INTERIM RECOVERY PLAN NO. 53

Aquatic root mat communities numbers 1-4 of caves of the Leeuwin-Naturaliste Ridge

Interim Recovery Plan 2000-2003

by

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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

IRPs outline the recovery actions that are required to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

CALM is committed to ensuring that Critically Endangered ecological communities are conserved through the preparation and implementation of Recovery Plans or Interim Recovery Plans and by ensuring that conservation action commences as soon as possible and always within one year of endorsement of that rank by CALM's Director of Nature Conservation.

This Interim Recovery Plan will operate from 28 February 2000 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked Critically Endangered after three years, this IRP will be replaced by a full Recovery Plan.

The provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting CALM, as well as the need to address other priorities.

Information in this IRP was accurate at February 2000.

SUMMARY

Name: Aquatic root mat communities numbers 1-4 of caves of the Leeuwin-Naturaliste Ridge

Description: On the Leeuwin-Naturaliste Ridge, and at Yanchep, permanent streams occur below the surface and support dense root mats. The root mats, which provide a constant and abundant primary food source, sustain some of the richest faunal communities known from groundwater in caves anywhere in the world. The communities comprise a complete food web; the rootlets and their associated microflora provide the primary food source, and root mat grazers, predators, parasites, detritivores, and scavengers complete the interactions.

Following seven years of intensive searching on the Leeuwin-Naturaliste Ridge, four caves have been located that contain aquatic root mat communities. Each of these caves is considered to contain a distinct community as the species composition differs significantly. Root mats are produced by karri (*Eucalyptus diversicolor*) in Easter Cave and Strongs Cave, marri (*Corymbia calophylla*) in Calgardup Cave and karri and peppermint (*Agonis flexuosa*) in Kudjal Yolgah Cave.

Aquatic cavernicoles (cave animals) in Leeuwin-Naturaliste caves include koonacs (*Cherax preissii*), mites, rotifers, microscopic worms, tardigrades, insects and crustaceans. Some of the species appear to be endemic to these cave streams, and some are confined to a single cave.

A total of 37 species of fauna (excluding nematodes and rotifers for which the individual species have not yet been identified) have been located in the four caves that contain root mat communities. At least half of these are newly discovered. Furthermore, at least three amphipods (marked # in Table 1 and Appendix 1) and the syncarid crustaceans that occur in the communities are relicts from when Australia was part of the supercontinent of Gondwana, or even the earlier Pangaean period.

The community occurring in caves at Yanchep is considered to be different from the four communities on the Leeuwin-Naturaliste Ridge as the species composition differs significantly. The Yanchep cave community is the subject of a separate Interim Recovery Plan (IRP).

CALM Region(s): Central Forest Region

CALM District(s): South West Capes District

Shire(s): Shire of Augusta-Margaret River

Recovery Team: To be appointed. Membership is proposed to consist of representatives of CALM (WATSCU, Central Forest Region), Waters and Rivers Commission, Western Australian Speleology Group, Augusta-Margaret River Tourist Bureau, the Museum of Western Australia and scientists with knowledge of the cave communities. The Recovery Team will report annually to CALM's Corporate Executive.

Current status: All four cave communities assessed 18 April 1996 as Critically Endangered.

Habitat requirements: The cave streams that contain root mat communities flow at the base of a layer of Tamala limestone and are within 20 km of the coastline. Cave streams form part of a westward flowing drainage system and are either of groundwater origin or, particularly in the case of temporary streams, a continuation of surface creeks that flow into the karst (Jasinska 1997). To support these communities, permanent streams need to occur in caves that are sufficiently warm, and shallow enough for tree roots to reach the water.

The roots from living trees occur in the waters of these cave streams and are able to survive due to the permanent water supply. The rootlets contain extensive growths of microscopic fungi within their tissues that probably increase the nutritional value of the mats. The root mats or their detritus house more than 50 percent of the animals that occur in any one cave stream. The remainder occurs in open water, and in the soils in the stream-bed. None of the Gondwanic relicts that occur in the caves appear to have drought resistant stages. This indicates that they are entirely dependent on permanent water for survival.

IRP Objective(s): To maintain or improve the overall condition of the aquatic root mat communities of caves of the Leeuwin-Naturaliste Ridge and reduce the level of threat, with the aim of reclassifying them from Critically Endangered to Endangered.

Criteria for success:

1. A better understanding of the extent of occurrences of these threatened ecological communities.

2. An increase in the area of these communities under conservation management.
3. An increase in area of catchments of the cave streams managed in a manner that is likely to be consistent with the water requirements of the communities.
4. A better understanding of the factors influencing the stream flow and levels and their careful management.
5. Maintenance in terms of diversity and basic composition of species in the aquatic root mat assemblages (as described in Jasinska 1997) as well as hydrological and biological processes, taking account of natural change of the communities over time.
6. A better understanding of the effects of potential pollutants of groundwater streams (fertilisers, herbicides, pesticides) on the aquatic cavernicoles.
7. Improvement in terms of reduction of threatening processes as defined in this document.

Criterion for failure: Significant loss of area or major modification of one or more of the threatened ecological communities, including the drying up of the streams in any single cave, or loss of individual fauna species that are endemic to these caves.

Summary of Recovery Actions:

1. Establish Recovery Team	13. Manage fire regimes around trees with roots in caves
2. Clarify and monitor extent and condition	14. Develop regulations on cave management
3. Establish cave management committee	15. Remove cave locations from maps
4. Implement permit system for wild caves	16. Survey for additional occurrences
5. Restrict activities in Cave Protection Areas	17. Disseminate information
6. Monitor water levels in caves	18. Investigate water quality requirements
7.Investigate and map cave streams	19. Manage water quality in likely catchments
8. Liaise to manage water levels in likely catchments	20. Develop and implement a regeneration program for trees with roots in caves
9. Research relationship between groundwater abstracted and water-table levels	21. Develop walkways
10. Initiate short term management of cave stream levels if monitoring indicates the need	22. Report on management strategies
11. Ensure the planning process places controls on land-uses	23. Seek to acquire occurrences
12. Monitor and protect trees with roots in caves	

1. BACKGROUND

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

There are several areas of caves in the south west of Western Australia, from north to south; Arrowsmith River, Jurien Bay, Nambung River, Moore River, Yanchep, Mandurah, Yallingup, Margaret River and Augusta (Bastian 1964). The only caves that are known to contain aquatic root mat communities occur at Yanchep and in the Augusta - Margaret River area.

Most dark caves throughout the world are inhospitable places for fauna to live permanently mainly due to the lack of a reliable source of nutrients. Cave waters are generally too deep to be reached by tree roots, or the cave conditions are unsuitable for the growth of aquatic roots; for example, high humidity in caves provides better conditions for growth of aerial roots only.

The caves that contain root mat communities in the Augusta - Margaret River area occur on a geological formation known as the Leeuwin-Naturaliste Ridge. The caves occur within 20 km of the coastline on a Tamala (coastal) Limestone ridge that rises to 220 m above sea level (Jasinska 1997).

Cave streams that feed the root mats flow through each of the caves. These streams flow at the base of the limestone, sometimes directly over the Precambrian rocks but, more frequently, over a sandy or lateritic layer. The cave streams form part of a westward flowing drainage system and are either of groundwater origin or, especially in the case of temporary streams, are a continuation of surface creeks that flow into the karst (Jasinska 1997).

The limestone formations in which the Leeuwin-Naturaliste caves occur are much thicker and deeper than those at Yanchep, in places being up to 150 m thick (Jasinska 1997). The larger caves on the Leeuwin-Naturaliste Ridge probably occur due to a combination of the presence of this thicker limestone and the greater calcification of the aeolian calcarenite as a result of the wetter climate (Jasinska 1997). Many of the caves on the Leeuwin-Naturaliste Ridge have developed along the subterranean water-courses (Jasinska,1997).

On the Leeuwin-Naturaliste Ridge the root mat communities occur in Calgardup, Easter, Kudjal Yolgah, and Strongs caves (see Figure 1). A variety of tree species extend roots into these four caves. Easter and Strongs caves contain the roots of karri (*Eucalyptus diversicolor*), whereas Calgardup cave contains marri roots (*Corymbia calophylla*), and the roots of karri and peppermint (*Agonis flexuosa*) occur in Kudjal Yolgah.

Based on their physicochemistry, the groundwaters of the four caves appear to originate from different sources, with the possible exception of Strongs and Kudjal Yolgah which have similar water chemistry but, nevertheless, very different faunas. The caves that contain root mats are between 5.5 and 25 kilometres apart. The species present vary greatly in composition and abundance from cave to cave (refer Table 1, Appendices 1 and 2). Table 1 below indicates that only seven of the 39 faunal species recorded from the four caves are common to two or more caves. Table 2 shows the variation in water chemistry between the caves. There are some significant differences between levels of major ions, total ionic concentrations, electrical conductivity, temperature and pH of the water between caves. Consequently, for the purpose of this Interim Recovery Plan, the four caves are considered to contain four distinct communities.

Table 1: Species collected from the four caves containing root mats on the Leeuwin-Naturaliste Ridge: listed from species restricted to one cave, to those found at all sites (from Jasinska 1997)

TAXON	Calgardup Cave	Easter Cave	Kudjal Yolgah Cave	Strongs Cave	Total occur
Soldanellonyx sp. ?2 (eyeless)	1				**1**
Oribatida sp. 4	1				**1**
Oribatida sp. 5*	1				**1**
Paracyclops sp. 1	1				**1**
Cherax preissii (Erichson)	1				**1**
Chironomus aff. alternans Walker	1				**1**
Polypedilum sp. (?V3)	1				**1**
Harpacticoida sp. 3	1				**1**
Harpacticoida sp. 4	1				**1**
?Acanthocyclops sp. 1		1			**1**
Paramelitidae (gen. nov.) sp. nov. 2 #		1			**1**
Candona sp. 3		1			**1**
Perthia aff. acutitelson Straskraba #		1			**1**
Paracyclops sp. ? (not sp. 1)		1			**1**
Helodidae sp. 1			1		**1**
Enchytraeidae sp. 5			1		**1**
Phreodrillidae sp. 3			1		**1**
Eutardigrada sp. 1			1		**1**
Microcyclops sp.1			1		**1**
Harpacticoida sp. 5			1		**1**
Harpacticoida sp. 6			1		**1**
Oniscoida sp. 1*			1		**1**
Bathynellacea (gen. nov.) sp. nov. 1 # *			1		**1**
Alloeocoela sp. 1			1		**1**
Catenula sp. 1			1		**1**
Catenula sp. 2				1	**1**
Enchytraeidae sp. 4				1	**1**
*Stenostomum sp. ? **				1	**1**
Macrostomum sp. 4				1	**1**
Soldanellonyx sp. nov. 1				1	**1**
Rotifera spp.	1			1	**2**
Stenostomum sp. 3	1		1		**2**
Oribatida sp. 6 (eyeless)			1	1*	**2**
Insulodrilus campbellianus Benham	?	?		1	**3**
Perthia acutitelson Straskraba #	1	1		1	**3**
Parastenocaris sp. 2		1	1	1	**3**
Nematoda spp.	1	1	1	1	**4**

Total occur = total number of sites
Rare species (less than four individuals in total collected) are marked with an asterisk.
= Gondwanan relicts

Table 2: Comparison of the general physicochemistry of the Leeuwin-Naturaliste caves during the period 1992-1996 (from Jasinska 1997)

Cave	Relative concentrations of major cations (%)	Total concentration of major cations (mg/L)	Range in electrical conductivity at 25 °C (µS/cm)	Water temp (ºC)	pH
Calgardup Cave (WI 49)	Na (74)>Ca (16)>Mg (9)>K (1)	153.9	700 - 1120	14.0	5.3
Easter Cave (AU 14)	Na (73)>Ca (19)>Mg (6)>K (2)	632.2	2500 - 2750	16.5	7.2
Kudjal Yolgah (WI 9)	Ca (50)>Na (42)>Mg (7)>K (1)	141.4	455 - 700	15.6	6.9
Strongs Cave (WI 63)	Na (50)>Ca (44)>Mg (5)>K (1)	158.9	640 - 650	15.5	6.8

By contrast, the caves that contain root mats at Yanchep are fed by the same groundwater mound, are between a few hundred metres and three kilometres apart, have greater similarities in species composition, and are all considered to contain the same community. The caves on the Leeuwin-Naturaliste Ridge occur at depths between 10 and 35 metres below the surface and are larger and generally deeper than those at Yanchep, which are only around ten metres below the surface.

The presence of tree roots that form thick mats in the four caves on the Leeuwin-Naturaliste Ridge provides a constant and reliable primary food source, as well as a complex habitat, and allows a complete and intricate ecosystem to exist. Microscopic fungi grow within the tissues of the rootlets and may increase the nutritional value of the mats (Jasinska *et al*. 1996).

The fauna of the caves that contain root mats on the Leeuwin-Naturaliste Ridge (and at Yanchep) is unusual in that there is high species diversity and abundance (Jasinska 1997). Some of the fauna are endemic to these cave streams and some are confined to a single cave. The four Leeuwin-Naturaliste caves each contain between 9 and 14 species of animal (individual species of nematodes and rotifers have not been identified and each of these two groups is treated as one species). Three to six species tend to be the norm for caves that lack root mats, but are otherwise similar, elsewhere in the world (Jasinska *et al*. 1996).

In the Leeuwin-Naturaliste caves, the root mat faunas consist entirely of invertebrates, of which a total of 37 species have been identified and at least half of these are newly discovered. Aquatic cavernicoles (cave animals) in Leeuwin-Naturaliste caves include koonacs (*Cherax preissii*), mites, rotifers, microscopic worms, tardigrades, insects and crustaceans.

At least the three amphipods (marked # in Table 1 and Appendix 1) that occur in the communities are relicts from when Australia was part of the supercontinent of Gondwana about 350 to 100 million years ago. Furthermore, the newly discovered syncarid crustacean (also marked #) may even have its origins in the earlier Pangaea period.

Northcote Grotto at Yallingup may have contained a similar community (refer Appendix 1 for fauna list), but the stream has been severely degraded by misuse through various forms of pollution including dumped car batteries. It is possible that others also may have existed and have dried up, or may occur in caves that are inaccessible (E. Jasinska[1], personal communication). However, as far as is known, each of these four communities occur only in one cave each and are under threat from the processes discussed in section 1.5 below.

A Management Plan is in place for Leeuwin-Naturaliste National Park (CALM 1989). The status of the recommended management actions that may benefit conservation of the aquatic root mat communities for each of these areas is listed under recovery actions in this IRP (refer section 3).

Two of the caves that contain aquatic root mat communities on the Leeuwin-Naturaliste Ridge are not within Leeuwin-Naturaliste National Park and are not subject to the Management Plan. Strongs Cave was vested in the Western Australian Museum so that it could be managed for archaeological purposes, however, the Museum no longer has responsibility for archaeological matters and this cave has now been locked to restrict access, with the

[1] Edyta Jasinska, formerly Zoology Department, University of Western Australia, Mounts Bay Rd, Nedlands, 6009

key held by CALM. The care, control and management of Easter Cave are placed in the Augusta-Margaret River Tourist Bureau and access to this cave is controlled.

The chamber containing the aquatic root mat community in Calgardup cave is locked. Much of this cave contains lighting as an aid to access, however, lighting has not been installed in the chamber that contains root mats and cavers use their own lighting whilst in this area.

1.2 Extent and location of occurrences

Community - aquatic root mat community number 1 of caves of the Leeuwin-Naturaliste Ridge

Occurrence Number	Location	Estimated area
1	Easter Cave, reserve 8438	Approximately 10 m^2

The entrance of Easter Cave is in Sussex Location 4174 (for which care, control and management are placed in the Augusta-Margaret River Tourist Bureau) within Class A Reserve 8438, (most of which is vested in the National Parks and Nature Conservation Authority) with the purpose "Protection and Preservation of Caves and Flora and for Health and Pleasure Resort". The cave itself lies underneath Reserve 8438 (Cliff Spackman Reserve), which is part of Leeuwin-Naturaliste National Park.

Community - aquatic root mat community number 2 of caves of the Leeuwin-Naturaliste Ridge

Occurrence Number	Location	Estimated area
1	Strongs Cave, Reserve 8437	Approximately 10 M^2

Strongs Cave is located in Class A Reserve 8437, which is vested in the Western Australian Museum for the purpose of "Protection and Preservation of Caves and Flora and for Pleasure Resort".

Community - aquatic root mat community number 3 of caves of the Leeuwin-Naturaliste Ridge

Occurrence Number	Location	Estimated area
1	Kudjal Yolgah, reserve 8434	Approximately 10 M^2

Community - aquatic root mat community number 4 of caves of the Leeuwin-Naturaliste Ridge

Occurrence Number	Location	Estimated area
1	Calgardup cave, reserve 8434	Approximately 10 M^2

Kudjal Yolgah and Calgardup caves are located in Class A Reserve 8434 - Leeuwin-Naturaliste National Park. The park is vested in the National Parks and Nature Conservation Authority for the purpose of "Protection and Preservation of Caves and Flora and for Health and Pleasure Resort".

1.3 Biology and ecology

The primary food source for the aquatic root mat communities is the roots of mature trees that extend into the caves, and probably the extensive fungal growth within the tissue of the rootlets (Jasinska *et al*. 1996). The soil above the caves contains little water and growth of tree roots into the caves is promoted by the availability of permanent water in the cave streams.

The root mat communities consist of the primary food source, grazers, predators, parasites, detritivores, and scavengers (Jasinska 1995; Jasinska 1997). Appendix 1 provides a list of the fauna collected from root mat communities from the Leeuwin-Naturaliste Ridge (from Jasinska 1997). The density of these fauna is listed at Appendix 2 (from Jasinska 1997).

1.4 Hydrology

The tree roots that are the basis of the food web in these aquatic root mat communities only occur in the caves as a result of the availability of permanent fresh water in cave streams. These ecosystems appear to be totally dependent on a supply of water of sufficient quantity and quality to sustain them.

Water depth and flow may be critical in controlling diffusion rates of microbial and animal wastes out of the root mats and the levels of nutrients and dissolved gases within them (Jasinska 1995). Diffusion of these substances would be aided by fast flows through the root mats. Faster flows may, however, erode and corrode stream banks, change the course of the stream, and/or damage root mats (Jasinska 1995). Ultimately, increased flow may result in cave collapse. Lower flows may impede transfer of nutrients, allow increased deposition of sediments and also displace streams from their course (Jasinska 1995).

The caves that contain the root mat communities occur on gneiss granites of the Leeuwin-Naturaliste Ridge. The Dunsborough Fault Line separates the ridge from the sedimentary sands that contain fresh groundwater aquifers in the Vasse Shelf to the east. The Busselton Fault occurs on the eastern edge of the Vasse Shelf, and separates this shelf from the Bunbury Trough. The Trough also contains significant amounts of fresh groundwater in shallow aquifers. The regional direction of flow of this groundwater is north-south, with the town of Karridale being at the divide of the north-south flow (A. Davidson[2] personal communication).

There is no sedimentary rock underlying the caves, consequently there are no large aquifers in the area, and there is little groundwater on the ridge. The regional flow of water is probably east to west in the area of the caves on the Leeuwin-Naturaliste Ridge.

Karst drainage is often very complex, and can flow under and cross surface divides and emerge in a surface catchment different to the one under which it originated (Gillieson 1996). Therefore, groundwater held in the sediments to the east of the Leeuwin-Naturaliste Ridge may be connected to cave streams. This is possibly the case in Kudjal Yolgah and Strongs caves, where groundwaters may flow under the limestone ridge, 30 to 110 metres below the surface (E. Jasinska personal communication).

Pools in Easter Cave probably occur where the cave floor dips below the surface of the local water table (Jasinska 1997; refer also Section 1.4.2). Such pockets of water may be connected to solution channels. If this is the case then any factors affecting the upstream sections will impact the cave.

These cave streams, some of which are several metres deep, are much deeper than streams that support root mats at Yanchep. The decline in the stream levels, as noted by Jasinska (1997), has generally been proportionally significant, however, as described in section 1.5.

The observed decline in the ground water in this area is likely to be partly a consequence of lower rainfall, which has been decreasing since 1976 (Greay 1993). Additional impacts on water levels may be caused by abstraction or increased use (eg. by plantations) in areas of the Leeuwin-Naturaliste Ridge itself where upstream areas are linked, possibly by solution channels, to the caves. It is also possible that abstraction of groundwater from sediments to the east of the ridge may be impacting cave stream levels, if such areas form part of the catchments for cave streams. This is discussed further under threatening processes in Section 1.5.

1.4.1 Water Chemistry and Physical Characteristics

Jasinska (1997) examined specific cave stream parameters (temperature, pH, conductivity, calcium, potassium, magnesium, sodium, chloride and dissolved oxygen) from water samples taken from near root mats within each of the four caves. Two sites were sampled within Kudjal Yolgah cave ('Kudjal Yolgah-deep' and 'Kudjal Yolgah-shallow'). These data help indicate origins of cave streams, as discussed below (from Jasinska 1997).

The only caves on the Leeuwin-Naturaliste Ridge that were found to have similar water chemistry are Kudjal Yolgah-deep and Strongs Caves. The streams in these caves may therefore be fed by the same aquifer, or the waters may flow through the same geological structure. The waters of Kudjal Yolgah-deep were also found to resemble that of cave streams at Yanchep, except that the temperature was lower.

Distinct water chemistry and separation by distance indicate the water source for Easter cave is unlikely to be common to any other cave. Stability of pH and temperature, and lack of colour indicate this cave is fed by groundwater and this stream is believed to dip below the surface of the local water-table.

Waters in Kudjal Yolgah Cave originate as active underground springs a short distance upstream of the sampling site. Strongs Cave is also fed by active groundwater springs or seepages, but the source is believed to be a considerable distance upstream of the sampling site, and without notable input from other sources along the conduit.

[2] Angus Davidson, Water and Rivers Commission, 3 Plain Street, Perth, WA, 6004

The tannin colour of waters in Calgardup Cave indicates that it is fed by a temporary surface stream. In keeping with surface water sources, the water levels, temperature and pH also undergo seasonal fluctuations in this cave.

The most stable water levels and physicochemistry are found in cave steams fed by nearby underground springs, and the least stable in caves fed by seasonal surface streams.

1.5 Threatening Processes

1.5.1 Historical and current threatening processes

The aquatic root mat communities of caves in the Leeuwin-Naturaliste area have been subject to historical disturbance and are likely to be subject to future threats. The immediate threats are as follows:

- decline of the level of the water-table
- destruction of the food source (the tree roots)
- misuse, accidental damage to the root mats.

Longer term threats include the following:

- pollution of groundwater
- cave collapse
- invasion of exotic species.

- **Decline of the Groundwater Table**

Alterations to the levels of streams in the caves on the Leeuwin-Naturaliste Ridge that contain root mats have the potential to destroy the communities. Increased flow has been noted to cause diversion of the course of streams, increased sedimentation, scouring of the banks and may ultimately cause cave collapse. Alternatively, a decline in the level of the water, as seems to be occurring currently, may cause the cave streams to dry out. This would have disastrous consequences for communities containing species that have no dormant stages and that could not survive drying.

The depth of cave streams that contain root mat communities on the Leeuwin-Naturaliste Ridge is much greater than those in caves containing root mat communities at Yanchep. However, some large falls have been noted in the level of the cave streams that supply water to these root mat communities (E. Jasinska personal communication). Only sparse monitoring data are available for caves in this area, mostly from observations made by speleologists visiting the caves.

The level in Easter Cave fell by 1.5 m during the 1970s (Jasinska 1997; Western Australian Speleologists' Group (WASG) data). The water level in this cave was at an all time low when surveyed in 1995. There have also been great seasonal fluctuations and a progressive drop in levels in Strongs Cave since 1991 (Jasinska 1997; WASG, Speleological Research Group (SRG) data). This may be partly due to water usage by plantations to the east of this cave (E. Jasinska personal communication). Observations in 1995 by Jasinska (1997) indicated parts of that cave stream were completely dry and that the steam was not flowing. The shallow water section of Kudjal Yolgah was also predominantly dry at the same time. The levels of the deep section of Kudjal Yolgah did not change over the period of the Jasinska (1997) study - 1991 to 1995. Large seasonal fluctuations were, however, noted for Calgardup Cave stream during this time.

Jasinska (1997) indicates that all of the caves that contain root mats would have contained permanent waters prior to 1996. However, in 1996, most of Strongs, Kudjal Yolgah-shallow streams and one of the Yanchep caves (Gilgie cave) dried up for the first time since recordings began (Jasinska 1997) (recordings for Easter Cave have been made since 1965 - WASG and SRG data; Jasinska 1997). The presence in the Leeuwin-Naturaliste caves of species that cannot survive drying indicates that the regime in these caves over evolutionary time has allowed the long-term survival of these species; that is, drying out of the caves has apparently not occurred previously. However, periods of climate drier than that currently being experienced have occurred previously in evolutionary time, suggesting that human activity, such as abstraction of water for human uses or increased usage by plantation trees, is a major factor in the recent drying of the caves (Jasinska 1997).

Little is known of the hydrology of these cave streams, and specifically, the catchment areas for the caves are not known. Abstraction of water from areas up-gradient of cave streams has the potential to impact the caves. Such up-

gradient areas are most likely to occur on the Leeuwin-Naturaliste Ridge, but may also occur in sediments to the east of the caves.

The Leeuwin-Naturaliste Planning Policy (Ministry for Planning 1998) contains recommendations on management of water quality and quantity through land use planning. Information on the catchment areas is vital to understanding and managing the flow to the cave streams.

- **Destruction of the Tree Roots**

Another immediate threat to the root mat communities is destruction of the primary food source. All of the tree species that have roots in cave streams (karri, marri and peppermint) may be destroyed by clearing, or killed by frequent or very hot fires, or by a variety of pathogens. It is therefore important to locate, monitor and protect the trees that have roots in each of the four caves. Fires of sufficient intensity or frequency to kill these trees should be avoided or prevented. The potential pests and pathogens of each of these tree species need to be investigated. It may be necessary to implement a regeneration program if monitoring indicates trees with roots in cave streams are in decline as a result of human influences.

- **Misuse, accidental damage to the root mats**

Vandalism by direct physical destruction can also destroy the root mat communities. At least one ex-tourist cave that may have contained a root mat community has been vandalised through pollution of the cave stream with wiring, batteries, and drink containers and it possibly receives subterranean drainage from a waste disposal site nearby and upstream of the cave (Jasinska 1997). This type of vandalism may be avoided by keeping the location of the caves confidential as far as possible; and through an education program that provides information about the significance of cave stream communities and how to avoid adversely impacting them.

Access to all of the caves on the Leeuwin-Naturaliste Ridge that contain root mats is already controlled to some extent and this helps to prevent physical damage to the communities. Locking each of the caves and allowing entry only by permit and with experienced guides may be necessary to ensure future protection of root mat communities in caves. A walkway (made from limestone boulders) through the muddy root mat chamber would help to protect root mats in Kudjal Yolgah Cave (E. Jasinska personal communication).

- **Pollution of Groundwater**

Longer-term threats to these communities include pollution of the groundwater. Water quality can have significant influence on the taxa present and their growth and survival (Trayler and Davis 1996; Cairns *et al*. 1993).

The pattern and management of future land developments, particularly in specific areas of the ridge itself, and possibly on sediments to the east that may form part of the catchments for the caves, are likely to be crucial in maintaining the water quality in the cave streams.

Long term planning is required to ensure waters entering caves are not polluted with fertilisers, fungicides or pesticides used in agricultural production, by runoff from urban uses, or by waters carrying pollutants from land-uses such as rubbish tips or industrial areas. As mentioned elsewhere, the Leeuwin-Naturaliste Planning Policy contains recommendations on managing water quality and water levels in the area through land use policy.

The caves on the Leeuwin-Naturaliste Ridge are all protected within reserves with purposes that include protection of caves. There are, however, agricultural lands within two kilometres east of both Calgardup and Kudjal Yolgah Caves. Activities on nearby land, especially to the east, may influence the hydrology of these two caves. Boranup forest, a part of the Leeuwin-Naturaliste National Park, is located about 200 metres east of Strongs Cave. The strip of forest at this point is about two kilometres wide, with privately owned agricultural lands on the eastern edge of the forest. Agricultural lands also occur about 1.5 kilometres east of Easter Cave. Although the general direction of flow in the area is east to west, given the intricate nature of karst hydrology it is possible that land in other directions from caves will also influence cave streams.

Activities such as agriculture, large tourist developments such as caravan parks and hotels that produce substantial amounts of effluent and require large quantities of water already occur near caves that contain root mats on the Leeuwin-Naturaliste Ridge, and these types of development could be expected to expand in future. The Western Australian Water Corporation also abstracts water from springs on the ridge itself for town water supplies. Long term planning and liaison with landholders and water managers are therefore required to ensure developments do not impact the cave streams.

- **Cave Collapse**

Cave collapse presents another longer-term threat to the root mat ecosystems. The main natural cause of cave collapse is natural weathering of limestone. This obviously cannot be avoided but the rate of weathering can be influenced by human activities. Increased runoff could result in cave collapse from scouring of cave walls. Relatively small changes in flow rates can alter the path of streams. If water levels were to increase significantly, for example, due to land clearance in the catchment that increases groundwater recharge, then presumably rapid erosion and corrosion of stream banks could occur. In the extreme situation, this erosion may result in cave collapse.

Other possible causes of cave collapse may include heavy human or vehicular traffic over the caves and the use of explosives nearby. These impacts could be avoided by ensuring any tracks or commonly used walk trails do not occur above the caves, and by ensuring heavy machinery and explosives are not used near the caves. No further development should be permitted within or near the cave belt without due consideration for cave preservation.

- **Invasion of Exotic Species**

Introduced fauna such as Yabbies (*Cherax destructor*) may compete with or prey upon other fauna in the community, alter habitat and represent a threat to the root mat communities. Introduced crayfish have been recorded from caves at Stockyard Gully, Eneabba, and are thought to have had a significant impact on the cave fauna in that area (Jasinska *et al*. 1993).

1.6 Conservation Status

The aquatic root mat communities of caves of the Leeuwin-Naturaliste Ridge meet the following criteria for critically endangered communities (from English and Blyth 1997):

B (i) current distribution is limited, and currently subject to known threatening processes that are likely to result in total destruction in the immediate future (within approximately 5 years), and

B (ii) current distribution is limited and very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes.

1.7 Strategy for Recovery

Three strategies will be implemented:

- To identify and influence the management of the areas in which the community occurs, especially their catchments, so maintaining natural biological and non-biological attributes of the sites and the current area covered by the community.

- To maintain a hydrologic regime that provides permanent flow of water.

- To conduct appropriate research into the ecology and hydrology of the community to develop further understanding about the management actions required to maintain or improve the condition of the community.

2. RECOVERY OBJECTIVE AND CRITERIA

2.1 Objective

To maintain or improve the overall condition of the aquatic root mat communities of caves of the Leeuwin-Naturaliste Ridge and reduce the level of threat, with the aim of reclassifying them from Critically Endangered to Endangered.

2.2 Criteria

2.2.1 Criteria for success

1. A better understanding of the extent of occurrences of these threatened ecological communities.

2. An increase in the area of these communities under conservation management.

3. An increase in area of catchments of the cave streams managed in a manner that is likely to be consistent with the water requirements of the communities.

4. A better understanding of the factors influencing the stream flow and levels and their careful management.

5. Maintenance in terms of diversity and basic composition of species in the aquatic root mat assemblages (as described in Jasinska 1997) as well as hydrological and biological processes, taking account of natural change of the communities over time.

6. A better understanding of the effects of potential pollutants of groundwater streams (fertilisers, herbicides, pesticides) on the aquatic cavernicoles.

7. Improvement in terms of reduction of threatening processes as defined in this document.

2.2.2 Criterion for failure

Significant loss of area or major modification of the threatened ecological community, including the drying up of the streams in any single cave, or loss of individual faunal species endemic to one or more of the caves.

3 RECOVERY ACTIONS

Note: The responsible authority is frequently listed as the relevant CALM District. This refers largely to initiating and guiding actions. However, in general the relevant CALM District, in cooperation with the Recovery Team has the primary responsibility for securing funds for recovery actions.

3.1 Establish a Recovery Team

Responsibility: Western Australian Threatened Species and Communities Unit (WATSCU)
Cost: $0 (the small cost of attending meetings is expected to be met by members of the Recovery Team)
Completion date: Year 1.

3.2 Clarify and continue to monitor the extent and condition of the communities

The species composition, and water level and quality in streams that contain occurrences of the communities as described above and in the Appendices should be determined as soon as possible, and monitored at least every second year.

The composition and structure of the cave faunal communities is likely to be a good indicator of changes in water quality or quantity.

Monitoring would also indicate the presence of introduced fauna such as yabbies. Such animals may represent a threat to the community if introduced into the streams that contain root mats.

Photographic monitoring of the habitat at specific sites would provide a record of physical condition and possibly extent of the root mats. This should be included in the monitoring program.

Caving groups that regularly visit caves containing root mats may be interested in being involved in a monitoring program to measure water depths, take photographs and report on condition and extent of the root mat communities. Local CALM District staff will request such monitoring through the Cave Management Committee. A CALM Ranger should become familiar with all monitoring sites and techniques used.

Responsibility: CALM (South West Capes District); Water and Rivers Commission (WRC) (CALM to liaise with Cave Management Committee to achieve monitoring of water quality parameters)
Cost: $5,000 for one monitoring period for fauna survey, water analysis and reporting
Completion Date: Implementation begun, ongoing

3.3 Urgently implement management recommendations adapted from CALM (1989) as follows (3.3.1 - 3.3.7)

Recommendations in the Management Plan for Leeuwin-Naturaliste National Park refer only to caves within the park boundaries - Kudjal Yolgah and Calgardup caves. All of these recommendations should be applied to all caves that contain the root mat communities on the Leeuwin-Naturaliste Ridge.

3.3.1 Establish a Cave Management Committee to advise on cave management

A Cave Management Committee has been established that controls access to caves through a 'business plan' and a cave permit system.

Responsibility: CALM (South West Capes District)
Cost: $0
Completion date: Completed - the activities of the committee are ongoing.

3.3.2 Implement a permit system for entry to wild caves

Locking the caves and allowing entry only with experienced guides may be necessary to ensure protection of some or all of the cave communities. The community in Calgardup Cave is in a locked chamber and Strongs Cave is locked. The entrance to Kudjal Yolgah should be locked and the chamber that contains root mats in Calgardup Cave put into the restricted access category.

Responsibility: CALM (South West Capes District); Cave Management Committee
Cost: $1,500 (for gate on Kudjal Yolgah cave); $1,000 pa to administer permit system
Completion date: Gates completed, administration ongoing

3.3.3 Restrict use of heavy vehicles and other activities such as visitor traffic within Cave Protection Areas

Provide information through Fire Management Plans to groups likely to be using heavy equipment in Cave Protection Areas (in particular, CALMfire Fire Crews) to prevent physical impacts to the communities.

Responsibility: CALM (South West Capes District); Augusta-Margaret River Tourist Bureau; Western Australian Museum
Cost: Signs in caves $200
Completion date: Ongoing

3.3.4 Monitor water levels in caves to establish long term trends

Speleologists' clubs have historically monitored water levels in the caves. Many of the caves in the Leeuwin-Naturaliste National Park are now dry. Water level monitoring was undertaken opportunistically rather than systematically, and there is no report available. A data logger has recently been purchased by the Speleologists Research Group under a grant obtained through the Gordon Reid Foundation, and this will enable more systematic data collection (N. Taylor[3] personal communication).

The Speleologists Research Group may be open to suggestions for priority areas for monitoring if the significance of the communities is recognised.

Responsibility: CALM (South West Capes District); Cave Management Committee, Speleology groups and WRC
Cost: Materials (one data logger, three gauge boards) - $1,100; installation $1,200; data collection and computing $5,400 pa
Completion date: Completed, all four caves now being monitored regularly.

3.3.5 Investigate and map cave streams to determine direction of flow and connections between cave streams, and between surface hydrology (seeps and springs). Management of catchments should aim to retain the hydrological balance and the water quality

The specific catchments and source aquifers of each of the four caves should be identified.

[3] Neil Taylor, CALM South West Capes District, 14 Queen St, Busselton, WA 6280

The Centre for Groundwater Studies at The University of Western Australia has expressed interest in investigating the hydrogeology of the cave catchments (A. Endres[4], personal communication)

Maps indicating the location of caves that have water in them are now available (produced by B. Loveday), and these have been acquired by CALM's South West Capes District.

The technique of tracing rhodamine dyes to establish flow patterns should be tried, and if the technique is successful, it should be applied to all caves (J. Kite[5] personal communication).

Responsibility: CALM (South West Capes District); WRC in liaison with the Centre for Groundwater Studies
Cost: $10,000 for trial tracer experiments
Completion date: Year 2.

3.3.6 Develop specific regulations on cave management under the CALM Act, with legislation to be investigated in the longer term if necessary

Regulations are in draft form (D. Hampton[6] personal communication).

Responsibility: CALM (Corporate Executive); in liaison with South West Capes District
Cost: $0
Completion date: Year 2

3.3.7 Remove locations of all but self-guiding and tourist caves from published maps

Department of Land Administration (DOLA) maps still contain such locations, but they have been removed from other published maps.

Responsibility: CALM (South West Capes District); liaison with DOLA
Cost: Costs of liaison $300
Completion date: Implemented in part, to be completed when new maps are published by DOLA.

In addition to the implementation of the above general recommendations in the Management Plan for Leeuwin-Naturaliste National Park, the following specific recommendations relate to management of the communities.

3.4 Survey likely areas for additional occurrences of root mat communities, especially caves on private land in the Leeuwin Naturalist Ridge area

Additional root mat communities, or additional occurrences of communities already identified, that have not yet been located, may occur either in caves on public lands or in caves on private land. Data could be gathered opportunistically through liaison with caving groups (through the Cave Management Advisory Committee), and by requesting permission to survey for root mat communities in areas known, or likely to contain caves.

Any additional occurrences of root mat communities should then be subject to cooperative management actions as listed in this IRP, including assessment of any development proposals that may impact occurrences.

Responsibility: CALM (South West Capes District); in liaison with Cave Management Advisory Committee and landholders
Cost: $1,000 pa
Completion date: Ongoing

3.5 Disseminate information about the communities

To prevent accidental destruction or deliberate vandalism of the communities, and gain public support for their conservation it is recommended that information be disseminated about them.

[4] Anthony Endres, Centre for Groundwater Studies, University of Western Australia, Stirling Highway, Nedlands, 6009
[5] Jeff Kite, Water and Rivers Commission Commission, 3 Plain Street, Perth, WA, 6004
[6] David Hampton, Department of Conservation and Land Management, Locked bag 104, Bentley Delivery Centre, WA 6983

A publicity campaign targeting caving groups, utilising media including circulars in caving magazines and detailed signs about the community at the cave entrances should be undertaken to encourage awareness about this threatened ecological community.

Responsibility:	CALM (Corporate Relations Division, South West Capes District, WATSCU) responsible for general publicity; Cave Management Committee responsible for interpretive signs and any associated activities
Cost:	$2,000
Completion date:	Ongoing.

3.6 Liaise with all stakeholders to monitor and manage water levels in likely catchment areas for cave streams

Management practices around the caves may significantly influence water levels in the cave streams. Management strategies required include the management of public and private abstraction and other activities that may influence water levels or quality such as plantations, in the vicinity of the caves. Activities in State Forest, National Park, reserves for other purposes and agricultural areas (particularly to the east of those caves on the Leeuwin-Naturaliste Ridge that contain root mat communities) may impact cave stream hydrology. A management strategy should be included in the full Recovery Plan (RP) for the community, if a full RP is developed.

Responsibility:	CALM (South West Capes District) and WRC to liaise with land-owners and other authorities whose activities may influence hydrology of each of the areas
Cost:	Costs of all liaison $3,000
Completion date:	Ongoing

3.7 Undertake research to determine the relationship between volume of groundwater abstracted and the resulting fine-scale changes in water table gradients and levels measured progressively away from the extraction site (Jasinska 1995)

An understanding of the regional hydrology - the water levels driving cave streams and the interface of regional flows into the karst system - is necessary to understand the likely impacts of abstraction. A study of the volume of water abstracted may then help indicate the likely impacts of abstraction on cave streams. Linking piezometers into established bores would be significantly less expensive than establishing new bores.

Responsibility:	CALM (South West Capes District); WRC, in liaison with other individuals and authorities (see 3.6) whose activities may influence the community
Cost:	$10,000 (to initiate investigations)
Completion date:	Year 2

3.8 Initiate short term management solutions if monitoring of cave stream levels indicates the need

Water levels in cave pools can drop very rapidly in the drier months of the year. Emergency responses, such as those instituted at several Yanchep caves, may need to be initiated very quickly to ensure the survival of cave fauna that depend on water in pools. Weekly monitoring of pool levels over summer should be undertaken for streams at risk of complete drying out (under Action 3.3.4), and remedial actions such as deepening and lining of pools initiated when necessary, under the guidance of the Recovery Team. Pumping into cave streams from shallow bores in caves may provide a feasible alternative option to provide emergency water supplies to maintain cave fauna in the event of imminent drying of cave streams.

Responsibility:	CALM, (Leeuwin-Naturaliste National Park Rangers), the Augusta - Margaret River Tourist Association and the Museum; liaison with Cave Management Committee
Cost:	Likely cost of establishing bores to supply caves will be about $50,000; however, pumping within caves may be feasible at a much lower cost (actual costs will be determined if action is required)
Completion date:	As required.

3.9 Investigate water quality requirements of the root mat community

The levels of change of water quality that may constitute a threat to the root mat communities, and what factors may cause such levels of change are not known, and require investigation. Ecotoxicological testing would help elucidate likely impacts of pollutants such as pesticides, herbicides and fertilisers on the cave communities. Such techniques

are not currently available in Australia, but should become accessible in the near future (E. Jasinska, personal communication). The results of such investigations would help indicate strategies for managing water quality necessary to maintain the root mat communities (see 3.10). In the absence of detailed information it can be assumed that pesticides, herbicides and nutrients are likely to severely impact the community.

Responsibility: CALM (South West Capes District); WRC; (liaison necessary with Agriculture Western Australia and Zoology Department, The University of Western Australia)
Cost: To be determined
Completion date: To be determined.

3.10 Manage water quality in likely catchment areas for cave streams

The management strategy developed should be included in a full Recovery Plan for the community. The use of fertilisers, fungicides or pesticides used in agricultural production, runoff from urban uses, or waters carrying pollutants from land-uses such as rubbish tips or industrial areas may need to be managed in the cave catchments to protect water quality in the caves.

A cooperatively prepared Catchment Management Plan would be required to guide management of the catchment areas for the cave streams. Such a plan would help achieve water quality improvements through cooperative consultation.

Responsibility: CALM (South West Capes District); WRC; liaison with Ministry for Planning (MFP) and Agriculture Western Australia
Cost: $20,000 for plan preparation
Completion date: Ongoing.

3.11 Ensure the planning process places controls on land-uses that have the potential to impact the cave systems

Developments in the catchments and adjacent to caves have the potential to impact the caves through direct physical impacts such as cave collapse, or by indirect effects such as altering water quality or quantity in the caves. Operations that have potential to impact hydrology including urban development, irrigation projects, rubbish tips, and intensive farming should undergo impact assessment in these areas. All developments in the catchment or adjacent to the cave belt should be referred to the Department of Environmental Protection for assessment.

The Leeuwin-Naturaliste Planning Policy (Ministry for Planning 1998) contains recommendations on management of water quality and quantity through land use planning.

Responsibility: CALM (South West Capes District) (in liaison with WRC, Department of Environmental Protection (DEP), MFP, and Shire of Augusta Margaret River.)
Cost: Costs of liaison included in 3.6
Completion date: Ongoing

3.12 Determine the location of trees with roots in caves, and monitor and protect them

Trees likely to have roots in caves should be monitored every second year for detrimental parasitic diseases and infections, and their condition, size classes and density determined.

Responsibility: CALM (South West Capes District); Western Australian Museum; and Margaret River - Augusta Tourist Bureau
Cost: $1,200 every second year
Completion date: Ongoing.

3.13 Develop and implement a regeneration program for appropriate tree species in the area where trees have roots in caves if monitoring indicates the need

Responsibility: CALM (South West Capes District); Western Australian Museum; and Margaret River - Augusta Tourist Bureau
Cost: To be determined as necessary
Completion date: As necessary

3.14 Manage fire regimes in a buffer area around trees with roots in caves, to prevent fires of sufficient intensity to kill mature trees

A local CALM staff member should be present during wildfires and prescribed burns in remnants that contain occurrences of the community, to advise on protecting the conservation values of the community.

Responsibility: CALM (South West Capes District, CALMfire) (liaison needed with Western Australian Museum; and Margaret River - Augusta Tourist Bureau and with local Bush Fire Brigades)
Cost: $3,000 (every three years)
Completion date: Ongoing

3.15 Develop walkways where necessary, to protect the communities

A walkway (made from limestone boulders) through the muddy root mat chamber in Kudjal Yolgah cave would help to protect root mats (E. Jasinska, personal communication).

Responsibility: CALM (South West Capes District)
Cost: $1,000
Completion date: Year 1

Actions required for Aquatic root mat communities numbers 1 and 2 of caves of the Leeuwin-Naturaliste Ridge

3.16 Seek to acquire occurrences if the communities are not being successfully managed for conservation, or if areas that contain the caves become available

If effective management for conservation of caves containing root mat communities that are outside the Leeuwin-Naturaliste National Park seems unlikely under current land management arrangements (see 1.2 above), or if areas that contain caves become available, CALM will seek to negotiate a change of purpose and management of caves and buffers. Such areas should be amalgamated with adjacent class A reserves and vested in the NPNCA. Strongs Cave, in particular, should be included in the Leeuwin-Naturaliste National Park if it is not being adequately managed for conservation. CALM would then be responsible for implementing control of threatening processes on lands vested in the NPNCA, and for seeking planning arrangements to minimise threatening processes originating outside lands managed by CALM.

Responsibility: CALM (Park Policy and Tourism Section; South West Capes District;)
Cost: Cost of liaison included in 3.6
Completion date: As required

3.17 Report on success of management strategies for the four communities

Reporting should be part of annual reports prepared by the Recovery Team for CALM's Corporate Executive. A final report would be presented as part of, or complementary to, the full recovery plan for the community, if a full recovery plan is necessary.

Responsibility: CALM (South West Capes District; WATSCU); Recovery Team
Cost: $0
Completion date: Year 3

Table 3: Summary of recovery actions

Recovery Action	Community No.	Responsibility	Completion date
Establish Recovery Team	All	CALM (WATSCU)	Year 1
Clarify and monitor extent and condition	All	CALM (South West Capes District), WRC, Cave Management Committee	Ongoing
Establish cave management committee	All	CALM (South West Capes District)	Completed
Implement permit system for wild caves	3, 4	CALM (South West Capes District), Cave Management Committee	Year 1

Restrict activities in Cave Protection Areas	All	CALM (South West Capes District), WA Museum, Augusta-Margaret River Tourist Bureau	Ongoing
Monitor water levels in caves	All	CALM (South West Capes District); liaison with Cave Management Committee, Speleology Groups and WRC	Ongoing
Investigate and map cave streams	All	CALM (South West Capes District); WRC in liaison with the Centre for Groundwater Studies	Year 2
Liaise to manage water levels in likely catchments	All	CALM (South West Capes District), WRC, in liaison with relevant land owners and other authorities	Ongoing
Research relationship between groundwater abstracted and water-table levels	All	CALM (South West Capes District), WRC, in liaison with other individuals and authorities who may influence the community	Year 2
Initiate short term management of cave stream levels if monitoring indicates the need	All	CALM, (Leeuwin National Park Rangers), Augusta - Margaret River Tourist Association and the WA Museum; liaison with Cave Management Committee	Urgent response if action is required
Manage water quality in likely catchments	All	CALM (South West Capes District); WRC; liaison with MFP and Agriculture Western Australia	Ongoing
Ensure the planning process places controls on landuses	All	CALM (South West Capes District); liaison with WRC, DEP, MFP, Shire of Busselton	Ongoing
Monitor and protect trees with roots in caves	All	CALM (South West Capes District,); liaison with WA Museum and the Margaret River - Augusta Tourist Bureau	Ongoing
Manage fire regimes around trees with roots in caves	All	CALM (South West Capes District, CALMfire); liaison with WA Museum and the Margaret River - Augusta Tourist Bureau and local Bush Fire Brigades and Fire and Rescue Service	Ongoing
Develop regulations on cave management	All	CALM (Corporate Executive); in liaison with South West Capes District	Year 1
Remove cave locations from maps	All	CALM (South West Capes District); liaison with DOLA	To be completed when new maps are published by DOLA
Survey for additional occurrences	-	CALM (South West Capes District); in liaison with Cave Management Committee and landholders	Ongoing
Disseminate information	All	CALM (Corporate Relations Division, South West Capes District, WATSCU, Cave Advisory Committee	Ongoing
Investigate water quality requirements	All	CALM (South West Capes District), WRC, liaison with Agriculture Western Australia, UWA	To be determined
Implement a regeneration program for trees with roots in caves	All	CALM (South West Capes District), liaison with Western Australian Museum and the Margaret River - Augusta Tourist Bureau	As necessary
Develop walkways	3	CALM (South West Capes District)	Year 1
Report on management	All	CALM (South West Capes District,	Year 2

strategies		WATSCU), Recovery Team	
Seek to acquire occurrences	To be determined	CALM (Park Policy and Tourism Section; South West Capes District)	As required

Table 4: Summary of costs for each recovery action

Recovery Action	Year 1	Year 2	Year 3
Establish Recovery Team	-		
Clarify and monitor extent and condition	$5,000		$5,000
Establish cave management committee	-		
Implement permit system for wild caves	2,500	1,000	1,000
Restrict activities in Cave Protection Areas	200		
Monitor water levels in caves	7,700	5,400	5,400
Investigate and map cave streams	5,000	5,000	
Liaise to manage water levels in likely catchments	1,000	1,000	1,000
Research relationship between groundwater abstracted and water-table levels	5,000	5,000	
Initiate short term management of cave stream levels if monitoring indicates the need	To be determined if action required (cost up to $50,000)		
Ensure the planning process places controls on landuses	-		
Monitor and protect trees with roots in caves	1,200		1,200
Manage fire regimes around trees with roots in caves	3,000		
Develop regulations on cave management	-		
Remove cave locations from maps	300		
Survey for additional occurrences	1,000	1,000	1,000
Disseminate information	1,000	1,000	
Investigate water quality requirements	To be determined		
Manage water quality in likely catchments	10,000	10,000	
Develop and implement a regeneration program for trees with roots in caves	To be determined if action required		
Develop walkways	1,000		
Report on management strategies	-		
Seek to acquire occurrences	-		
Total	**$43,900**	**$29,400**	**$14,600**

Summary of costs over three years

Total $87,900 (doesn't include costs of short term management to maintain stream levels or costs of investigating water quality requirements, or regeneration program for trees)

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Neil Taylor	CALM, South West Capes District
Robert Klok	CALM Ranger, Leeuwin-Naturaliste National Park
Jeff Kite, Angus Davidson	Water and Rivers Commission, Perth
Peter Hanly	CALM, Bunbury
Lex Bastian	Caver

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APPENDIX 1
Fauna recorded in root mat communities in caves of the Leeuwin-Naturaliste Ridge (from Jasinska 1997)

TAXON	Calgardup Cave	Easter Cave	Kudjal Yolgah - deep	Kudjal Yolgah - shallow	Northcote Grotto	Strongs Cave	Total occur
ACARINA: Prostigmata							
HALACARIDA							
Soldanellonyx sp. nov. 1						1	**1**
Soldanellonyx sp. ?2 (eyeless)	1						**1**
ORIBATIDA							
Oribatida sp. 4	1						**1**
Oribatida sp. 5	1*						**1**
Oribatida sp. 6 (eyeless)			1	1		1*	**3**
ANNELIDA: Oligochaeta							
Enchytraeidae sp. 4						1	**1**
Enchytraeidae sp. 5				1			**1**
Phreodrillidae sp. 3			1	1			**2**
Insulodrilus campbellianus Benham	?	?				1	**3**
Tubificidae sp. 3					1		**1**
CRUSTACEA							
Amphipoda							
Paramelitidae (gen. nov.) sp. nov. 2 #		1					**1**
Perthia acutitelson Straskraba #	1	1				1	**3**
Perthia aff. acutitelson Straskraba #		1					**1**
Copepoda							
CYCLOPOIDA							
?Acanthocyclops sp. 1		1					**1**
Microcyclops sp.1			1	1			**2**
Paracyclops sp. 1	1						**1**
Paracyclops sp. ? (not sp. 1)		1					**1**
HARPACTICOIDA							
Parastenocaris sp. 2		1	1			1	**3**
Harpacticoida sp. 3	1						**1**
Harpacticoida sp. 4	1						**1**
Harpacticoida sp. 5				1			**1**
Harpacticoida sp. 6				1			**1**
Decapoda: PARASTACIDAE							
Cherax preissii (Erichson)	1						**1**
Isopoda							
Oniscoida sp. 1			1	1*			**2**
Ostracoda							
Candona sp. 3		1					**1**
Syncarida							
Bathynellacea (gen. nov.) sp. nov. 1 # *			1	1			**2**

APPENDIX 1 (continued)

TAXON	Calgardup Cave	Easter Cave	Kudjal Yolgah - deep	Kudjal Yolgah - shallow	Northcote Grotto	Strongs Cave	Total occur
INSECTA							
Coleoptera							
Helodidae sp. 1			1				**1**
Diptera: CHIRONOMIDAE (larvae)							
Chironomus aff. alternans Walker	1						**1**
Polypedilum sp. (?V3)	1						**1**
NEMATODA							
Rhabditidae sp. 1					1*		**1**
Nematoda spp.	1	1	1	1		1	**5**
PLATYHELMINTHES: Turbellaria							
ALLOEOCOELA							
Alloeocoela sp. 1			1	1			**2**
CATENULIDA							
Catenula sp. 1				1			**1**
Catenula sp. 2						1	**1**
Stenostomum sp. 3	1			1			**2**
Stenostomum sp. ?						1*	**1**
MACROSTOMIDA							
Macrostomum sp. 4						1	**1**
ROTIFERA							
Rotifera spp.	1					1	**2**
TARDIGRADA							
Eutardigrada sp. 1				1			**1**

Total occur = Total number of sites at which the species occurred.
Rare species (less than four individuals collected in total) are marked with an asterisk.

Gondwanan relicts

APPENDIX 2

Fauna Densities (number of animals per gram dry weight of root mats) in Leeuwin-Naturaliste caves (from Jasinska 1997)

Calgardup Cave 19 October 91	**animal density**	**Easter Cave (Tiffany's pool) 14 April 93**	**animal density**	**K. Y. - deep 19 October 91**	**animal density**	**K. Y. - shallow 19 October 91**	**animal density**	**Strongs Cave 20 October 91**	**animal density**
Oribatida sp. 4	11.9	*?Acanthocyclops sp. 1*	1.9	Oribatida sp. 6	35.8	Oribatida sp. 6	21.8	*Parastenocaris sp. 2*	10.0
Soldanellonyx sp. ?2	4.4	Paramelitidae sp. nov. 2	0.1	Oniscoida sp. 1	5.5	*Catenula sp. 1*	21.4	Nematoda spp.	6.3
Rotifera sp. 1	3.7	*Candona sp. 3*		Phreodrillidae sp. 3	3.4	Nematoda sp(?p)	20.0	*Soldanellonyx sp. nov. 1*	1.5
Paracyclops sp. 2	3.7	*Perthia aff. acutitelson*		Helodidae sp. 1	1.8	Bathynellaceae sp. nov. 1	17.6	*Catenula sp. 2*	
Rotifera sp. 2	3.0			Alloeocoela sp. 1	1.3	Eutardigrada sp. 1	12.5	Enchytraeidae sp. 4	
Nematoda sp(p).	2.2			*Microcyclops sp. 1*	0.3	Harpacticoida sp. 5	11.3	*Macrostomum sp. 4*	
Insulodrilus campbellianus	2.2			*Parastenocaris sp. 1*	0.3	Harpacticoida sp. 6	7.0	*Perthia acutitelson*	
Stenostomum sp. 3	1.9			Bathynellaceae sp. nov. 1	0.3	Enchytraeidae sp. 5	5.7	Rotifera spp.	
Chironomus aff. alternans	0.7			Nematoda sp(?p).	0.3	Alloeocoela sp. 1	5.3		
Polypedilum sp. (?V3)	0.7					Phreodrillidae sp. 3	4.9		
Harpacticoida sp. 3	0.4					Microcyclops sp. 1	2.1		
Total animal density	**35**	**Total animal density**	**2**	**Total animal density**	**49**	**Total animal density**	**130**	**Total animal density**	**18**

GLOSSARY

Aeolian: brought in by the wind

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

Macro-invertebrates: any animal without a backbone that is large enough to be seen with the naked eye

Palaeozoic: the geological time period between 600 million and 375 million years ago.

Pangaea: an ancient landmass that is thought to have split up at the end of the Palaeozoic era, into the continents of Gondwana and Laurasia

Precambrian: the period from 4 500 to 570 million years ago