual for the Pilbara area. • Two stygofauna of conservation significant were found outside the zone of impact but were unlikely to be impacted by mining. Specimens found within the impact zone had not been fully identified at the time of assessment, however the habitat assessment suggests that the species found within the impact • zone are not expected to be restricted to the project area due to the connectivity between aquifers and the presence of similar geology and hydrogeology to that occurring throughout the Fortescue Region. This opinion is supported by the presence of similar specimens collected both within and outside the project area. • Changes to hydrology were thought to be the main potential impacts on subterranean fauna, especially the upconing of saline water into the Fortescue River Aquifer due to the dewatering of the borefield in the Stage 2 area. Thus such management of dewatering was recommended to ensure the factor was managed in an environmentally acceptable manner <ul style="list-style-type: none"> o The proponent shall ensure that during 	<p>Two appeals were made against the EPA's report (315 and 316 of 2009) however they were respectively withdrawn and invalid.</p>	<p>Ministerial Statement 824. The proposal may be implemented. Conditions:</p> <p>6-1 The proponent shall ensure that during construction and operation of the proposal that groundwater abstraction from the Stage 1 and Stage 2 mine areas does not adversely affect vegetation to be retained in the project area and that drawdown of groundwater does not extend beyond the co ordinates specified.</p> <p>6-2 To verify that the requirements of condition 6-1 are met the proponent shall: 1. undertake baseline monitoring of native vegetation health and abundance in the project area prior to dewatering; 2. monitor groundwater levels at the boundary of the project area and in the vicinity of riparian and groundwater-dependent vegetation; and 3. monitor the health and cover of riparian and groundwater dependent vegetation to be retained in the proposal area and in adjacent areas.</p> <p>6-3 The proponent shall submit annually the results of monitoring required to CEO.</p> <p>6-4 In the event that monitoring required by condition 6-2 indicates a decline in the health and condition of riparian and groundwater dependent vegetation: 1. the proponent shall report such findings to the CEO within 21 days of the decline being identified; 2. the proponent shall provide evidence which allows determination of the cause of the decline; 3. if determined by the CEO to be a result of activities undertaken in implementing the proposal, the proponent shall submit actions to be taken to remediate the decline within 21 days of the determination being made to the CEO; and 4. The proponent shall implement actions to remediate the decline of riparian and groundwater dependent vegetation upon approval of the CEO and shall continue until such time the CEO</p>

			<p>construction and operation of the proposal that groundwater abstraction from the Stage 1 and Stage 2 mine areas does not adversely affect vegetation to be retained in the project area and that drawdown of groundwater does not extend beyond the co ordinates specified.</p> <ul style="list-style-type: none"> o To verify that the requirements of condition 6-1 are met the proponent shall: 1. undertake baseline monitoring of native vegetation health and abundance in the project area prior to dewatering; 2. monitor groundwater levels at the boundary of the project area and in the vicinity of riparian and groundwater-dependent vegetation; and 3. monitor the health and cover of riparian and groundwater dependent vegetation to be retained in the proposal area and in adjacent areas. o The proponent shall submit annually the results of monitoring required to CEO of DEC. o In the event that monitoring required by condition 6-2 indicates a decline in the health and condition of riparian and groundwater dependent vegetation: 1. the proponent shall report such findings to the CEO of DEC within 21 days of the decline being identified; 2. the proponent shall provide evidence which allows determination of the cause of the decline; 3. if determined by the CEO of DEC to be a result of activities undertaken in implementing the proposal, the proponent shall submit actions to be taken to remediate the decline within 21 days of the determination being made to the CEO of DEC; and 4. The proponent shall implement actions to remediate the decline of riparian and groundwater dependent vegetation upon approval of the CEO of DEC and shall continue until such time the CEO determines that the remedial actions may cease. o The proponent shall make the monitoring reports publicly available. 	<p>determines that the remedial actions may cease.</p> <p>6-5 The proponent shall make the monitoring reports publicly available.</p>
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26	<p>Roy Hill Iron Ore Mining Project Stage 2, 110 kms north of Newman, A'mnt 1822, Rep 1345 Dec 2009.</p> <p>A s45c amendment occurred to February 2012 such that access to Stage 1 and Stage 2 areas can occur for the life of the mine.</p>	<p>Proposal can be managed to meet the EPA's environmental objectives, provided there is satisfactory implementation by the proponent of the recommended conditions.</p> <p>Proposal can be managed to meet the EPA's environmental objectives for this factor provided that the condition to limit the amount of dewatering is implemented.</p>	<ul style="list-style-type: none"> • As for Roy Hill Iron Ore Stage 1 above, and additional information was presented to the EPA. • The stygofauna community within the impact zone of the remote borefield is also located outside the zone of impact or is widespread throughout the Pilbara. The proponent has committed to monitoring the reference bores to ensure that the stygofauna bores located outside of the zone of impact are not at threat from increased salinity resulting from dewatering. • The EPA considers that it is unlikely that mine dewatering and borefield abstraction would significantly affect subterranean fauna. Conditions applied to groundwater abstraction: <ul style="list-style-type: none"> ○ The proponent shall ensure that groundwater abstraction from the Stage 2 mine areas and borefield do not adversely affect vegetation beyond the area identified by the coordinates specified in schedule 2 and that drawdown of groundwater does not extend beyond the co-ordinates specified in schedule 2. ○ To verify that the requirements are met the proponent shall: 1. submit a proposed monitoring program to measure vegetation health to the requirements of the CEO of the OEPA; 2. undertake baseline monitoring of native vegetation health and abundance in the proposal area prior to dewatering; 3. monitor groundwater levels at the boundary of the project area and in the locations where riparian and groundwater-dependent vegetation exist; and 4. monitor the health and cover of riparian and groundwater dependent vegetation outside of the area specified by the co-ordinates given in schedule 2. ○ The proponent shall submit annually the results of monitoring to the CEO of the OEPA. ○ In the event that monitoring indicates a decline in the health and condition of riparian or groundwater dependent vegetation: 1. the proponent shall report such findings to the CEO of the OEPA 	<p>Appeal 338 of 2009 was received but did not address matters related to subterranean fauna.</p>	<p>Ministerial Statement 824. The proposal may be implemented.</p> <p>Conditions</p> <p>6-1 The proponent shall ensure that groundwater abstraction from the Stage 2 mine areas and borefield do not adversely affect vegetation beyond the area identified by the coordinates specified and that drawdown of groundwater does not extend beyond the co-ordinates specified.</p> <p>6-2 To verify that the requirements of condition 6-1 are met the proponent shall:</p> <ol style="list-style-type: none"> 1. submit a proposed monitoring program to measure vegetation health to the requirements of the CEO; 2. undertake baseline monitoring of native vegetation health and abundance in the proposal area prior to dewatering; 3. monitor groundwater levels at the boundary of the proposal area and in the locations where riparian and groundwater-dependent vegetation exist; and 4. monitor the health and cover of riparian and groundwater dependent vegetation outside of the area specified by the co-ordinates given in Schedule 2. <p>6-3 The proponent shall submit annually the results of monitoring required by condition 6-2 to the CEO.</p> <p>6-4 In the event that monitoring required by condition 6-2 indicates a decline in the health and condition of riparian or groundwater dependent vegetation:</p> <ol style="list-style-type: none"> 1. the proponent shall report such findings to the CEO within 21 days of the decline being identified; 2. the proponent shall provide evidence which allows determination of the cause of the decline; 3. if determined by the CEO to be a result of activities undertaken in implementing the proposal, the proponent shall submit actions to be taken to remediate the decline within 21 days of the determination being made to the CEO; and 4. the proponent shall implement actions to remediate the decline of riparian or groundwater dependent vegetation upon approval of the CEO on advice of DEC and shall continue until such time the CEO determines that the remedial actions may cease. <p>6-5 The proponent shall make the monitoring reports required by</p>
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27	<p>Spinifex Ridge Molybdenum Project approximately 50 km north east of Marble Bar (a'mnt 1657) Bull 1285, Apr 2008.</p>	<p>Unlikely that the EPA's objectives would be compromised, provided there is satisfactory implementation by the proponent of recommended conditions set out in Appendix 4, and summarized in Section 4.</p>	<ul style="list-style-type: none"> • Subterranean fauna (stygo fauna) surveys showed the majority of species found were considered to be common within the Pilbara. • The EPA identified the changes in groundwater to have potential impacts on stygo fauna but noted that this could be managed through groundwater. <ul style="list-style-type: none"> o The proponent shall ensure that the run-off or seepage from the waste dumps and the tailings storage facility do not cause the quality of surface or ground water in or leaving the proposal area to exceed ANZECC requirements, taking into consideration natural background water quality, so that existing and potential uses, including ecosystem maintenance, are protected. o The proponent shall monitor the quality of any run-off or seepage from the tailings storage facility and waste dumps to surface and ground water on and in proximity to the project area. This monitoring is to be done to the satisfaction of the CEO of DEC. o The proponent shall submit a monitoring program to the CEO of DEC prior to 	<p>Three appeals received (38, 39 and 40 of 2008) but did not address matters related to subterranean fauna.</p>	<p>Ministerial Statement 772. The proposal may be implemented. Conditions:</p> <p>6-1 The proponent shall ensure that the run-off or seepage from the waste dumps and the tailings storage facility do not cause the quality of surface or ground water in or leaving the proposal area to exceed ANZECC requirements, taking into consideration natural background water quality, so that existing and potential uses, including ecosystem maintenance, are protected.</p> <p>6-2 Where the requirements are not met, the proponent shall provide proposed management measures to the CEO within three months.</p> <p>6-3 The proponent shall implement the proposed management measures to the satisfaction of the CEO.</p> <p>6-4 The proponent shall monitor the quality of any run-off or seepage from the tailings storage facility and waste dumps to surface and ground water on and in proximity to the project area. This monitoring is to be done to the satisfaction of the CEO.</p> <p>6-5 The proponent shall ensure that water levels in Coppin Gap Pool are not adversely affected by the implementation of the proposal. From the commencement of mining, the proponent shall monitor the groundwater levels between the pit and Coppin Gap to detect groundwater level</p>

			<p>construction.</p> <ul style="list-style-type: none"> ○ The proponent shall submit the results of the monitoring to the CEO. ○ The proponent shall provide proposed management measures to the CEO of DEC if they are not met. 		<p>depression arising from mining activities. This monitoring is to be carried out to the satisfaction of the CEO.</p> <p>6-6 The proponent shall submit monitoring programs relating to the CEO prior to construction.</p> <p>6-7 The proponent shall submit the results of the monitoring to the CEO.</p> <p>6-8 The proponent shall provide proposed management measures to the CEO in the event that the monitoring required by condition 6-5 indicates that mining activities are causing depression of the water levels in Coppin Gap Pool.</p> <p>6-9 The proponent shall provide proposed management measures to the CEO of DEC if they are not met.CEO.</p>
28	<p>Balmoral South Iron Ore Project Cape Preston Region 80 km south of Karratha (a'mnt 1677) Bull 1340, Oct 2009</p>	<p>EPA has therefore concluded that it is unlikely that the EPA's objectives would be compromised, provided there is satisfactory implementation by the proponent of the recommended conditions.</p>	<ul style="list-style-type: none"> • Fifteen species of sytofauna were identified from the groundwater drawdown impact zone but all have also been recorded elsewhere in the Cape Preston area. Nine species of troglofauna were collected at the project area. • Two troglofauna species found at Balmoral South were not found outside the footprint are during the assessment. The lack of major discontinuities between the ore-bodies suggests that the Cape Preston troglofauna community extends through all ore-bodies in the area. • Groundwater drawdown can potentially affect troglofauna by reducing the relative humidity of the subterranean habitat where the animals occur. Relative humidity however is not expected to change within the troglofauna habitat as it is considered that relative humidity is dependent on distance from root zone rather than the water table. Therefore as the water table lowers, the relative humidity is expected to remain unchanged and the impacts to troglofauna are considered to be minimal. • No conditions specific to subterranean fauna were included. 	<p>Appeal 303 of 2009 was received but did not address matters related to subterranean fauna.</p>	<p>Ministerial Statement 823. The proposal may be implemented. No conditions specific to subterranean fauna were included.</p>

29	Pardoo Direct Shipping Ore (DSO) Project Port Hedland (a'mnt 1685) Bull 1289, Jun 2008.	EPA has concluded that it is unlikely that the EPA's objectives would be compromised, provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • Prior to commencement of operations within the South Limb deposit, the proponent shall have demonstrated the presence of the troglobitic species <i>Ideoblothrus</i> n. sp. in an area outside the mining footprint, to the requirements of the Minister for the Environment on advice of the EPA. 	Appeal 51 of 2008 ⁹ included grounds inadequate knowledge of the impacts of the project on subterranean fauna. Dismissed as the Minister was satisfied that that survey was adequate and conducted in accordance with EPA guidance.	<p>Ministerial Statement 775. The proposal may be implemented. Conditions:</p> <p>8-1 Prior to commencement of operations within the South Limb deposit, the proponent shall have demonstrated the presence of the troglobitic species <i>Ideoblothrus</i> n. sp. in an area outside the mining footprint, to the requirements of the Minister for the Environment on advice of the EPA.</p> <p>The Minister imposed EPA's condition that a survey for troglobitic fauna be undertaken more widely than the area of impact. This was done and the species was not re-sampled and therefore not found outside the area of impact.</p> <p>A Section 46 change was required to enable proponent to implement their proposal (see below).</p>
	Pardoo Direct Shipping Ore Project Report 1320 – Proposal under s46 to remove condition 8-1 related to troglofauna.	Recommendation that Condition 8.1 referring to the troglofauna species <i>Ideoblothrus</i> n.sp. be removed from Ministerial Statement 775.	<ul style="list-style-type: none"> • The intent of the condition which was recommended to the Minister by the EPA to: <ol style="list-style-type: none"> 1. Demonstrate that mining in south limb was not likely to pose a threat to the population of the species <i>Ideoblothrus</i> n. sp; 2. Ensure that the proponent had been sufficiently diligent in assessing risks to the species; and 3. Contribute to risk assessment of this fauna into the future. • In response to this condition Atlas Iron Limited conducted substantial troglofauna survey work both within and outside the South Limb Deposit (161 samples collected during the assessment process, and an additional 228 specimens after approval from a variety of other locations); however, no further specimens of <i>Ideoblothrus</i> n. sp have been collected from the Pardoo project area. Atlas requests that the condition be removed from Ministerial Statement 775 in order to allow mining at the South Limb deposit to 	No appeals recorded.	<p>Ministerial Statement 797. Statement to amend conditions applying to a proposal (s46 of the EP Act).</p> <p>The implementation of the proposal to which the aforementioned reports of the EPA is subject to the conditions and procedures contained in Ministerial Statement No. 775, as amended by the following:</p> <p>Condition 8-1 referred to the troglofauna species <i>Ideoblothrus</i> n.sp. be removed from Ministerial Statement No. 775</p>

⁹ The Minister advised the appellant that he shared the concern about possible extinction of subterranean fauna and committed to write to the key agencies and other experts and request that they work together to examine approaches and methodologies to build confidence when decisions are required to be made under levels of risk and uncertainty.

			commence. The EPA found that the proponent has demonstrated appropriate diligence in performing troglofauna surveys in the Pardoo area and has contributed sufficient knowledge to future troglofauna risk assessments.		
30	Mesa K Remnant Iron Ore Mining Project 11 km south-west of Pannawonica Shire of Ashburton (a'mnt 1728) Bull 1283, Mar 2008. Robe River Valley	EPA considers that the proposal can be managed to meet the EPA's environmental objectives, subject to the EPA's recommended conditions being made legally binding.	<ul style="list-style-type: none"> • The proponent shall implement the proposal to avoid disturbance of areas where troglofauna taxa represented by only one individual have been recorded as shown in Figure 4. • The proponent shall establish a monitoring regime to the requirements of the Minister for the Environment on advice of the EPA to demonstrate the effectiveness of the disturbance avoidance areas as shown in Figure 4. 	Appeals 25 and 26 of 2008 included two grounds of appeal related to subterranean fauna – the risk of extinction was not adequately addressed and the use of Mesa K in the Mesa A approval. Dismissed.	Ministerial Statement 776. Proposal may be implemented. Conditions: 6-1 The proponent shall implement the proposal to avoid disturbance of areas where troglofauna taxa represented by only one individual have been recorded as shown in Figure 4. 6-2 The proponent shall establish a monitoring regime to the requirements of the Minister for the Environment on advice of the EPA to demonstrate the effectiveness of the disturbance avoidance areas as shown in Figure 4. Troglofauna avoidance areas were defined (boundaries and co-ordinates).
31	Callawa and Cundaline Mining Operations approximately 200 km east of Port Hedland (a'mnt 1812) Rep 1338, Sept 2009.	Proposal can be managed to meet the EPA's environmental objectives, subject to the EPA's recommended conditions being made legally binding.	<ul style="list-style-type: none"> • Surveys identified a moderate diversity of stygofauna, however all species which were located inside the deposit have also been located outside of the proposed disturbance area. • Fifty six percent of the troglofaunan species collected occur on both the Cundaline and Callawa ridges. The study indicates that the troglofauna communities in the project area are likely to be continuous across the Nimingarra formation, and are unlikely to be restricted to the area of disturbance associated with the proposal. Potential troglofauna habitat on the Cundaline and Callawa ridges is not limited to the area of disturbance (6% of available habitat at Cundaline and 1% of habitat at Callawa). • No conditions specific to subterranean fauna were recommended. 	No appeals recorded.	Ministerial Statement 814. Proposal may be implemented. No conditions specific to subterranean fauna were included.

32	<p>Carina Iron Ore Mine north-east of Southern Cross Shire of Yilgarn (a'mnt 1756) Rep 1368, Oct 2010</p> <p>BIF</p>	<p>Proposal can be managed to meet the EPA's objectives subject to the conditions being implemented.</p>	<ul style="list-style-type: none"> • The proponent shall undertake a baseline troglofauna survey within 15 kilometres of the Project Boundary in similar geological formations to validate predictions of habitat connectivity and improve knowledge of troglofauna populations in the region to inform future management of mining and associated operations. • The baseline troglofauna survey shall be undertaken in accordance with the draft GS54a and to the satisfaction of the CEO. • Within 30 months of ground disturbing activities the proponent shall prepare and submit a technical report based on the results of the survey required to the requirements of the CEO on advice of DEC. • The proponent shall make the report publicly available in a manner approved by the CEO. 	<p>Appeal 93 of 2010 was received but did not address matters related to subterranean fauna.</p>	<p>Ministerial Statement 852. Proposal may be implemented. Conditions:</p> <p>8-1 The proponent shall undertake a baseline troglofauna survey within 15 kilometres of the Project Boundary in similar geological formations to validate predictions of habitat connectivity and improve knowledge of troglofauna populations in the region to inform future management of mining and associated operations.</p> <p>8-2 The baseline troglofauna survey shall be undertaken in accordance with the draft GS54a and to the satisfaction of the CEO.</p> <p>8-3 Within 30 months of ground disturbing activities the proponent shall prepare and submit a technical report based on the results of the survey required to the requirements of the CEO on advice of DEC.</p> <p>8-4 The proponent shall make the report publicly available in a manner approved by the CEO.</p>
33	<p>Spotted Quoll open pit nickel mine (part of Forrestania Nickel Project) approximately 160 km south of Southern Cross (a'mnt 1334) Rep 1334, July 2009.</p>	<p>Proposal can be managed to meet the EPA's environmental objectives, subject to the EPA's recommended conditions being made legally binding.</p>	<ul style="list-style-type: none"> • Core samples and groundwater sampling results indicated that there was no suitable habitat for troglofauna within the project area, however a new species of troglomorphic pseudoscorpion was identified from a bore hole located outside of the proposed mine pit. The EPA accepted that there would be no direct impacts from the proposal and the change in humidity within the zone of impact for dewatering was not expected to be significant. • Stygofauna habitat would be affected by a lowering of the water table by approximately 50m and the EPA recommended that the proponent takes all practicable measures to minimise dewatering and develop a stygofauna management plan. • No conditions specific to subterranean fauna were recommended. 	<p>No appeals are recorded.</p>	<p>Ministerial Statement 808. Proposal may be implemented.</p> <p>No conditions specific to subterranean fauna were included.</p>

34	Koolyanobbing Iron Ore Project - Mount Jackson J1 Deposit Approximately 100km north-north-east of Southern Cross Shire of Yilgarn, Rep1347, Feb 2010.	EPA has concluded that it is unlikely that the EPA's objectives would be compromised provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • Six potential troglotauna species were identified, also recorded at other locations and were either <i>in</i> continuous habitat or particularly mobile species • No conditions specific to subterranean fauna were recommended. 	Appeals 14 and 15 of 2010 were received including the ground that changes to the dewatering rate may impact on stygofauna assemblages. Dismissed ¹⁰ .	No conditions specific to subterranean fauna were recommended.
35	Western Turner Syncline - Section 10 Iron Ore Mine 20 km west of Tom Price (a'mnt 1786) Rep1325, May 2009.	Proposal could be managed to meet its environmental objectives, provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • Systematic sampling for subterranean fauna revealed several thousand individual specimens, none of which were unequivocally troglotauna. Reviews of geological records of rock types, fracture densities and down-hole camera images suggest that the mine pit area does not appear to be a core habitat for subterranean fauna. • Proposal impacts on subterranean fauna are considered environmentally acceptable. • No conditions specific to subterranean fauna were recommended 	Appeal 83 of 2009 was received but did not address matters related to subterranean fauna.	Ministerial Statement 807. The proposal may be implemented. No conditions specific to subterranean fauna were included.
36	Marillana Iron Ore Mine approximately 100 km north north west from Newman (a'mnt 1781) Rep 1376, Dec 2010. Weeli Wolli Creek	EPA's objectives can be met provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • It is likely that the proposal can be managed to meet the EPA's environmental objectives for this factor. • No conditions specific to subterranean fauna were recommended (groundwater quality, Fortescue Marsh and Weeli Wolli Creek all have associated conditions). 	No appeals recorded.	Ministerial Statement 855. Proposal may be implemented. No conditions specific to subterranean fauna were included.

¹⁰ The Minister dismissed the appeal but clarified the pumping and error estimations on the Ministerial Statement. The EPA's report did not include consideration of impacts on stygofauna as an environmental factors and the Minister's report did not but did not comment on subterranean species.

37	<p>Jimblebar Iron Ore Project 40 km east of Newman Shire of East Pilbara (a'mnt 1847), Rep 1371, Oct 2010.</p> <p>Ethel Gorge</p>	<p>EPA has concluded that the proposal can be managed to meet the environmental objectives, provided there is satisfactory implementation by the proponent of the recommended.</p>	<ul style="list-style-type: none"> • The proponent shall monitor the Ethel Gorge Aquifer Stygobiont Community TEC from prior to implementation until 12 months after completion of discharge into the Ophthalmia Dam. This monitoring program shall be designed and carried out to the requirements of the CEO of the OEPA on advice of DEC and include: 1. Monitoring of groundwater levels and chemistry, including ionic balance; 2. Monitoring of stygofauna species richness; and 3. Interpretation of the results in relation to influences on stygofauna and their habitat. • The proponent shall develop trigger levels for stygofauna species richness and groundwater chemistry for the approval of the CEO of the OEPA on advice of DEC. • Should the results of monitoring show that trigger levels identified have been reached for the stygofauna species richness and/or water chemistry the proponent shall provide a report to the CEO of the within 21 days of the decline or change being identified which: 1. describes the decline or change; 2. provides information which allows determination of the likely root cause of the decline or change; and 3. if considered likely to be the result of activities undertaken in implementing the proposal, proposes the actions and associated timelines to remediate the decline or change to the requirement of the CEO of the OEPA on advice of DEC. • The proponent shall, on approval by the CEO of the OPEA implement the actions identified until the CEO of the OEPA determines that the remedial actions may cease. • The proponent shall make the results of the monitoring program, the trigger levels, and the report publicly available in a manner approved by the CEO of the Office EPA. 	<p>Appeal 94 of 2010 was received but it did not address matters related to subterranean fauna.</p>	<p>Ministerial Statement 857. Proposal may be implemented. Conditions:</p> <p>8-1 The proponent shall monitor the Ethel Gorge Aquifer Stygobiont Community TEC from prior to implementation until 12 months after completion of discharge into the Ophthalmia Dam. This monitoring program shall be designed and carried out to the requirements of the CEO of the OEPA on advice of DEC and include: 1. Monitoring of groundwater levels and chemistry, including ionic balance; 2. Monitoring of stygofauna species richness; and 3. Interpretation of the results in relation to influences on stygofauna and their habitat.</p> <p>8-2 The proponent shall develop trigger levels for stygofauna species richness and groundwater chemistry for the approval of the CEO of the OEPA on advice of DEC.</p> <p>8-3 Should the results of monitoring show that trigger levels identified have been reached for the stygofauna species richness and/or water chemistry the proponent shall provide a report to the CEO of the within 21 days of the decline or change being identified which: 1. describes the decline or change; 2. provides information which allows determination of the likely root cause of the decline or change; and 3. if considered likely to be the result of activities undertaken in implementing the proposal, proposes the actions and associated timelines to remediate the decline or change to the requirement of the CEO of the OEPA on advice of DEC.</p> <p>8-4 The proponent shall, on approval by the CEO of the OPEA implement the actions identified until the CEO of the OEPA determines that the remedial actions may cease.</p> <p>8-5 The proponent shall make the results of the monitoring program, the trigger levels, and the report publicly available in a manner approved by the CEO of the Office EPA.</p>
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38	Solomon Project comprising the Firetail and Kings mines and 127 km railway to existing FMG North-South railway approximately 60 km north of Tom Price Pilbara Region (a'mnt 1841) Rep 1386, Mar 2011.	EPA's objectives would be achieved provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • The proponent shall undertake troglofauna surveys biannually at a minimum in geological formations similar to the project area to validate predictions of habitat connectivity and improve knowledge of troglofauna populations in the region to inform future management of mining and associated operations, until such time as the CEO of the OEPA determines that sufficient knowledge of troglofauna populations has been acquired. • The troglofauna surveys shall be undertaken in accordance with the EPA draft GS54a to the satisfaction of the CEO of the OEPA. • Within 30 months of ground disturbing activities the proponent shall prepare and submit a technical report based on the results of the surveys to the requirements of the CEO of OEPA. • Three months prior to commencement of ground disturbing activities associated with the Zion deposit, the proponent shall demonstrate that similar and connected troglofauna habitat exists outside of areas that have been or are likely to be impacted by mining to the satisfaction of the CEO of OEPA on advice of DEC. • The proponent shall prepare and submit annually further technical reports based on the results of the surveys to the requirements of the CEO of the OEPA on advice of DEC. • The proponent shall make the reports publicly available in a manner approved by the CEO of the OEPA. 	No appeals recorded	<p>Ministerial Statement 862. The proposal may be implemented. Conditions:</p> <p>13-1 The proponent shall undertake troglofauna surveys biannually at a minimum in geological formations similar to the project area to validate predictions of habitat connectivity and improve knowledge of troglofauna populations in the region to inform future management of mining and associated operations, until such time as the CEO of the OEPA determines that sufficient knowledge of troglofauna populations has been acquired.</p> <p>13-2 The troglofauna surveys shall be undertaken in accordance with the EPA draft GS54a to the satisfaction of the CEO of the OEPA.</p> <p>13-3 Within 30 months of ground disturbing activities the proponent shall prepare and submit a technical report based on the results of the surveys to the requirements of the CEO of the OEPA.</p> <p>13-4 Three months prior to commencement of ground disturbing activities associated with the Zion deposit, the proponent shall demonstrate that similar and connected troglofauna habitat exists outside of areas that have been or are likely to be impacted by mining to the satisfaction of the CEO of the OEPA on advice of DEC.</p> <p>13-5 The proponent shall prepare and submit annually further technical reports based on the results of the surveys to the requirements of the CEO of the OEPA on advice of DEC.</p> <p>13-6 The proponent shall make the reports publicly available in a manner approved by the CEO of the OEPA.</p>
39	West Pilbara Iron Ore Project, Stage 1 Mine and Rail Proposal (a'mnt 1767) Rep1409,	EPA's objectives would be achieved, provided there is satisfactory implementation by the proponent of the recommended	<ul style="list-style-type: none"> • The proponent shall carry out work within two years of the commencement of mining to further define the extent of the troglofauna habitat in and adjacent to the project area. This survey is to be carried out using methodology satisfactory to the CEO of the 	Two appeals (87 & 88 of 2011) were received but did not relate to subterranean fauna.	<p>Ministerial Statement 881. Proposal may be implemented. Conditions:</p> <p>6-1 The proponent shall carry out work within two years of the commencement of mining to further define the extent of the troglofauna habitat in and adjacent to the project area. This survey is to be carried out using methodology satisfactory to the CEO of the OEPA.</p>

	Aug 2011.	conditions.	OEPA.		
40	Jack Hills, expansion of the Jack Hills iron mine, 400km northeast of Geraldton (a'mnt 1789) Rep1413 Aug 2011.	The EPA's objectives would be achieved, provided there is satisfactory implementation by the proponent of the recommended conditions.	<ul style="list-style-type: none"> • Previous Jack Hills assessment (1637, Bulletin 1220) in 2006 found there was not likely to be any significant impact on troglofauna as their habitat is unlikely to be restricted to the area to be mined. The aquifers subject to groundwater extraction were not thought to support stygofauna • The assessment for the expansion of Jack Hills iron ore mine identified potential impacts on stygofauna through changes in water quality and abstraction. Conditions recommended: <ul style="list-style-type: none"> ○ From the commencement of water extraction from the Murchison Palaeochannel Borefield the proponent shall monitor potentially affected aquifer stygofauna communities until at least twelve months after the cessation of borefield operations, unless otherwise agreed by the CEO of the OEPA. Monitoring program shall be designed and carried out to the requirements of the CEO of the OEPA on advice from DEC and DoW and include: 1. monitoring of groundwater levels and chemistry at impact locations and reference sites; 2. monitoring of stygofauna species richness; and 3. interpretation of the results in relation to influences on stygofauna and their habitat. ○ The proponent shall develop trigger levels for ground water level and groundwater chemistry for the approval of the CEO of the OEPA on advice of DEC and DoW. ○ Should the results of monitoring show that trigger levels identified in condition 10-2 have been reached for the ground water level or chemistry the proponent shall provide a report to the CEO of the OEPA within 21 days of the decline or change being identified which: 1. describes the decline or change; 2. provides information which allows determination of the likely root cause of the 	No appeals recorded.	<p>Ministerial Statement 886. The proposal may be implemented. Conditions:</p> <p>10-1 From the commencement of water extraction from the Murchison Palaeochannel Borefield the proponent shall monitor potentially affected aquifer stygofauna communities until at least twelve months after the cessation of borefield operations, unless otherwise agreed by the CEO of the OEPA. Monitoring program shall be designed and carried out to the requirements of the CEO of the OEPA on advice from DEC and DoW and include: 1. monitoring of groundwater levels and chemistry at impact locations and reference sites; 2. monitoring of stygofauna species richness; and 3. interpretation of the results in relation to influences on stygofauna and their habitat.</p> <p>10-2 The proponent shall develop trigger levels for ground water level and groundwater chemistry for the approval of the CEO of the OEPA on advice of DEC and DoW.</p> <p>10-3 Should the results of monitoring show that trigger levels identified in condition 10-2 have been reached for the ground water level or chemistry the proponent shall provide a report to the CEO of the OEPA within 21 days of the decline or change being identified which: 1. describes the decline or change; 2. provides information which allows determination of the likely root cause of the decline or change; and 3. if considered likely to be the result of activities undertaken in implementing the proposal, proposes the actions and associated timelines to remediate the decline or change to the requirement of the CEO of the OEPA on advice of DEC and DoW.</p> <p>10-4 The proponent shall, on approval by the CEO of the OEPA, implement the actions identified until the CEO of the OEPA determines that the remedial actions may cease.</p> <p>12 – Offsets. Subterranean fauna offsets not included.</p>

			<p>decline or change; and 3. if considered likely to be the result of activities undertaken in implementing the proposal, proposes the actions and associated timelines to remediate the decline or change to the requirement of the CEO of the OEPA on advice of DEC and DoW.</p> <ul style="list-style-type: none"> o The proponent shall, on approval by the CEO of the OEPA, implement the actions identified until the CEO of the OEPA determines that the remedial actions may cease. o There are residual impacts and risks of the project to the Priority 1 <i>Triodia melvillei</i> Ecological Community, nine priority flora species and short range endemics (including <i>Idiosoma nigrum</i> and subterranean fauna). The proponent shall undertake measures during the implementation of the proposal, consistent with the environmental offsets plan (April 2011) as approved by the CEO of the OEPA. 		
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41	Wiluna Uranium Project Toro Energy Limited (a'mnt 1819) scoping document published Jun 2010	Currently at PER stage of assessment.	<ul style="list-style-type: none"> • The uranium-bearing calcrete deposits in the northern part of the Yilgarn are known to support a rich and diverse stygofauna, including three main calcretes in proximity to the proposal (Hinkler Well, Uramurdah and Lake Violet). Less is known about the troglofauna and the compact clays and high water table in the project area are not considered highly prospective troglofauna habitats. • Baseline surveys have been conducted for subterranean fauna, with twenty-seven stygofauna identified and the majority found in other calcretes in the Murchison. Further surveys are planned. • Five subterranean assemblage PECs are located in or near the project area (Hinkler Well calcrete community, Lake Violet calcrete community, Millbillillie Bubble Well calcrete groundwater calcrete assemblage type, Uramurdah Lake calcrete groundwater assemblage, Wiluna BF calcrete groundwater assemblage type). 	N/A at present	N/A at present
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