Government of **Western Australia**
Department of **Environment and Conservation**

CAMERONS CAVE TROGLOBITIC COMMUNITY, CAMERONS CAVE MILLIPEDE AND CAMERONS CAVE PSEUDOSCORPION

INTERIM RECOVERY PLAN 2012-2017

A harvestman (*Glennhuntia glennhunti*).

INTERIM RECOVERY PLAN NUMBER 324

May 2012
Department of Environment and Conservation
Species and Communities Branch
Locked Bag 104, Bentley Delivery Centre, WA, 6983

FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (CALM) Policy Statements Nos. 44 and 50. The Department of CALM formally became the Department of Environment and Conservation (DEC) in July 2006. DEC will continue to adhere to these Policy Statements until they are revised and reissued.

IRPs outline the recovery actions that are required to urgently address threatening processes most affecting the ongoing survival of threatened taxa or threatened ecological communities, and provide a formal framework for the recovery efforts that are generally initiated prior to development of the plan.

DEC is committed to ensuring that threatened taxa and communities are conserved through the preparation and implementation of Recovery Plans (RPs) or IRPs, and by ensuring that conservation action commences as soon as possible and, in the case of critically endangered (CR) taxa and communities, always within one year of endorsement of that rank by the Minister.

This Interim Recovery Plan replaces plan number 76 Camerons Cave Troglobitic Community, Camerons Cave Millipede and Camerons Cave Pseudoscorpion Interim Recovery Plan No. 76 by S. Black, A. Burbidge, D. Brooks, P. Green, W. F. Humphreys, P. Kendrick, D. Myers, R. Shepherd and J. Wann, 2000-2003.

This IRP will operate from May 2012 to April 2017 but will remain in force until withdrawn or replaced. It is intended that, if the community is still ranked critically endangered at the end of the five-year term, this IRP will be reviewed and the need for further recovery actions assessed.

This IRP was approved by the Director of Nature Conservation on 9 May 2012. The provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting DEC, as well as the need to address other priorities.

Information in this IRP was accurate as at May 2012.

IRP PREPARATION

This IRP was prepared by Valerie English.

ACKNOWLEDGMENTS

The following people have provided assistance and advice in the preparation of this IRP:

Dr William Humphreys	Western Australian Museum
Mr Darren Brooks	WA Speleological Group
Ms Kirsty Dixon	DEC Exmouth
Ms Katrina Burton	Department of Water
Ms Brooke Halkyard	DEC Exmouth
Mr Mathew Prophet	DEC Exmouth
Cr Bob Todd	Shire of Exmouth
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Cover photograph by Douglas Elford (WA Museum).

CITATION

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SUMMARY

Name: Camerons Cave troglobitic community, Camerons Cave Millipede *Stygiochiropus peculiaris*, and Camerons Cave Pseudoscorpion *Indohya damacles*.

Description: Camerons Cave troglobitic community (obligatory cave inhabitants) is known only from Camerons Cave (karst index C-452) on the Cape Range peninsula. The community contains a unique assemblage of species, at least eight of which are known only from this location. The assemblage is related to those in some other caves, however, all species with congeneric members in caves in Cape Range proper have, to date, proved to be distinct species. Camerons Cave occurs within the Exmouth townsite. It is unprotected and the area around the cave is subject to various proposed developments. The listed threatened species Camerons Cave Millipede *Stygiochiropus peculiaris* and Camerons Cave Pseudoscorpion *Indohya damacles* (previously *Hyella* sp. BES 1154.2525, 1546, 2554) are endemic to Camerons Cave. *Milyeringa veritas* (blind gudgeon), and *Drakuloides bramstokeri* (Barrow Island Drakuloides) also occur in the cave but additional populations are also known from other sites.

DEC Region(s): Pilbara

DEC District(s): Exmouth

Local Government: Shire of Exmouth

IBRA Region/Subregion: Cape Range, Carnarvon

Status: Community endorsed for listing in the rank of critically endangered by the Minister for Environment in November 2001. *Indohya damocles* and *Stygiochiropus peculiaris* were listed by the Minister for Environment as Specially Protected Fauna on 28 November 1997 and assessed as meeting IUCN category critically endangered. (Note: *Indohya damocles* was originally listed as an undescribed species of *Hyella.*)

Habitat requirements: The single known occurrence of Camerons Cave troglobitic community occurs within Camerons Cave (karst index C-452), located on the Cape Range peninsula. The assemblage relies on particulate and dissolved sources of organic carbon for food. This food source is allochthonous, that is, comes in from outside the cave at the surface. The community is also reliant on the humid conditions in Camerons Cave, which are created through contact with the water table and specific surface conditions.

Important occurrences: As there is only one known occurrence, the conservation of the assemblage in Camerons Cave is critical to survival of the community and associated species.

Affected interests: Managers and users of the land and groundwater that supports the assemblage in Camerons Cave may be affected by actions in this plan.

Indigenous interests: The North West Cape Exmouth Aboriginal Corporation is represented on the North West Cape Karst Management Advisory Committee who assisted in the drafting of, and implementation of, the recovery plan for Camerons Cave. Comments and input have been sought from members of the recovery team on various drafts of this updated plan.

Social and economic impacts and benefits: Access to Camerons Cave is controlled by gating and has potential to allow the scientific values of the community to be appreciated without degrading the community, and this provides a social benefit. Where specific active recreational pursuits such as cave access are prevented, this may be perceived as a social impact, however such access control also helps to prevent the continued degradation of the community and so helps maintain other social benefits.

Occurrences may be threatened by proposals to clear for various developments or from hydrological change from development of, or use of groundwater for other uses on nearby lands. Implementation of actions such as seeking to protect the hydrological processes in the Camerons Cave community may result in an impact on development.

Related biodiversity impacts and benefits: Recovery actions implemented to improve the quality or security of the community and the associated listed threatened endemic fauna *Indohya damocles* and *Stygiochiropus peculiaris* are likely to improve the status of any species within the community, including the threatened *Draculoides bramstokeri* and *Milyeringa veritas*, and other endemic or restricted fauna.

Term of plan: The plan will operate from 2011 to 2016 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked critically endangered in Western Australia after five years, the need for further recovery actions and the need for an updated recovery plan will be evaluated by the recovery team.

Critical habitat: Camerons Cave, the doline in which the entrance occurs, the water in the cave, the groundwater feeding the water in the cave and its catchment, and the interstices in the limestone adjacent to the cave in which the terrestrial components of the community live.

IRP Objective(s): To maintain or improve the overall condition of the community and reduce the level of threat to its survival towards downgrading it from critically endangered to endangered.

Criteria for success:

- Camerons Cave, and an appropriate buffer zone around it, provided formal protection.
- Appropriate land use controls in place for land considered to be in or above the catchment affecting the groundwater or surface inflows to Camerons Cave.
- The continuing existence of *Indohya damocles* and *Stygiochiropus peculiaris* within Camerons Cave.
- The identification of existing and potential threatening processes affecting the troglobitic community and Camerons Cave habitat, and instigation of actions to ameliorate or reduce them.

Criterion for failure: Failing to detect *Indohya damocles* and *Stygiochiropus peculiaris*, or failing to ameliorate major threats to the habitat.

Summary of recommended actions

- Develop, implement monitoring plan
- Review requirement for management actions such as fencing
- Monitor surface input of water-borne food sources
- Continue to liaise with stakeholders about land uses and threatening processes
- Liaise with stakeholders
- Ensure land use planning, development control effectively protect the community
- Amalgamate and manage monitoring data, develop hydrological model
- Survey further likely areas for additional occurrences
- Resolve buffer area required
- Report on success
- Continue to seek to reserve Camerons Cave

1. BACKGROUND

1.1 History, defining characteristics of ecological community, and conservation significance

Investigations of coastal karst in Western Australia have led to the discovery of a distinct troglobitic community (obligatory cave inhabitants) endemic to Camerons Cave (karst index C-452). Camerons Cave occurs on the eastern coastal plain of the Cape Range peninsula, an area also known as the North West Cape. Camerons Cave is a doline about 10m x 15m in diameter, with a hole in the middle that drops into a horizontal cave that goes down to and beyond the watertable.

The Camerons Cave troglobitic community contains a unique assemblage of terrestrial and aquatic hypogean species, of which at least eight are known only from this location.

Camerons Cave troglobitic community is, in the strictest sense, related to assemblages found in caves in Cape Range (papers in Humphreys 1993a). However, all species with congeneric members in caves in Cape Range proper have, to date, proved to be distinct species. A number of caves, like Camerons Cave, have been artificially irrigated and supplied with leaf litter to try and find additional occurrences of the troglobitic community, without success. Camerons Cave occurs within the Exmouth townsite. It is unprotected and the area around the cave is subject to various proposed developments.

1.2 Extent and location of occurrences

Only a single occurrence of Camerons Cave troglobitic community is known. The community occurs within Camerons Cave, which is located within the Exmouth townsite on Lot No. 1388, on the eastern coastal plain of the Cape Range peninsula. Camerons Cave entrance occurs at an altitude of about 13 m. The cave has a maximum depth of 17 m and is approximately 65 m long by up to 34 m wide. The roof of the cave is 5 m thick.

1.3 Habitat critical to survival

The habitat critical to the survival of Camerons Cave troglobitic community and of Camerons Cave Millipede *Stygiochiropus peculiaris* and Camerons Cave Pseudoscorpion *Indohya damocles* is Camerons Cave, the doline in which the entrance occurs, the water in the cave, the groundwater feeding the water in the cave and its catchment, and the interstices in the limestone adjacent to the cave in which the terrestrial components of the community live.

1.4 Biology and ecology

Camerons Cave contains four species of threatened fauna listed as Specially Protected Fauna under the Western Australian *Wildlife Conservation Act 1950* - *Milyeringa veritas* (blind gudgeon), *Indohya damocles* (Camerons Cave pseudoscorpion)*, Draculoides bramstokeri* (Barrow Island Draculoides), and *Stygiochiropus peculiaris* (Camerons Cave millipede). *M. veritas* is listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *Milyeringa veritas* and *Draculoides bramstokeri* are ranked as vulnerable, and *Stygiochiropus peculiaris* and *Indohya damocles* are ranked as critically endangered in Western Australia under IUCN criteria. Of these threatened species, *Stygiochiropus peculiaris* and *Indohya damocles* are apparently endemic to Camerons Cave.

Milyeringa veritas (stygomorphic) and Copepoda are among Camerons Cave's aquatic fauna. Most of the troglobitic species found there are known from nowhere else and therefore likely to be subject to the same level of threat as the cave community itself. These include:

- *Stygiochiropus peculiaris* Shear and Humphreys (Diplopoda: Polydesmida: Paradoxosomatidae Australiosomatinae: Antichiropodini) which is only known from six specimens (2 collected dead)

from Camerons Cave. Three other species of the genus, which is endemic to Cape Range (Shear and Humphreys 1996), occur in Cape Range *sensu stricto*;
- *Indohya damocles* (previously *Hyella* sp.) (Pseudoscorpionida: Hyidae) which is only known from the dark zone of Camerons Cave, from four female, one adult male and five immature specimens (specimens BES 2545, 2546, 2554, 4249, 4148, 4149, 4154, 1154 and 2525). Another species of the genus, which is endemic to Cape Range (Harvey 1993) occurs in Cape Range *sensu stricto*;
- A troglomorphic harvestman *Glennhuntia glennhunti* (Opilionida: Phalangodidae) which is the only known specimen of the family Phalangodidae from Cape Range (Shear 2001);
- An undescribed troglomorphic species of cave spider (Hahniidae: Araneae), known from one specimen (specimen BES 1155). A related troglomorphic species is known from caves in Cape Range proper;
- *Phaconeura* sp. nov. (Hemiptera: Meenoplidae), which is troglomorphic (H. Hoch[1] pers. comm.) and very different from all other *Phaconeura* (specimen BES 2544). It is know only from Camerons Cave. Another species of *Phaconeura* occurs in caves in Cape Range proper (Hoch 1993);
- An undescribed troglomorphic species of cave spider (Ctenidae: Araneae) known from three juvenile specimens (specimens BES 2526, 2539 and 2541). Related epigean and troglobitic species are known from Cape Range proper (Harvey *et al*. 1993); and,
- *Trichocyclus* sp. (Pholcidae: Araneae) which is known from three specimens (specimens BES 2021 and 4248).

Other interesting and characteristic species include:
- *Draculoides bramstokeri* Harvey and Humphreys (Schizomida: Hubbardiidae), which is known from one other location in Exmouth and from Barrow Island (Harvey and Humphreys 1995). Several other species in the order Schizomida are known from Cape Range caves both from the coastal plain and the range proper, they are mostly troglomorphic (Harvey *et al.* 1993; M.S. Harvey[2] pers. comm.);
- *Trichocyclus* sp. (Pholcidae: Araneae), which is known from only three specimens (specimens BES 2021 and 4248); and,
- Other fauna (probably epigean) whose status is unknown include: Isopoda: Oniscoidea: Armadillidae; *Ploiaria* sp.1 (Hemiptera: Reduviidae: Emesinae); ?*Centrogonus* sp. (Hemiptera: Reduviidae: Emesinae); Coleoptera: Trogidae; Blattodea; Collembola; and Calanoida.

Camerons Cave troglobitic community probably relies on particulate and dissolved sources of organic carbon as a primary source of food and occasional intruding plant roots. This food source is allochthonous, that is, comes in from outside the cave, and is primarily transported by the influx of water. Hence the intensity, frequency, and periodicity of rainfall will also determine that of their energy recharge (Humphreys 2000b). The community is also reliant on the humid conditions in Camerons Cave, which are created through contact with the water table, as well as specific surface conditions and from water stored in sediment banks.

1.5 Hydrology and Geology

The limestone peninsula at Cape Range is composed of Tertiary limestone deposited from the Oligocene to the mid-Miocene (between 25-30 and 15 Million years before present) (Finlayson and Hamilton-Smith 2003). The area is known to contain several hundred caves. These caves contain a remarkably rich fauna which is largely a relict from when the climate was much wetter and tropical forests occurred in the area (Finlayson and Hamilton-Smith 2003).

The karst terrain precludes surface runoff except after exceptional rainfall. No runoff is likely to occur following a single rainfall event of less than about 25 mm. Such rainfall, and hence minor energy recharge of some caves, occurs on average once every 5.4 months, but with very low predictability. Major flows of water that are sufficient to flood caves deeply, are likely to occur once in 4.7 years (single falls of rain >150 mm). Rainfall events of more than 100 mm occur about once

[1] Prof. Dr H. Hoch, Institut für Systematische Zoologie, Museum für Naturkunde der Humboldt-Universität, Invalidenstr. 43, 10115 Berlin, Federal Republic of Germany.
[2] Dr Mark Harvey, Western Australian Museum, Perth.

every three years (Humphreys 2000a). Owing to the unpredictable climate, there is no seasonality associated with rainfall or energy influx. Caves on the Cape Range peninsula rarely contain drip-water; where it occurs, it is very localised following heavy rain. Hence, the percolation of fine particulate and dissolved organic matter into caves must be extremely restricted or even non-existent.

Cameron's Cave entrance occurs about 1.4 km from the coast and in parts extends below the water table. The source of this groundwater is the highly porous, unconfined Cape Range Group aquifer system (the Trealla and Tulki limestone). The overlying Trealla limestone is the youngest layer, and is between 0 and 20 m thick near Exmouth. It is transmissive and contains many karst features. The underlying Tulki limestone is around 80 m thick, is transmissive, and contains the major karst features of the range. The Mandu limestone is the oldest limestone layer, is the least transmissive, lacks karst, and is predominantly unconsolidated limestone sediments that act as a barrier to water flow and so cave development extends laterally along its surface.

Groundwater levels in the area are only marginally above sea level, and the general hydrogeological model for oceanic islands has been applied to the groundwater of Cape Range peninsula (following the Ghyben-Herzberg principle – 'under steady-state conditions the ratio of the head of fresh water above sea level, to the depth of fresh water/sea water interface in a coastal area will equal 1:40').

Lee (2008) notes that the limestone aquifers in the Cape Range area are very dynamic and fragile as they are highly permeable and fractured and located in an arid environment. A thin lens of fresh groundwater overlies a saltwater wedge that extends up to 5 km from the coast (Lee 2008). Mixing between fresh and tidal salt water and the groundwater abstraction zone results in a thick brackish zone that varies in particular with extreme tides and rainfall events (Lee 2008). In the Exmouth area, the fresh water-salt water transition is, at *c.* 5 km, described as exceptionally far inland. However, this is to be expected as the greater the transmissivity of the limestone and the more arid the area, the further inland the wedge should penetrate.

The connection of Camerons Cave to the marine environment is slight compared with the west coast of the Cape Range and the response of Camerons Cave to the semidiurnal tide is negligible (Dr S. Goater[3] pers. comm.).

Heavy rainfall events result in groundwater recharge in the unsaturated zone within broad drainage channels in the Cape Range area (Lee 2008). Natural groundwater discharge occurs as submarine discharge along the coast but now significant discharge occurs through water abstraction for human use in the upflow borefield.

The seawater – freshwater interface would have fluctuated as a consequence of relative sea level changes caused by natural climatic change in the Quaternary period (during about the last 2.6 million years) (Lee 2008) and tectonic uplift of the Cape Range anticline. The current main influences on the Cape Range aquifer system are mixing of fresh and salt water associated with tides, especially during spring; low rainfall, and damage to the aquifer caused by abstraction in the 1960s (Lee 2008). Low pumping rates are currently having negligible impacts on groundwater salinity (Lee 2008).

Recent monitoring and analysis was provided to the Exmouth Karst Recovery Team (S. Goater pers. comm.) from data from the bores closest to Camerons Cave. One bore is within 30 m of the cave entrance, and another occurs 80 m from the cave. Rapid recharge occurred in Camerons Cave in early 2008 caused significant flooding in the cave, with the water rising about 1m and taking some time to recede following the rain. DoW data loggers also showed more than 1 m rise and responded within 2 hours of rainfall, and this suggests that the cave is well connected to the aquifer. After three months the level of the interface between saline water and fresh water in the cave (salinity interface) returned to its original position.

[3] Dr Sarah Goater: previously, Water Corporation

DEC is providing resources for compilation of bore sampling data and for further sampling that may include a larger area. This may include some areas around Bundera Sinkhole as well, another critically endangered karst TEC (K. Dixon[4] pers. comm.).

1.6 Threatening processes

There are a number of existing and potential threats to Camerons Cave troglobitic community and its endemic fauna. The severity of threat results from the fact that the community is known only from this single site. The immediate threats are as follows:

- uncontrolled access to Camerons Cave and its surrounds,
- modification of the local or regional hydrological processes,
- pollution, and dumping of rubbish or toxic waste that may affect conditions in Camerons Cave.

- **Uncontrolled access to Camerons Cave**

As the cave is located in a residential area of Exmouth Township, it is readily accessible to people and vehicles. Uncontrolled vehicle or heavy machinery activity or building on-site, particularly directly above the cavity, or explosives used too close to the cave, could cause surface subsidence or partial cave collapse.

People entering the subterranean cavity of the cave could also disturb the habitat and fauna if access was not controlled.

A drilling rig has driven along the rim of the cave to establish the bores, and this track needs to be rehabilitated as Camerons Cave should be a walk-in site.

DEC has developed a draft cave and karst policy, which recommends the development of a cave classification system on DEC land. Camerons Cave should be designated for scientific purposes and have highly restricted access.

- **Modification to hydrology**

Modifications to local catchment

The fauna of Camerons Cave are considered vulnerable to changes in groundwater level and quality and therefore to changes in quantity and quality of surface waters that recharge the aquifers and provide nutrients to cave fauna (Brown & Root 2000).

Urban, rural, industrial, recreational or other forms of development on-site, and in the area around Camerons Cave, are likely to modify the catchment area and, hence, surface water input to the cave, through altering drainage patterns, flow rates and volumes, and water-soil infiltration rates. Changed hydrological conditions are likely to affect the input of allochthonous food resources, and to impact on the humidity in the cave.

Modifications to regional groundwater

Changes to groundwater levels and quality in the Exmouth Groundwater Subarea have the potential to affect the stygofauna of the Cape Range peninsula, including that of Camerons Cave. Altered groundwater hydrology within Camerons Cave could result in loss or modification of habitat for aquatic taxa, and could impact on humidity levels important to troglobitic fauna.

[4] Ms Kirsty Dixon: Previously DEC Exmouth Dsitrict

Groundwater is naturally discharged from the aquifer by flow to the ocean, by several springs along the coast (including submarine springs), and by evapotranspiration from vegetation on the coastal plain. It is also discharged by abstraction from the well or borefield. Groundwater is the major water resource for Cape Range peninsula and is currently utilised to meet the public water requirements of the town of Exmouth plus private, tourist and industrial uses. This water resource is limited and is already heavily utilised in the Exmouth area.

Significant population growth is expected in Exmouth, with an associated increase in groundwater use. In addition to Water Corporation, other users who draw smaller amounts of water in the area include private bores, and the naval base. Water Corporation has an extensive borefield that supplies drinking water to the Exmouth Township, derived from bores in the Upper Tulki Karst Aquifer. About 75% of the water abstracted from the aquifer is taken by Water Corporation (about 1029 ML). Another 258 ML is used by the Harold E Holt borefield (naval base), and about 133 ML is used in private bores. Water Corporation has made a commitment to monitor water quality in the bores, with main commitments as follows (Brown & Root 2000):

- monthly rest water levels in all appropriate production and Salt Water Interface Monitoring (SWIM) Bores
- SWIM bores to be installed adjacent to selected production bores
- stygofauna observation bores (SOB) to be established downstream and sampled for water and fauna monitoring
- salinity of production bores and analysis of all major ions, pH, salinity and Total Dissolved Solids.

Bennelongia (2008) note that the following environmental conditions were imposed on Water Corporation when the licence to extend the Exmouth borefield was granted in 1997. The commitments in relation to stygofauna are:

- finalize a detailed stygofauna and aquifer monitoring program
- submit data on stygofauna species composition and numbers
- implement actions to protect stygofauna populations and habitat to the requirements of the EPA on the advice of DEC (the trigger for management response was amended in 2000 from loss of a species in one-third of monitoring bores to apparent reduction in stygofauna densities and/or stygofaunal diversity within production field when compared with DSO bores) (Brown & Root 2001)

In relation to detection of hydrological change, commitments were that if monitoring reveals that salinity of production or monitoring wells is increasing, the proponent will:

- immediately reduce the rate of pumping from the bore(s)
- reduce the total production from the group of bores in the area
- if the above measures do not improve salinity levels, cease groundwater production from the bores involved.

There has been a proposal to site a horse-racing track on or adjacent to the area above the cave, and the general area is subject to a boat harbour, marina and canal residential developments. LandCorp commenced development and construction of the Exmouth Marina Village canal system in 2002. Further development of the harbour is expected in relation to new infrastructure for the offshore industry. At the time of writing, residential development occurred about 400 m to the south of the cave, and a canal occurred within about 1500 m to the north east of the cave. Clearing for the marina development was about 1300 m to the north east.

The canal development had been an issue of concern, however salinity impact from the marina has apparently not extended very far inland, which is indicative that the karst system is not a very open system in the coastal area. It is not known what has occurred since the canal development. DoW suggest that it is likely to have had some significant alterations to the system. Lee (2008) notes that there is increasing saline composition in many bores in the borefield and that this is likely to be associated with a drift towards changing water chemistry due to drawdown associated with the Exmouth borefield. SWIM bore data is being collected by Water Corporation.

The Exmouth borefield and submarine coastal areas are primary areas of groundwater discharge. (Lee 2008). Low abstraction rates of 7% of the annual recharge (i.e. 700,000 cubic metres of the total annual recharge of 4 million cubic metres) are set in the high-yielding production bores due to the proximity to the saltwater interface (Lee 2008). The borefield covers about 50 km^2 and contains 24 production and 34 monitoring bores. The closest production bore in the Water Corporation borefield is about 1.5 km west of Camerons Cave. The borefield was established in the 1960s, and poor management resulted in salt water intrusion in the northern parts of the borefield (Lee 2008). It is estimated that there is about 200 million cubic metres /km length of the range, and a 'safe' yield is estimated to be about 100,000 m^3 a^{-1} km^{-1} length of range (Lee 2008).

Water levels in the Exmouth borefield bores fell between 1981 and 1991, apparently due to low rainfall (Lee 2008) and, concurrently, salinity has increased across many bores in the borefield. The borefield itself is currently being extended. There are also plans to further extend it to the south, with some bores planned about 2 km south west of Camerons Cave. The freshwater lens has thinned and there has been more mixing with seawater in the northern half of the borefield presumably because of a longer history of excessive abstraction relative to recharge, and due to higher conductivities in the Upper Tulki Karst Aquifer (Lee 2008). Increasing groundwater salinity was also noted in periods of lower rainfall (Lee 2008). The lens has thinned considerably with seawater intrusion mainly due to historical groundwater abstraction, long term below average rainfall and tidal influences (Lee 2008). The sustainability of the aquifer will be dependent on ensuring that drawdown does not cause seawater to encroach into the aquifer, as this kind of damage to aquifers is not reversible (Lee 2008).

The Department of Water (DoW) allocates and manages groundwater in Western Australia. On the Cape Range Peninsula the licensing of all groundwater abstraction has been compulsory since the 1999 groundwater allocation plan was released, however this may change in the future. Groundwater licensing is the responsibility of the DoW's Mid West Gascoyne district office in Carnarvon. DoW proposed to discontinue licensing of domestic bores in Exmouth. The North West Cape Karst Management Advisory Committee (NWCKMAC) have expressed support for continued licensing and monitoring. Current arrangements will continue until a new management plan is released and changes made.

Monitoring undertaken for Camerons Cave by DoW and DEC through the original borehole sampling had two purposes. These were to determine the extent of fauna at the cave, and to clarify the significance of the cave system to the continued survival of the Camerons Cave TEC. Monitoring originally included examining water profiles and water depth but the program was only planned to be short term, and was ceased in 2006. Ad hoc sampling still occurs and the DoW and Water Corporation have discussed reinitiating periodic sampling.

The Groundwater allocation plan – Exmouth groundwater subarea (WRC 1999) was developed to establish the limits for allocating groundwater and the policies for licensing abstraction. It provides the framework for the department to sustainably allocate and licence groundwater in the Exmouth subareas. In the area around Cameron's Cave (Exmouth Central subarea) water allocation is restricted to within the allocation limits (currently 86% allocated 2010) and restrictions to the location of draw points, and the volume pumped are applied to minimise the impacts on the groundwater-dependent ecosystems and inland movement, or upconing, of saline water.

Bennelongia (2008) state that groundwater management will have little effect on troglofaunal communities in the Exmouth area, but a series of data that conflict with this conclusion were apparently not considered in that report. For example, Bennelongia (2008) does not discuss epikarst, which is now considered a major source of biodiversity. Various references indicate that small perched aquifers may be very important for stygofauna (eg Pipan *et al.* 2006, Pipan 2007a and b).

- **Pollution and/or dumping of rubbish or toxic waste in Camerons Cave**

Camerons Cave and the troglobitic community could be threatened by contamination from nutrients, toxic substances or other waste originating from point or diffuse sources. The thin soil cover, typical of karst areas, provides little filtration of percolating fluids making such areas prone to contamination. In addition, the open conduit hydrological systems permit the rapid and distant spread of any contaminants such as nutrients or toxins introduced to the system. As the flushing of groundwater in the arid Cape Range area is exceptionally low, the residence time of contaminants would be long (Humphreys *et al*. 1999). The introduction of energy, via nutrients entering subterranean systems, changes the energy balance and enhances the competitive abilities of epigean organisms, allowing them to displace hypogean organisms that are adapted to a low energy environment (Humphreys *et al*. 1999). Hence, these ecosystems are sensitive to pollution.

The risk of waste dumping and pollution will increase if access to the site and urban, rural, industrial or recreational development in the immediate area is not controlled.

There are three potential aquatic sources of nutrients (S. Goater pers. comm.). These are:

1. Freshwater lens – karst movement, determined by cracks in the ground
2. Marine intrusion – marine influence and downstream effects of land use
3. Freshwater influx from seasonal rainfall.

Little pollution of the groundwater of the Cape Range peninsula, either from point sources (e.g. petrol tanks) or diffuse sources (e.g. fertilisers) was observed in 1994 (Humphreys 1994) but the current status is unknown.

1.7 Guide for decision-makers

Developments in the region of Camerons Cave require assessment. No developments should be approved unless the proponents can demonstrate that they will have no significant impact on the cave or its faunal communities. Impacts on the aquifer, either leading to its depletion or pollution, would be expected to have a significant impact on the threatened ecological community. Developments downstream as well as upstream of Camerons Cave need assessment, as downstream (eastward) changes may lead to an inflow of salt water.

1.8 Conservation status

Camerons Cave Troglobitic Community meets the following criteria for critically endangered communities (DEC 2009):

B) Current distribution is limited, and

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years);

ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes;

Stygiochiropus peculiaris and *Indohya damocles* meet criteria for critically endangered under IUCN (2001) Red List criterion B1ab(iii)+B2ab(iii), the extent of occurrence is less than 100 km^2 or the area of occupancy is less than 10 km^2, the species is known from a single location and a continuing decline in area, extent or quality of habitat is inferred or projected. Both species are listed as threatened fauna under the *Wildlife Conservation Act 1950* and are ranked as critically endangered.

Important occurrences: As there is only one known occurrence, the conservation of the assemblage in Camerons Cave is critical to survival of the community.

Affected interests: Managers and users of the land and groundwater that supports the assemblage in Camerons Cave may be affected by actions in this plan. This includes Water Corporation, Shire of Exmouth, and other private users of water resources in the vicinity of the cave.

Indigenous interests: The North West Cape Exmouth Aboriginal Corporation is represented on the North West Cape Karst Management Advisory Committee who assist in the implementation of the recovery plan for Camerons Cave. Comments and input have been sought from members of the recovery team on various drafts of this updated plan.

Social and economic impacts and benefits: Access to Camerons Cave is controlled by gating and has potential to allow the scientific values of the community to be appreciated without degrading the community, and this provides a social benefit. Where specific active recreational pursuits such as uncontrolled cave access are prevented, this may be perceived as a social impact, however such access control also helps to prevent the continued degradation of the community and maintain other social benefits.

Occurrences may be threatened by proposals to clear for various developments or from hydrological change from development of, or use of, groundwater for other uses on nearby lands. Implementation of actions such as seeking to protect the hydrological processes in the Camerons Cave community may result in an impact on development.

Related biodiversity impacts and benefits: Recovery actions implemented to improve the quality or security of the community and the associated endemic listed threatened fauna *Indohya damocles* and *Stygiochiropus peculiaris* are likely to improve the status of other species within the community, including the threatened *Draculoides bramstokeri* and *Milyeringa veritas* and other endemic species not listed as threatened.

Term of plan: The plan will operate from May 2012 to April 2017 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked critically endangered in Western Australia after five years, the need for further recovery actions and the need for an updated recovery plan will be evaluated by the recovery team.

1.9 Strategy for recovery

Two strategies will be implemented:

- To identify management requirements and influence the management of Camerons Cave, and its catchment, to maintain the natural biological and non-biological attributes of the site.

- To conduct appropriate research into the ecology of Camerons Cave Troglobitic Community in order to develop further understanding about the management actions required to maintain or improve the condition of the community and its habitat.

2. RECOVERY OBJECTIVE AND CRITERIA

2.1 Objective

To maintain or improve the overall condition of the community and its endemic fauna and reduce the level of threat to its survival towards downgrading it from critically endangered to endangered.

2.2 Criteria

2.2.1 Criteria for success

1. Camerons Cave, and an appropriate buffer zone around it, provided formal protection.

2. Appropriate land use controls being put in place for land considered to be in or above the catchment affecting the groundwater or surface inflows to Camerons cave

3. The continuing existence of *Indohya damocles* and *Stygiochiropus peculiaris* within Camerons Cave.

4. The identification of existing and potential threatening processes affecting the troglobitic community and Camerons Cave habitat, and instigation of actions to ameliorate or reduce them.

2.2.2 Criteria for failure

Failing to detect *Indohya damocles* and *Stygiochiropus peculiaris*, or failing to ameliorate major threats to the habitat.

3. RECOVERY ACTIONS AND COSTS

3.1 Existing recovery actions

The North West Cape Karst Management Advisory Committee (NWCKMAC) was established in 1999 to provide advice to DEC, and to other agencies and groups upon request, regarding the biological values of karst systems on Cape Range peninsula, and the management of those values. The committee functions as the recovery team for listed threatened species and ecological communities on Cape Range peninsula, and meets at least annually. Core membership includes representatives from: DEC (Pilbara Region, Exmouth District, Species and Communities Branch), the WA Speleological Group (Exmouth), North West Cape Exmouth Aboriginal Corporation, the Shire of Exmouth, WA Museum, the Department of Water, Water Corporation, and the Department of Defence.

Camerons Cave and a 500m buffer zone are included in the Exmouth Town Site Structure Plan (Taylor Burrell Barnett Town Planning and Design 2011) and this area comprises the proposed conservation reserve. The site is within the Exmouth townsite. Several developments are pending in the area near the proposed reserve, including subdivision of land, and relocation of the racecourse. Landgate has been advised of the occurrence of Camerons Cave Troglobitic Community, and liaison between Landgate and the NWCKMAC (through DEC) has been established. Landgate plotted the location of the cave on their preliminary subdivision design plans.

Liaison with numerous other appropriate authorities and land users has been established through the NWCKMAC. Additional bodies not represented on NWCKMAC, that have interests in, or responsibilities for, karst area management, or in managing exploitation of resources on the Cape Range peninsula, include the Environmental Protection Authority (EPA); the Department of Mines and Petroleum (limestone mining); the Gascoyne Development Commission (local social and economic development); the Gascoyne Development Commission, tourism operators (adventure

caving etc). The majority of these bodies were advised of the formation of the NWCKMAC and its aims.

In 1999, a Bankwest *Landscope* Conservation Visa Card grant was obtained to replace an old gate previously installed by the Shire of Exmouth. Works were overseen by a member of the WA Speleological Group (Mr D. Brooks) in liaison with DEC (Exmouth District) staff. The replacement gate is lockable and inconspicuous.

Rangelands Natural Resource Management through the Commonwealth's Caring for our Country program installed signage at the cave in 2008. The signs were placed to ensure that additional attention was not attracted to the cave area, but to provide information to people passing by on the rim track.

A large quantity of data have been collected about the regional and local hydrology relevant to Camerons Cave. This includes a PhD thesis completed by Dr S. Lee on the hydrogeology and hydrogeochemistry of the limestone karst aquifers at Cape Range (Lee 2008). The results were available for inclusion and consideration in management actions for Camerons Cave. Monitoring data have also been collected by Water Corporation, Department of Water, Mr D. Brooks, Dr W. Humphreys and other organisations and individuals, about the hydrology at the regional and local scales that will help in formulating management.

The principal investigations of the fauna along the Cape Range peninsula were undertaken by the Western Australian Museum and associated researchers (Adams and Humphreys 1993; Bruce and Humphreys 1993; Humphreys 1993a, 1993b, 1994, 1999a, 1999b; 1999c, 2000a, 2000b, 2001; Humphreys and Adams 1991; Humphreys and Feinberg 1995; Humphreys *et al*. 1999; Jaume and Humphreys 2001; Jaume *et al.* 2001; Karanovic *et al*. 2001; Pesce *et al*. 1996a, 1996b; Poore and Humphreys 1992; and Yager and Humphreys 1996). Further investigations into the karst environment and the subterranean fauna have been undertaken by the Water Corporation as part of the Consultative Environmental Review (Muir 1995), and in consultation with the Department of Environmental Protection (now DEC) (Hamilton-Smith *et al*. 1998).

Considerable biological sampling has been completed for Camerons Cave. Recent troglofauna trapping in boreholes was undertaken by Mr D. Brooks. This monitoring included troglofauna but not stygofauna. It is believed that the stygofauna would probably include the usual types of fauna that may be found in this area (Dr W. Humphreys[5] pers. comm.). The troglofauna of the Cave have been described and studied as described in a series of papers including Bruce and Humphreys (1993), Harvey (1993), Harvey *et al*. (1993), Harvey and Humphreys (1995), Harvey and Volschenk (2007); Hoch (1993); Humphreys (1993a; 1993b; 1994; 1999b; 2000a); Shear and Humphreys (1996).

Monitoring undertaken for Camerons Cave by Department of Water (DoW) and Department of Environment and Conservation (DEC) through some original borehole sampling had two purposes. These were to determine the extent of fauna at the cave, and to clarify the significance of the cave system to the continued survival of the Camerons Cave TEC. DoW monitoring originally included examining water profiles and water depth but was only planned to be short term, and has since ceased .

Monitoring bores have been established adjacent to Camerons Cave. DoW bore data on the GIS system indicates private monitoring bores now occur within 70 m and 150 m of the cave entrance. The GIS locational data appear to be inaccurate as on-ground survey indicates a bore occurs within 30 m of the cave entrance.

Interpretive signage about the troglobitic community has been installed near the cave.

[5] Dr William Humphreys: WA Museum

3.2 Recommended recovery actions

1. Develop and implement a monitoring plan ('sampling analysis plan') for Camerons Cave and respond to results of monitoring

An interagency monitoring regime is required to amalgamate data, align monitoring efforts, coordinate access to boreholes, and ensure consistency with monitoring and evaluation techniques. Basic ongoing monitoring of the Camerons Cave troglobitic community and hydrological processes would permit ongoing assessment of the condition of Camerons Cave as a habitat, and provide insight into required strategies for managing the hydrology, and other important non-biological and biological processes.

Water profiles and water depth were originally monitored for Camerons Cave by DoW, but this has since ceased. It is planned that monitoring will recommence once a Sampling Analysis Plan (SAP) has been developed to specify the objectives and requirements of monitoring. The SAP will not be developed until completion of an Ecological Water Requirements (EWR) analysis. The EWR tender final report was submitted to Department of Water in 2009.

Considerable biological sampling has been completed for Camerons Cave. Recent troglofauna trapping in boreholes was undertaken by Mr D. Brooks. This monitoring included troglofauna but not stygofauna.

The plan will include clearly defined objectives and guidelines (frequency) of monitoring, and specify parameters that will be measured. The SAP is expected to include water level monitoring and measurements from *in-situ* water quality probes to determine natural groundwater variations. The SAP also needs to include water level, water quality, stygofauna and troglofauna monitoring. Other surrounding land use impact issues will need to be considered in monitoring design. The objectives of sampling, and responsibilities of each agency (DEC and DoW) will need to be verified in the document, and the sampling to be undertaken by each agency will be integrated. DoW proposes to ensure that the monitoring program is incorporated into the planning process for Exmouth.

A successful monitoring program requires careful consideration of the elements to be monitored and the reasons for including them need to be clearly identified (Vos *et al*. 2000). It will be difficult to find effective elements to monitor that will provide an effective feedback loop for management (Bennelongia Pty Ltd 2008). Therefore EWRs should be set in a precautionary manner and be based on widespread hydrological modelling and survey. Bennelongia Pty Ltd (2008) recommend monitoring depth to water, salinity, Ph, dissolved oxygen and nutrients where stygofauna occurs. Bennelongia Pty Ltd (2008) also suggest that salinity and dissolved oxygen should be measured at 1 m intervals to determine and monitor groundwater profile for bores associated with stygofauna. These data, and hydrocarbon monitoring would probably be useful for bores associated with Camerons Cave as well because as it penetrates the water table, and monitoring that is indicative of salt water intrusion will probably therefore be very important.

The NWCKMAC has identified the development of a monitoring plan for the fauna and physical environment of Camerons Cave as a priority action towards the conservation of the troglobitic community. As a minimum monitoring requirement for the troglobitic community, the presence of *Indohya damocles* and *Stygiochiropus peculiaris* within Camerons Cave should be confirmed by bait sampling every two years. Ideally, the species composition and abundance of all dominant taxa within the community should be monitored.

The WA Speleological Group and /or Speleological Research Group, may be able to undertake some monitoring activities such as the biodiversity monitoring.

Adverse monitoring results will be broadly indicative of management actions required to sustain the Camerons Cave community.

Responsibility: DEC (Exmouth District and Species and Communities Branch (SCB)) and DoW, in liaison with the NWCKMAC
Cost: To be determined
Completion date: Monitoring program to commence as soon as possible, then ongoing

2. Monitor surface input of water-borne food sources, to establish long term trends

There is still only a basic level of understanding of the Camerons Cave ecosystem and its ability to sustain subterranean fauna. Specific data for the cave with regard to groundwater movement, and on the effects of episodic rainfall on surface input of nutrients and water are lacking. Lee (2008) provides data on the effects of episodic rainfall on surface input of water, and this is probably indicative of nutrient flows into the cave too. Lee (2008) also provided a high level of detail about the regional groundwater.

Responsibility: DEC (Exmouth District and SCB) and DoW, in liaison with the NWCKMAC
Cost: To be determined
Completion date: Monitoring program to commence as soon as possible, then ongoing

3. Liaise with stakeholders to continue to manage groundwater quality and levels for the Cape Range peninsula

The NWCKMAC will continue liaison with DoW and other stakeholders that monitor, assess, and manage groundwater quality and levels for the Cape Range Group aquifer.

The DoW manages groundwater resource utilisation and conservation in Western Australian. On the Cape Range peninsula, the licensing of all bores and wells is compulsory. Groundwater licensing administration is the responsibility of the DoW's Gascoyne District Office, located in Carnarvon. The Groundwater Allocation Plan for the Exmouth Groundwater Subarea (Cape Range peninsula) has been developed to establish policies and principles for the sustainable allocation of groundwater resources. It provides direction for the district office in the issuing of groundwater licenses, with further specialist advice on groundwater matters available from the DoW's Allocation's Branch.

As mentioned, Cameron's Cave is located in the Exmouth Central Subarea, where water use is close to 90% allocated. The management of wells or bores in the area involves limiting the quantity of water abstracted from the aquifer, and the physical area in which pumping occurs in order to maintain water levels and restrict saline upconing (Water and Rivers Commission 1999).

The 1999 Exmouth Subarea Allocation Plan stated that additional work was required to estimate the Ecological Water Requirements and Environmental Water Provisions for the subterranean fauna of the Cape Range Group aquifer. In particular, there is a requirement for further monitoring which includes the establishment of baseline data to help in the identification of acceptable environmental change (Waters and Rivers Commission 1999).

DoW's process of reviewing the Exmouth Allocation Plan will begin soon and NWCKMAC has had the opportunity for input regarding management of the resources. Some of the issues being examined include Ecological Water Requirements (EWRs), licensing of domestic users, future water requirements and monitoring requirements. Water Corporation data with regard to monitoring EWRs that is expected to be available soon should be incorporated into this review. There is a need for continual monitoring of ground water level, effect of recharge on the system and surrounding land use impacts.

The Water Corporation is the major user of groundwater from the Cape Range Group aquifer, providing public water supply of 1029 ML per annum. The Exmouth Water Resource Operation Management Strategy (Water Corporation 1998) details the operational agreement between the

DoW and the Water Corporation, outlining how the Water Corporation will conduct its extraction operations under license from the Commission. The strategy includes commitments by the Water Corporation to implement a regular stygofauna and aquifer monitoring program, and that pumping be done in a manner that maintains appropriate water salinity levels at each bore.

The objectives that were listed for the last Water Corporation's Cape Range peninsula/Exmouth borefield monitoring program were to:

- accurately measure water level variation with time to determine the influence on water levels of water abstraction, tides and recharge events;
- accurately measure salinity variation with time to determine the influence of water abstraction on the thickness of the freshwater lens;
- characterise the patterns of variation in major ions and pH with time.

The previous monitoring protocol entails sampling 32 water level bores monthly, salinity sampling 29 production bores monthly, sampling the salinity profile of two stygofauna monitoring bores annually, sampling salinity of two sets of Salt Water Interface Monitoring bores annually, and sampling EC, pH and major ions from all production bores annually (Water Corporation 1998).

The Environmental Protection Authority (1998) have provided further guiding principals for water management to protect the ecological values of the Cape Range Province, in Position Statement No.1 for the Environmental Protection of Cape Range Province.

Responsibility: DoW and Water Corporation in liaison with the NWCKMAC
Cost: $5,000 pa
Completion date: Ongoing

4. Amalgamate and manage monitoring data, and develop a hydrological model

It is important to identify which agencies are conducting monitoring at the cave, and the EPA may have some of this information. The types of monitoring data being collected from boreholes has not been collated. The DoW has an information system on bore locations and constructions and this also includes monitoring data if submitted. This will need to be incorporated into the sampling analysis plan.

Fauna monitoring data for the cave, as at 2006 were held by WA Museum.

Development of a detailed hydrological model for groundwater is a high priority. Lee (2008) has developed a regional hydrological model. The DoW SAP data should be used to develop a local model of the cave if possible, however, given the karstic terrain this may be problematic. The sampling analysis plan will provide information on sampling to guide management of the system, but to date this work has not been scheduled.

Responsibility: DEC (Exmouth District), WA Museum, and DoW in liaison with the NWCKMAC
Cost: To be determined
Completion Date: Year 4

5. Resolve buffer area required to protect hydrology of Camerons Cave

A key objective for monitoring of Camerons Cave is to determine the boundary of the groundwater buffer required to prevent impacts from local surrounding developments.

A process was initiated to seek reservation of a specified area around Camerons Cave, but this has since stalled and the process needs to be resurrected. Two principles of maintaining surface vegetation, and protecting the groundwater flow were involved with producing the original buffer boundary. It is known that the cave continues southwards from the entrance for 80m and at the

lowest point, goes into inclined fissures filled with water that continue for an unknown extent (D. Brooks[6] pers. comm.). The karst side of the cave should be provided with more protection than the coastal side as it is likely to be more vulnerable to surface and ground water flows.

A 200m buffer is written into the Exmouth Structure Plan, but recently this was extended to 500m. Rural residential development is muted for just south of the cave. There is concern that this buffer is not big enough to protect the cave's important biota. Prior to completion of Town Planning Scheme number 4, it may be possible to extend the proposed reserve beyond the existing buffer, but not once the scheme is in place. The committee has recommended a 500m buffer for the cave. This was based on first principles – (general direction of flow of groundwater towards the coast), rather than on hydrological modelling of groundwater movement. The original placement of bores was intended to provide information about the distribution of fauna and a better picture of very localised hydrology, but this has not been completed.

The buffer requirements to ensure the cave is protected from more regional sources of impact such as coastal developments with potential to impact the saline-freshwater interface will require examination of regional data such as Lee (2008).

A research proposal with the objective of establishing the species composition and geographical extent of the fauna at Camerons Cave will also be developed.

The determination of surface levels and watersheds is a priority action. This work has commenced with the completion of a contour survey map for the Camerons Cave area, at a scale of 1:1000. The boundary of the contour survey map area has since been digitised, overlaid through a GIS System by DEC, and used to produce a digital map of the recommended reserve boundary around the cave. Surveys of the below-ground extent of the cave have been completed by the WA Speleological Society.

Dozer Cave which is in close proximity to Cameron's Cave is subject to vandalism, fish introductions and pollution and is considered a potential source of contamination for Camerons Cave. The potential for a hydrological linkage between these two caves will be investigated, and may indicate the need for particular controls and management at this additional nearby site.

Responsibility: DEC (SCB and Exmouth District) and the NWCKMAC
Cost: $10,000
Completion Date: Year 2

6. Continue to seek to reserve Camerons Cave and an appropriate buffer zone

As mentioned, the current Exmouth Townsite Structure Plan (Taylor Burrell Barnett Town Planning and Design 2011) indicates a 500m buffer from development around Camerons Cave. The NWCKMAC will continue negotiations with the Shire of Exmouth and other relevant bodies to have Camerons Cave and this buffer zone declared a Class A nature reserve vested in the Conservation Commission. DEC, with NWCKMAC advice, will then be responsible for implementing control of threatening processes, and for seeking planning arrangements to minimise threatening processes originating outside the reserve.

The reserve area needs to encompass at the surface, the full extent of the underground area of the cave and be sufficient for maintenance of the catchment area and surface conditions affecting the humidity of the cave and allochthonous food resource input for the troglobitic community. Due to the risk of surface subsidence, the driving of vehicles and heavy machinery over the ground surface above the cave will be prohibited.

[6] Mr Darren Brooks: WA Speleological Group

If it transpires that a Class A nature reserve vested in the Conservation Commission is not feasible, then an alternative form of statutory protection will be pursued.

Responsibility: DEC (Park Policy and Research Branch and Exmouth District)
Cost: $5,000 p/a in Year 1-4
Completion date: Year 4

7. Review requirement for management actions such as fencing of reserve

In 2000, the NWCKMAC discussed signage and fencing and decided that signs were unnecessary and may draw attention to the site. Fencing will be further considered when a reserve has been delineated and declared.

The track leading to the Camerons Cave sampling bores is of concern. A drilling rig has driven along the rim of the cave to put the bores in. The track should be ripped from the first bore (30m from the entrance) and access restricted from the north, as the existing track encourages people to drive along the rim of Camerons Cave. This track is getting bigger and more compact with use. Camerons Cave should be a walk-in site. Any track work at the site would be a Shire responsibility, so a proposal would need to be put to the Shire for consideration.

Responsibility: DEC (Exmouth District and SCB) and Shire of Exmouth in liaison with the NWCKMAC
Cost: To be determined
Completion Date: Year 3

8. Continue to liaise with stakeholders about land uses and threatening processes that may adversely impact on Camerons Cave and the troglobitic community

Liaison with other authorities and land users regarding land uses and threatening processes that may adversely impact on Camerons Cave and the troglobitic community, has been established and should be continued on an ongoing basis.

Provision of information to appropriate stakeholders regarding threats, and monitoring for threats (hydrocarbons and saline intrusion) would also aid future management of Camerons Cave.

Responsibility: DEC (Exmouth District and SCB) and the NWCKMAC
Cost: $2,000 pa
Completion date: Ongoing.

9. Ensure land use planning and development control processes effectively protect Camerons Cave and the troglobitic community

Camerons Cave lies on unallocated Crown land, and several developments are pending.

Operations or developments that have potential to cause pollution, or to impact on the hydrology of Camerons Cave ecosystem, should undergo environmental impact assessment. All developments on the Cape Range peninsula should be referred to the Environmental Protection Authority for assessment and should comply with both the Groundwater Allocation Plan for the Exmouth Groundwater Subarea drafted by the Water and Rivers Commission Policy and Planning Division, and the Exmouth – Learmonth (North West Cape) Structure Plan (drafted by the Western Australian Planning Commission in conjunction with the Gascoyne Development Commission). The Gascoyne Coast Planning Coordinating Committee Technical Advisory Group was tasked with implementing the recommendations of the report on karst management considerations for the

Cape Range Karst Province, Western Australia, prepared for the Environmental Protection Authority (EPA).

These plans provide the framework for state and local government decision making on development proposals, and will provide a level of certainty to the local community in terms of the type and scale of developments. Consequently, all development proposals, including all those that require groundwater, substrate, or waste disposal, will need to comply with the concepts within the structure plan. DEC, in liaison with the NWCKMAC, is currently investigating the potential for modifying the existing structure plan for the Exmouth area, considering that the area over and around Camerons Cave is currently marked for low intensity urban development.

Responsibility: DEC (Exmouth District and SCB) and the EPA, in liaison with the NWKCMAC
Cost: $5,000 p/a
Completion date: Ongoing

10. Survey further likely areas for additional occurrences of Camerons Cave Troglobitic Community and the species *Indohya damocles* and *Stygiochiropus peculiaris*, within the known distribution of elements of the community

Additional occurrences of the Camerons Cave Troglobitic Community (or new stygofauna community types containing *Indohya damocles* and *Stygiochiropus peculiaris*) may occur in other caves or sinkholes in north-western Australia. While considerable sampling of cave and groundwater habitats has occurred on the Cape Range peninsula and adjacent areas, investigation into the extent of the karst stygofauna should be continued, with examination of further sites within the extent of the north-western Australian karst fauna (Cape Range peninsula, Barrow Island, Robe and Fortescue alluvial aquifers). Any new-found occurrences of Camerons Cave Troglobitic Community or *Indohya damocles* and *Stygiochiropus peculiaris* should be subject to cooperative management actions as listed in this IRP.

The area in the vicinity of Camerons Cave, in particular, should be sampled for threatened fauna in seeking to extend the known geographic ranges of taxa. Some data could be gathered by the WA Speleological Group, in liaison with the North West Cape Karst Management Advisory Committee. Some holes have been drilled for sampling. With the cooperation of landholders, sampling of private water bores that are not in use could also be conducted. Bores on Department of Defence land may also be suitable for sampling.

Responsibility: WA Museum in liaison with NWCKMAC
Cost: $10,000 pa
Completion date: Year 5

11. Report on success of management strategies for Camerons Cave and the troglobitic community

The NWCKMAC will prepare annual reports for DEC's Corporate Executive. At the end of the life of this plan, implementation will be reviewed and a decision made as to whether the community still meets criteria for critically endangered, and if there is a need to update the plan.

Responsibility: DEC (Exmouth District and Species and Communities Branch) with input from the NWCKMAC
Cost: $25,000 if updated plan required
Completion date: Year 5

Action summary Table

Action	Year 1	Year 2	Year 3	Year 4	Year 5
Develop, implement Monitoring Plan	tbd	tbd	tbd	tbd	tbd
Monitor surface input of water-borne food sources	tbd	tbd	tbd	tbd	tbd
Liaise with stakeholders	5,000	5,000	5,000	5,000	5,000
Amalgamate and manage monitoring data, develop hydrological model				tbd	
Resolve buffer area required		10,000			
Continue to seek to reserve Camerons Cave	5,000	5,000	5,000	5,000	5,000
Review requirement for management actions such as fencing	tbd	tdb	tdb	tdb	tdb
Continue to liaise with stakeholders about land uses and threatening processes	2,000	2,000	2,000	2,000	2,000
Ensure land use planning, development control effectively protect	5,000	5,000	5,000	5,000	5,000
Survey further likely areas for additional occurrences	10,000	10,000	10,000	10,000	10,000
Report on success					25,000
TOTAL	**27,000**	**37,000**	**27,000**	**27,000**	**52,000**

Summary of costs over five years: in excess of $170,000. Additional costs to be determined.

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GLOSSARY

Allochthonous: originating from outside and transported into a system or area.

Doline: a shallow depression, either funnel- or saucer-shaped, and having its floor covered by cultivated soil, formed by solution in mountain karst.

Epigean: living or growing at or above the soil surface.

Epikarst: the upper surface of karst, consisting of a network of intersecting fissures and cavities that collect and transport surface water and nutrients underground. Depth of epikarst can range from a few centimetres to tens of metres.

Evapotranspiration: the combined effect of transpiration by plants and direct evaporation.

Gondwana: The southern supercontinent formed by the break up of Pangaea in the Mesozoic era.

Halocline: A salinity discontinuity; a zone of marked salinity gradient.

Hypogean: living or germinating underground.

Karst: Irregular limestone strata permeated by streams, typically with sinks, caves and other subterranean passages.

Laurasia: The northern supercontinent formed by the break up of Pangaea in the Mesozoic era.

Mesozoic: The geological time period occurring from about 240 million to 67 million years ago.

Pangaea: The single supercontinent comprising the present continental land masses joined together, which formed about 240 million years BP and began to break up about 150 million years BP.

Stygofauna: Any fauna that live within groundwater systems, such as caves and aquifers, or more specifically small, aquatic groundwater invertebrates.

Troglofauna: A fauna comprising troglobites.

Troglobite: Obligate subterranean species inhabiting air-filled voids. The term troglobite is sometimes used generally to encompass all hypogean fauna.

Troglomorphic: Morphological characters that are adaptions to living in the constant darkness of caves, such as loss of pigments and reduced eyes.