Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Nomination

Current conservation status	
Name of ecological community:	Aquatic Root Mat Community Number 1 of Caves of the Swan Coastal Plain
Other names:	Yanchep Caves
Description:	The community occurs in caves at sites that include Yanchep National Park and surrounds. It comprises root mats of *Eucalyptus gomphocephala* (tuart) supported by groundwater fed streams and pools that occur in the caves. The root mats support a highly diverse and distinctive assemblage of cave fauna including the critically endangered Crystal Cave *Crangonyctoid Hurleya* sp. (amphipod).
Nomination for:	Listing ☒ Change of status ☐ Delisting ☐

1. *Is the ecological community currently on any conservation list, either in a State or Territory, Australia or Internationally?* 2. *Is it present in an Australian jurisdiction, but not listed?*	*Provide details of the occurrence and listing status for each jurisdiction in the following table*

Jurisdiction	**List or Act name**	**Date listed or assessed (or N/A)**	**Listing category eg. critically endangered (or none)**	**Listing criteria eg. B1ab(iii)+2ab(iii) (or none)**
National	EPBC Act	16/07/2000	EN	
Western Australia	TEC list: WA Minister ESA list in policy	6/11/2001	Critically Endangered	CR B) i) CR B) ii)
	Priority list		1 ☐ 2 ☐ 3 ☐ 4 ☐	
Other State/Territory				

Nominated conservation status: category and criteria (include recommended status for deleted ecological communities)

Critically endangered (CR) ☒ Endangered (EN) ☐ Vulnerable (VU) ☐ Collapsed (CO) ☐

Priority 1 ☐ Priority 2 ☐ Priority 3 ☐ Priority 4 ☐ None ☐

<table>
<tr><td>What criteria support the conservation status category for listing as a threatened ecological community or collapsed ecological community?
Refer to Section 32 of the Biodiversity Act 2016 for definition of ‘Collapsed’, and Appendix 3 table ‘IUCN Red List Criteria for ecosystems version 2.2’.</td><td colspan="2">CR A1, A2b, A3; B1a(i),(ii),b,c; B2a(i),(ii),b,c; C1, C2b, C3</td></tr>
<tr><td colspan="3">Eligibility against the criteria</td></tr>
<tr><td colspan="3">Provide justification for the nominated conservation status; is the ecological community eligible or ineligible for listing against the five criteria. For <u>delisting</u>, provide details for why the ecological community no longer meets the requirements of the current conservation status.</td></tr>
<tr><td>A.</td><td>Reduction in geographic distribution
(evidence of decline)</td><td>☒ A1
☐ A2a
☒ A2b
☒ A3</td></tr>
<tr><td></td><td>Justification of assessment under Criterion A.</td><td>For criteria A and B, the ecosystem was assumed to collapse when the mapped distribution declines to zero.
• The root systems of this community are heavily dependent on the groundwater fed streams and pools habitats. Most of the community’s accessible expressions of root mats have dried up, however, there are possibilities of root mats occurring within deeper and inaccessible channels of the cave.
• In the early to mid-1990s shallow pools supported the growth of root mat assemblages within the 7 caves. Root mats now cover a small fraction of their original area. This is attributed to the rapid decline of the groundwater over the past 20 and more years (Knott et al. 2008). By 1998, water levels in several of the caves that contain extant root mat assemblages had declined to the point that it was necessary to supplement water flow artificially. Due to a consensus of complete drying of known pools within the cave systems that support these communities (Yanchep Caves Recovery Team 2017) it is highly likely that distribution has declined by ≥90%.
• Based on available evidence, the community meets criterion A1 as the distribution decline is an estimated ≥90% since the 1990s which meets the ≥80% threshold over the past 50 years to meet CR under A1.
• Meets CR under A2b as at least ≥90% of all known areas of potential habitat for this community has been lost over a previous 50 year period (since 1990s) (meets ≥80% threshold to meet CR).
• Meets CR under A3 as at least ≥90% of all known areas of known habitat for this community has been lost since 1750 (meets ≥90% threshold for CR).
• There may be extant cave fauna and root mats located in inaccessible parts of the cave systems (Knott et al. 2008). Tree roots are capable of reaching and growing in inaccessible spaces of caves to a depth of at least 40m (Eberhard 2004).
• Plausibly meets criteria for collapsed or critically endangered under A1, A2b, A3
• Conservatively meets CR as community may be located in inaccessible</td></tr>
</table>

		parts of the cave systems
B.	Restricted geographic distribution *(EOO and AOO, number of locations and evidence of decline)*	☒ **B1** (specify at least one of the following): ☒ **a)(i)** ☒**a)(ii)** ☐**a)(iii)** ☒**b)** ☐**c);** ☒ **B2** (specify at least one of the following): ☒ **a)(i)** ☒**a)(ii)** ☐**a)(iii)** ☒**b)** ☐**c);** ☐ **B3 (only for Vulnerable Listing)**
	Justification of assessment under Criterion B.	• B1: EOO is 3km² (<2,000km²). The community's EEO is less that the 2,000km2 threshold for rank CR. Community meets threshold for rank CR under criterion part B1. • B1 a) i) Monitoring of water levels and root mats from the 1990s to 2008, and general observations since this point, indicate a measurable decline of at least ≥90% in spatial extent. • B1 a) ii) Monitoring of the known habitat through direct monitoring and observations of the community from the 1990s to 2008, as well as current bore data adjacent to these caves, indicate a measurable decline in levels of the groundwater that support the community from the 1990s to 2020. Based on the rate of groundwater decline observed during this period, it is assumed pools known to support the community have now completely dried out. • b): Continuing decline observed mainly from the impacts of groundwater decline. Less significant threats contributing to the community's decline include; destruction of tree roots, vandalism, pollution of groundwater, cave collapse, and introduction of exotic species (see Appendix 1 for details of threats). • B1 c) Community is considered to occur at 1 threat-defined location. This is based on the identification of a single cluster and shared aquifer (Gnangara mound) indicative of similar threats such as those that affect that aquifer, or bushland location across the community's range. The community meets CR under B1c) as the threshold of number of threat-defined locations to meet CR is 1. • B2: AOO- the community covers 1 grid cell. The community meets CR under criterion part B2 for which the AOO threshold is 2 grid cells. (subcriteria b, and c are the same as for B2) • B3: community is considered to consist of 1 threat defined location, based on the identification of a single cluster of occurrences that may be subject to similar threats such as those that affect a particular aquifer, or bushland location. Meets VU under criterion B3, as community occurs at less than 5 threat defined locations and is prone to effects of stochastic events within a very short time period (eg hydrological change), and thus capable of collapse within a short time period. • **Plausibly meets Critically Endangered under B1a(i),(ii),b,c; B2a(i),(ii),b,c. Meets Vulnerable under B3.**
C.	Environmental degradation of abiotic variable	☒ **C1** ☒ **C2**

	(Evidence of decline over 50-year period)	☒ **C3**

	Justification of assessment under Criterion C.	• Hydrological change in the form of groundwater decline is the most significant abiotic variable affecting the community. • For criterion C, the assessment of decline in abiotic processes focussed on hydrological change using data on the depth of cave pools supporting aquatic root mat assemblages, and the groundwater levels relative to the cave floor. It is assumed that the community would collapse if the cave pools supporting this community completely dried out. • The monitoring bores within 20-70m of caves Cabaret, Carpark, Boomerang and Water, show rapid linear water decline, with a range of 1 to 1.5m drop over a range of 20 to 30 years (Appendix 1). Monitoring bores within 500 to 800m of caves Twilight, Gilgie and YN555, also show a rapid water decline consistent across the entire Gnangara aquifer (Appendix 1). Therefore, the water levels within these caves have dried out based upon direct observation, and the declining water levels of the Gnangara mound. Despite irregular monitoring after 2012, it is logical to assume a 100% severity across 100% of its known extent due to the continuing decline in ground water and the community's reliance on water. • Assumption of 100% of the extent of the community with severity of 100% due to assumption cave pool systems have dried, and observed decline in groundwater that fall significantly below the cave floor for four of the caves (See Appendix 1). As the surrounding caves are within close proximity, and all rely on the Gnangara Mound water system, it is inferred this decline is affecting the full known distribution community. Therefore, the community meets criteria for critically endangered or potentially collapsed. Thresholds for CR are met as both extent and severity are ≥80% over the past 50 years. Knott *et al*. (2008) indicate there may be extant root mat assemblages in inaccessible parts of the cave systems. • Collapsed or critically endangered are plausible under C1. • Community also meets CR C2b (meets ≥80% threshold) based on decline in extent and severity over any 50-year period, and CR under C3 (meets threshold ≥90%) for decline in extent and severity of groundwater levels since 1750. • Collapsed or Critically Endangered C1, C2b and C3 are plausible. • **As there may be extant root mat assemblages in inaccessible parts of the cave systems, more conservative rank is CR under C1, C2b and C3**.
D.	Disruption of biotic processes	☐ **D1**

	or interactions *(Evidence of decline over 50-year period)*	☐ **D2** ☐ **D3**
	Justification of assessment under Criterion D.	• Decline in the root mats that support the food web is a significant biotic variable affecting the community. • The collapse point is considered to be loss of biota that are critical parts of the food web as a consequence of decline of the root mats. • Species richness recorded from root mat samples taken in October 2007 ranged from zero in Carpark Cave to four in Cabaret cave (Knott *et al.* 2008). As the cave pools have increasingly dried, the status of the aquatic invertebrate fauna and particularly the stygofauna has deteriorated, as diversity and abundance have declined. Stygofauna investigation cannot be undertaken due to caves currently being dry. It is possible that faunae may recolonise the caves, if present in refuges. Stygofauna were located in nearby caves in the last year, Orpheus and Alcheringa, that are not known to host the root mats. • There are insufficient monitoring data to track decline in specific groups of cave faunae that are important in supporting the food web in relation to the size and health of the root mats. • **Insufficient data to assess the community against the criterion**
E.	Quantitative analysis *(statistical probability of ecosystem collapse)*	• No quantitative estimates of the risk of ecosystem collapse have been completed • **Does not meet criterion**

Reasons for change of status
Genuine change ☐ New knowledge ☐ Previous mistake ☐ Review/Other ☒
Provide details: The community was initially ranked as Vulnerable using ranking criteria developed in WA that differ from those in the IUCN Red List Criteria for Ecosystems (version 2.2).

Summary of assessment information *(provide detailed information in the relevant sections of the nomination form)*			
EOO	3km^2	AOO	4 (10x10km grid method).
No. locations	7	Severely fragmented	Yes ☒ No ☐ Unknown ☐
Current known area			
Pre-industrialisation extent or its former known extent (if known)			Approximate estimate 5.6 ha (likely a significant overestimate)
Estimated percentage decline			Decline assumed ~100% however community may occur in inaccessible

	parts of the cave systems

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	CR or collapsed	• ≥90% of known habitat lost within the past 50 years • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
A2a	-	• Future decline not estimated
A2b	CR or collapsed	• ≥90% of all known areas of potential habitat lost over a previous 50 year period • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
A3	CR or collapsed	• ≥90% of known habitat lost since 1750 • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
B1a	CR	• EOO is <2,000km^2 • Observed decline in spatial extent, and measured decline in groundwater levels • Meets criterion under CR B1a(i),(ii)
B1b	CR	• EOO is <2,000km^2 • Observed and inferred continuing decline from; hydrological change, loss of root mat habitat • Meets CR B1b
B1c	CR	• EOO is <2,000km^2 • Ecosystem exists at one threat defined location • Meets CR B1c
B2a	CR	• AOO is one grid cell • Observed decline in spatial extent, and measured decline in groundwater levels • Meets criterion under CR B1a(i),(ii)
B2b	CR	• AOO is one grid cell • Observed and inferred continuing decline from hydrological change, loss of root mat habitat • Meets criterion for CR
B2c	CR	• AOO is one grid cell • Ecosystem exists at 1 threat defined location • Meets criterion for CR
B3	VU	• Known from one threat-defined location • Prone to the effects of inferred changes to hydrological regime • Meets criterion for VU
C1	CR or collapsed	• Available data indicate community meets the thresholds for CR with 100% of the extent (≥80%) and 100% severity of degradation (≥80%) over the past 50 years • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
C2	CR or collapsed	• Available data indicate community meets the thresholds for CR with 100% of the extent (≥80% threshold) and 100% severity of degradation (≥80% threshold) over any 50-year period. • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
C3	CR or collapsed	• Available data indicate community meets the thresholds for CR with 100% of the extent (≥90% threshold) and 100% severity of degradation (≥90% threshold) since 1750 to meet CR. • Conservatively meets CR as community may be located in inaccessible parts of the cave systems
D1	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (30%) or proportional severity of disruption of biotic processes (30%) over past 50 years to meet VU.
D2	-	• Inadequate evidence to indicate the community meets the minimum

		thresholds for proportion of the extent (30%) or proportional severity of disruption of biotic processes (30%) over any 50-year period to meet VU.
D3	-	• Inadequate evidence to indicate the community meets minimum thresholds for proportion of the extent (50%) or proportional severity of disruption of biotic processes (50%) since 1750 to meet VU.
E	NA	• No quantitative estimates of the risk of ecosystem collapse.
		Meets CR or Collapsed under criteria A1, A2b, A3. Meets CR under B1a(i),(ii),b,c; B2a(i),(ii),b,c; C1, C2b, C3. Meets VU under B3. *'The highest risk category obtained by any of the assessed criteria will be the overall risk status of the ecosystem'* (IUCN RLE Guidelines V1.1 page 42). **Conservatively meets CR under criteria A1, A2b, A3; B1a(i),(ii),b,c; B2a(i),(ii),b,c; C1, C2b, C3.**

Summary of location (occurrence) information *(provide detailed information in the relevant sections of the nomination form)*						
Occurrence Site ID (Occurrence number)	Land tenure	Survey information: date of survey	Condition	Area of occurrence (ha)	Threats *(note if past, present or future)*	Specific management actions
CABAR01 (5) – Cabaret stream cave (YN5 YN 30)	DBCA (Reserve 9868)	1995 - 2008	Some root mats in good condition in 2008 but inferred poor/degrading as at 2020.	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring, management of fire regime
Boomerang Cave YN99 (4)	DBCA (Reserve 9868)	1995 - 2008	Root mats were dry in 2007 and inferred poor to degraded condition as of 2020	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring
WATER01 (6) – Water cave YN11	DBCA (Reserve 9868)	1998 - 2008	Root mats dry in 2007 as above the water table. Root mats are inferred degraded condition as of 2020. Vegetation above cave burnt in 2019 bushfire.	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring
CARPK01 (1) – Carpark cave YN18	DBCA (Reserve 9868)	1995 - 2008	Root mats were dry in 2007 and inferred poor to degraded condition as of 2020. Vegetation above cave burnt in 2019 bushfire.	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring
TWILGHT01 (3) – Twilight cave YN194	DBCA (Reserve 9868)	1995 - 2006	Root were likely in good condition in 2005 as submerged in pools. Root mats inferred poor to degraded condition as of 2020.	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring

GILGIE01 (2) – Gilgie cave YN27	DBCA (Reserve 9868)	1995 - 2008	Root mats were dry in 2007 and inferred poor to degraded condition as of 2020	0.8	Groundwater decline, altered surface drainage, too frequent fire, disease and water contamination	Root mat and water level monitoring
YN555 (7) Lot 51	DBCA (Lot 51 acquired 29 March 2019, for inclusion into Yanchep National Park)	2004 and 2008	Root mats dry in 2007 and inferred in poor to degraded condition as of 2020	0.8	Clearing, groundwater decline, altered surface drainage, too frequent fire and disease	Root mat and water level monitoring

*For the purposes of relating condition to IUCN Criteria, condition categories from (Keighery (1994) Vegetation Condition Scale (Government of WA 2000)) are defined below:

Good (‘Pristine’, ‘Excellent’, ‘Very Good’ using Bush Forever (2000) scale): This includes vegetation ranging from ‘Pristine’ - with no obvious signs of disturbance, to ‘Excellent’ - Vegetation structure intact, with disturbance only affecting individual species, weeds are non-aggressive species and ‘Very Good’ - Vegetation structure altered, obvious signs of disturbance eg: from repeated fires, dieback, logging, grazing.

Medium (‘Good’ using Bush Forever (2000) scale): This includes vegetation categorised as ‘Good’ - Vegetation structure altered but retains basic vegetation structure or ability to regenerate it, obvious signs of disturbance are present, from activities including partial clearing, dieback and grazing.

Poor (‘Degraded’ using Bush Forever (2000) scale): Basic vegetation structure severely impacted by disturbance such as partial clearing, dieback, logging and grazing. Scope for regeneration but not to a state approaching good condition without intensive management.

Beyond recovery (‘Completely degraded’ using Bush Forever (2000) scale): Vegetation structure is no longer intact and the area is completely or almost completely without native species. These areas are often described as ‘parkland cleared’ with the flora comprising weed or crop species with isolated native shrubs and trees.

APPENDIX 1 THREATS

Groundwater decline and quality

The highest elevations of the Gnangara Mound are about 23 km north east of the caves. From there the groundwater flows in a south westerly direction towards the caves. Pine plantations, native bushland and National Park occur between the crest of the mound and the caves. The level of the Gnangara Mound has dropped by up to five metres upstream of the caves since around 1976. Some of the impact can be attributed to below average rainfall since that time. Rainfall has been recorded since 1879, however, the current rainfall regime in relation to longer term climatic fluctuations is unknown.

Other factors besides climate have likely influenced the hydrologic regimes of the caves. The factors include the location and density of pine plantations that can result in a decline in water levels, together with abstraction for public water supply and by private users mainly for market gardening. Vegetation limits the amount of recharge to the aquifer through interception of rainfall and evapotranspiration. Once the pines have grown to a certain size and density a greater volume of water is intercepted by the trees and lost through transpiration than the amount intercepted and lost by native bushland, and recharge of the aquifer through rainfall decreases. In several areas within the pine plantation upstream of the caves there has been no recharge to the water table over many years due to the impact of the pines.

Following a significant decline in water levels at Loch McNess prior to 2011, a hydrology investigation was undertaken, DoW (2016). It was concluded that the “water table decline has mainly been due to abstraction from the Superficial Swan aquifer at Yanchep Nation Park, Leederville aquifer abstraction and reduced recharge due to declining rainfall” (Kretschmer and Kelsey 2016). Management recommendations incorporating managing licensed pumping, allocation planning and measurement, monitoring and assessment, have been made in Kretschmer and Kelsey (2016) and are intended to assist with restoring and maintaining water levels at Loch McNess, and potentially, also restoring flows to some of the Yanchep Caves. The current water levels at Loch McNess and Lake Yonderup (figure 1), reflective of the Gnangara aquifer, show a continual gradual linear decline. Recent fires at Yanchep caused a short term increase in water levels at Lake Yonderup, however the impact was minor with levels upstream of the lake continuing to decline (pers comm. [redacted][1]).

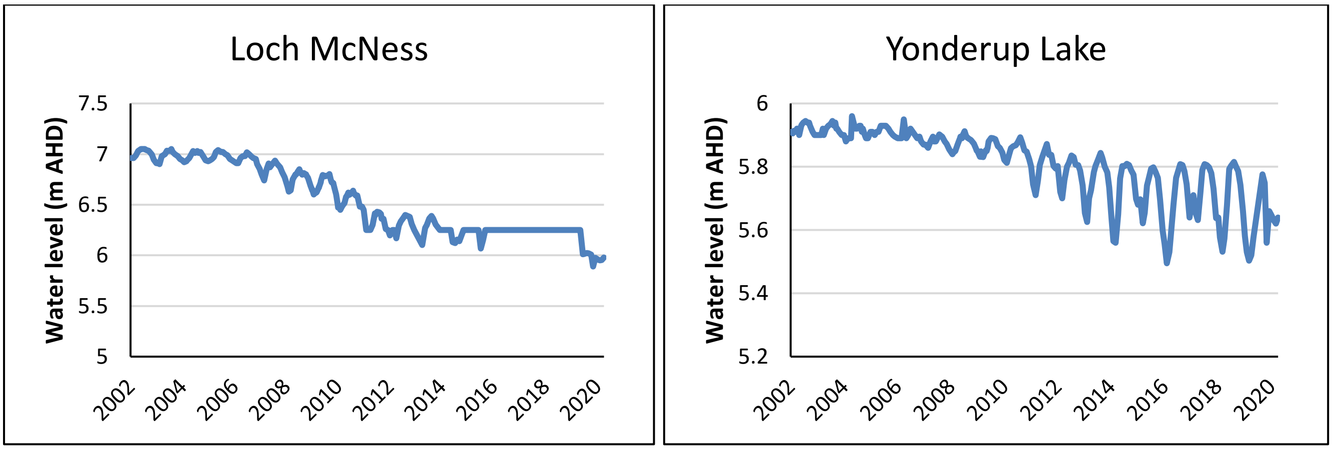

Figure 1. Declining water levels evident from the bore data of Loch McNess and Yonderup Lake from 2002 to 2020.

The Yanchep caves stream fauna requires the permanent inundation of the cave floor (Froend *et al*. 2004). Therefore, the ecological value of the caves as a habitat for the community is dependent on the maintenance of water levels that support the aquatic root mat assemblages. Bore data, and Australian Height Datum (AHD) of the cave floor, was available for four of the caves, Cabaret, Carpark, Boomerang and Water, that host the aquatic root mat community (figure 2-5). Twilight, Gilgie and YN55 also have nearby (500-800m) monitoring bores, however, have not had their depth measured and therefore interpretation of water levels relative to the cave floor is not possible (Knott et al. 2008). Water quality and stygofauna sampling was last undertaken 9, 10 October 2007. During this survey period, water levels in the vicinity of root mats in Cabaret, Boomerang and Carpark caves were artificially

[1] [redacted]: DBCA Swan Coastal District

maintained using sumps, pumps, floats and black plastic liners (Knott *et al*. 2008). The small-scale system was installed in four caves and consisted of a bilge pump, pumping water from the water table to the localised root mat communities. The large-scale system consisted of a production bore via a network of large diameter pipes delivering water directly to six of the caves. The purpose behind recharging the local aquifer under the caves using this system was to increase flows, increase vigour of root mats (sustain habitat) and allow the return of fauna. However, in 2007, the water levels of sumps were low with pumps struggling for water.

In 2007, Caberet cave had no natural surface flow and only held water in an artificial liner at the entrance to the main chamber. Sampling of water quality was only available from 1m below the floor of the cave (figure 2). The root mats appeared healthy but were infested with dipteran larvae. The other root mats in the cave were dry. Boomerang Gorge was completely dry in 2003 (water levels observably below cave floor; figure 3), and was still dry in 2007 due to the breakdown of the pump. Water cave still contained relatively deep pools in 2007, however, pools were 0.6-0.8m below the cave floor with all accessible root mats exposed and dry (figure 4). Carpark cave was also dry in 2007 due to issues with the local recharge system. Gilgie cave was also completely dry and has been dry since 1996. Twilight cave was unsafe to enter the survey year of 2007 but previously had root mats present within cave pools in 2005 (Knott *et al*. 2006). Cave YN555 was almost dry in 2007.

In summary, drying of caves has been an ongoing issue spanning more than 20 years. Due to the water supplementation systems becoming difficult to maintain, and the water decline of Loch McNess as a consequence, the system was ceased in 2011. It was not reinstated in 2012 (Yanchep Caves Recovery Team 2012). When last surveyed, pools known to support these assemblages were dry (Yanchep Caves Recovery Team 2017).

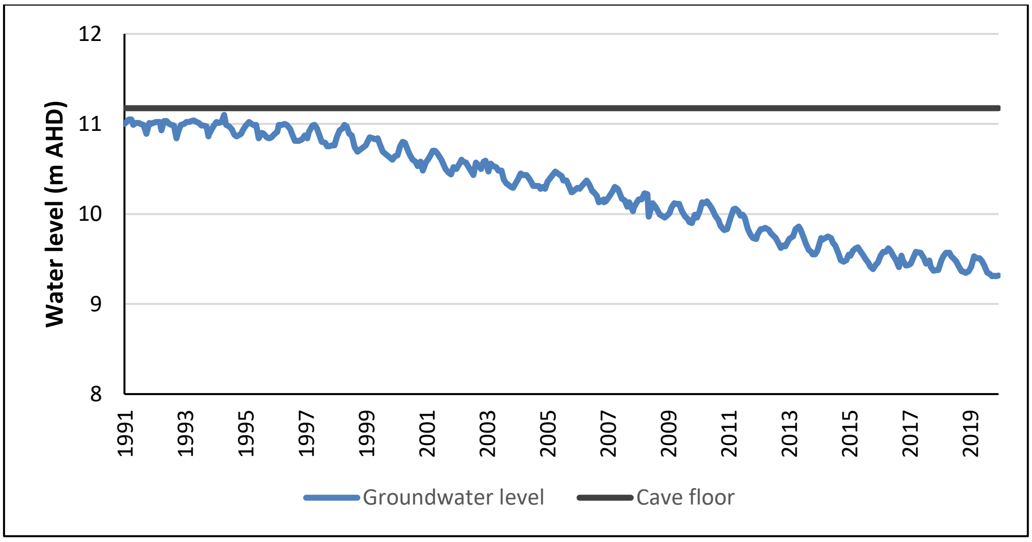

Figure 2. Temporal changes in water levels from adjacent monitoring bore (site ref: 61612103) against surveyed cave bed level of Cabaret cave, in Yanchep National Park.

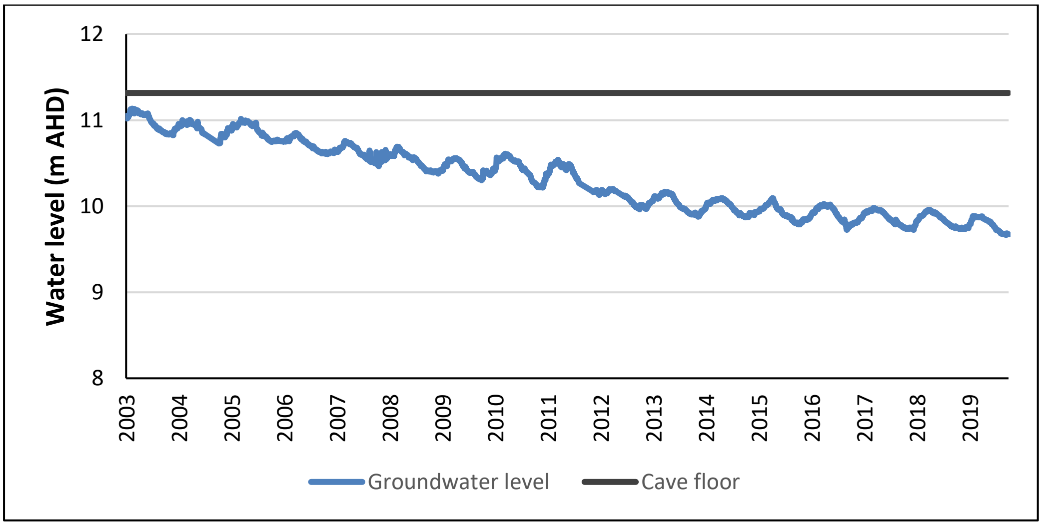

Figure 3. Temporal changes in water levels from adjacent monitoring bore (site ref: 61612111) against surveyed cave bed level of Boomerang Gorge, in Yanchep National Park.

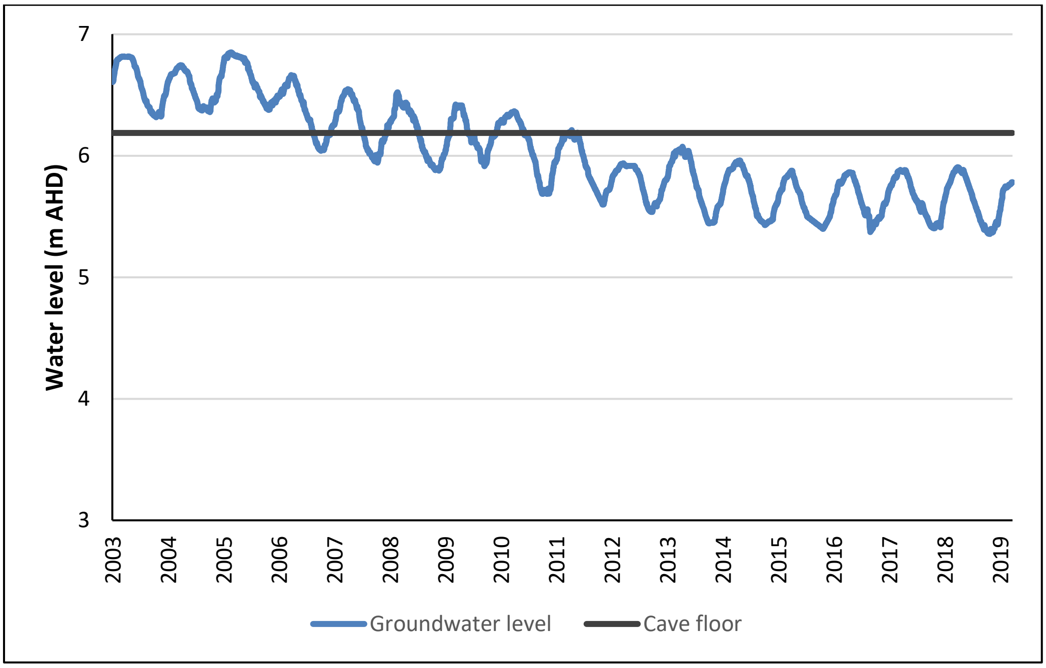

Figure 4. Temporal changes in water levels from adjacent monitoring bore (site ref: 61612115) against surveyed cave bed level of Water Cave, in Yanchep National Park.

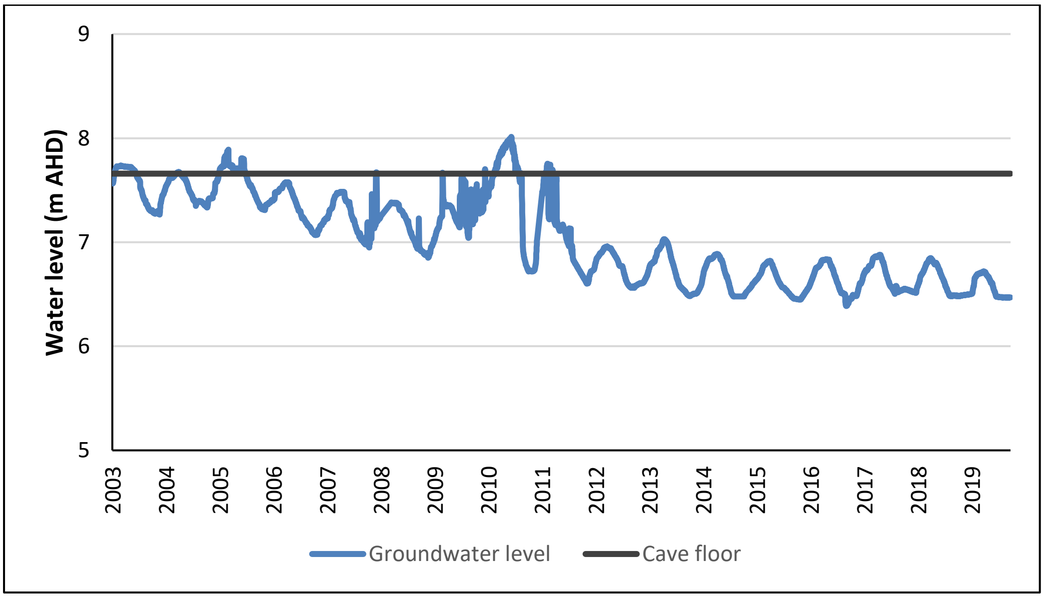

Figure 5. Temporal changes in water levels from adjacent monitoring bore (site ref: 61612112) against surveyed cave bed level of Carpark Cave, in Yanchep National Park.

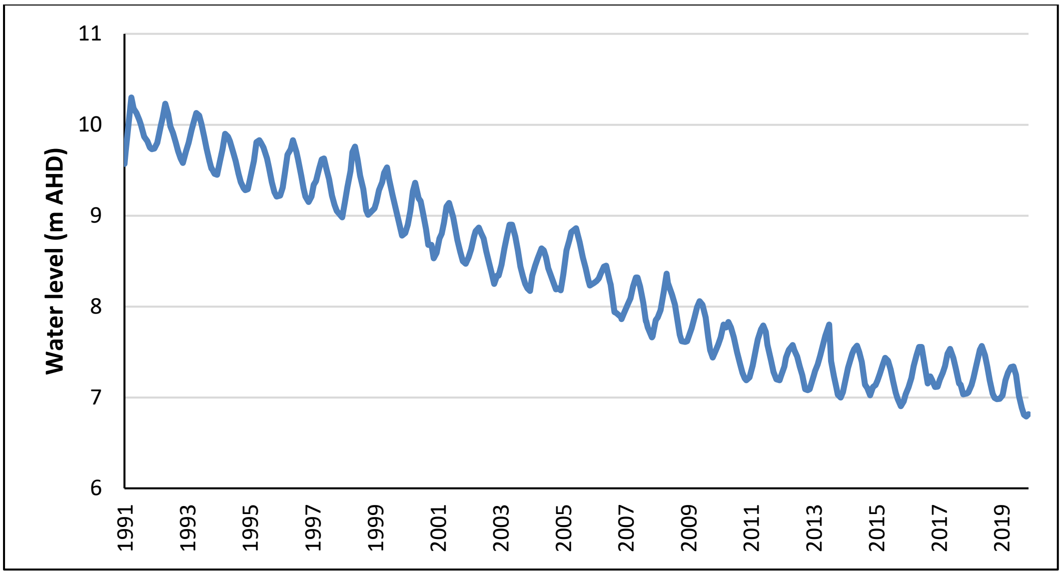

Figure 6. Temporal changes in water levels from monitoring bore approximately 500m from caves Twilight and Gilgie (site ref: 61612107), in Yanchep National Park.

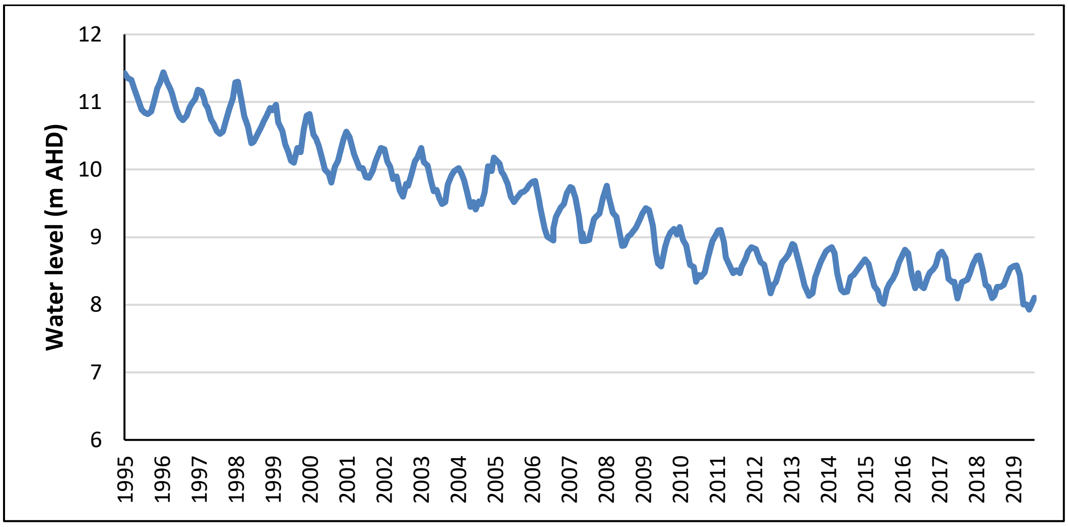

Figure 7. Temporal changes in water levels from monitoring bore approximately 800m from cave YN5555 (site ref: 61613208), in Yanchep National Park.

Water quality was relatively consistent across all caves and between monitoring years (1998 to 2007) (Knott *et al.* 2008). Water quality was generally characterised by low salinity, neutral pH and medium dissolved oxygen levels. Elevated concentrations of nitrogen and sulphate were recorded for YN555 (Knott *et al*. 2008).

As the cave pools are increasingly drying, the status of the aquatic invertebrate fauna and particularly the stygofauna deteriorated, as diversity and abundance declined. Stygofauna investigation cannot be undertaken due to the drying of accessible parts of the cave. It is expected that there are extant cave fauna on root mats located in inaccessible parts of the cave systems from which recolonisation may occur (Knott *et al*. 2008). Tree roots are capable of reaching and growing in inaccessible spaces of caves to a depth of at least 40m (Eberhard 2004). It is not known whether conditions in any non-accessible or undiscovered caves are suitable for the invertebrate assemblages, or if so, whether such assemblages are related to those in the known caves. The presence of drought-intolerant species indicates it is extremely unlikely that natural fluctuations in the groundwater level in the caves in the past have ever resulted in the complete drying of the cave streams or of some other connected refuge areas (Knott *et al*. 2008).

Stygofauna investigation within Orpheus and Alcheringa cave was undertaken in the last year. Orpheus cave is located approximately 3.3km north from the closest aquatic root mat community within Cabaret cave, and

Alcheringa cave is located approximately 50m north-west from the nearest aquatic root mat community, within Carpark cave. Only ticks, mites and insects were detected in both these caves (pers. comm. [redacted][2]).

Destruction of the tree roots

Trees that have roots in cave streams may be destroyed by clearing, frequent or very hot fires, or possibly by a variety of pathogens. The national park has a fire management plan that incorporates the caves and their catchment. In 2005 a large, arson-lit, bushfire impacted the park. Greater than 50% of the area of tuart trees above caves and are likely to supply roots to the community was burnt in bushfires in the summer of 2019-2020 (pers. comm. [redacted] [3]). Fire scar data indicate that 1.6 hectares (29%) of the vegetation above the community (occurrences Water01 and Carpk01) was burnt in this bush fire (data from DBCA Spatial Analysis Unit). The fire had a small and short term impact on groundwater levels at Loch McNess and a rise of < 0.1m was recorded between December and January, and again in early April which is likely due to the larger drop in transpiration as a result of the fire (see figure 8).

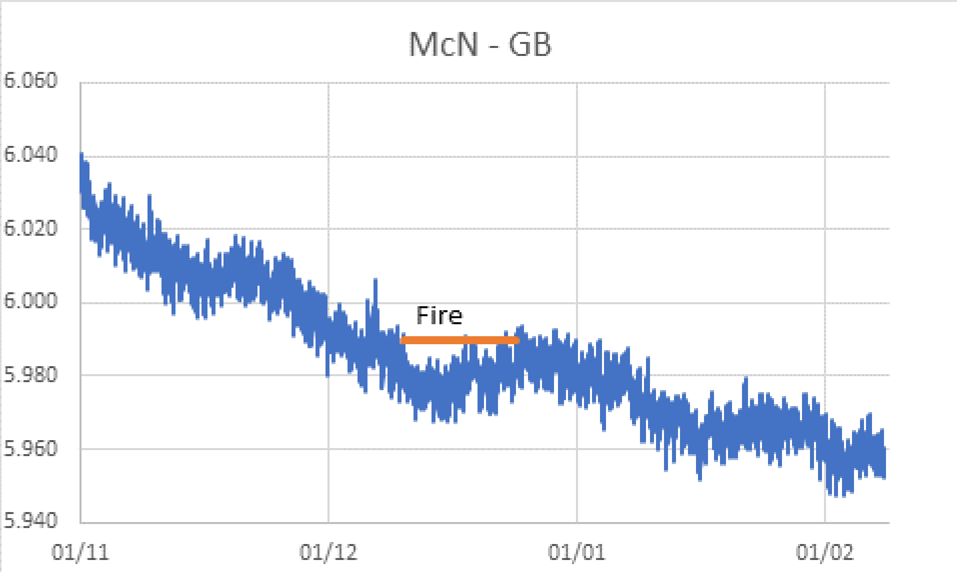

Figure 8. Trace data for water levels at Loch McNess within Yanchep National Park. A bushfire began on 11 December 2019 (data from Peter Muirden).

Vandalism

Vandalism by direct physical destruction can also destroy root mat communities. Access to the caves in Yanchep National Park is currently not controlled. At least one cave that may have contained a root mat community on the Leeuwin Naturaliste Ridge has been vandalised through pollution of the cave stream with batteries (pers. comm. E. Jasinska [4]).

Pollution of groundwater

The pattern and management of future land developments particularly to the east of each of the caves is likely to be crucial in maintaining the quality and level of the cave streams.

All of the Yanchep caves that contain root mats are located in Yanchep National Park, with the boundary of the park being one to two kilometres east of the caves. The proposed Ridges extension to the National Park is covered by native vegetation and spans two to four kilometres immediately east of the park. A 7-9 km width of pine plantations in State Forest 65 occurs adjacent to the eastern edge of Ridges. The pine plantations are currently planned for progressive harvesting and replacement with a variety of different vegetation types. Gnangara Water Reserve that has the purpose of protecting the Gnangara Mound occurs to the east of the pine plantations. The future uses of all these areas are important for the conservation of the aquatic root mat cave community. There is potential for

[2] [redacted]: PhD Candidate, Curtin University, Bentley
[3] [redacted]: DBCA Swan Region
[4] [redacted]: Previously University of WA.

waters entering caves to be 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.

Cave collapse

Possible causes of cave collapse may include heavy human or vehicular traffic over the caves and the use of explosives nearby. Indian Ocean Drive is a major road that is close to caves that contain root mats and to Crystal Cave.

Introduction of exotic species

Introduced fauna such as Yabbies (*Cherax destructor)* may compete with other fauna in the community, alter habitat and represent a serious threat to the root mat communities. Introduced crayfish have been recorded from caves at Dongara, and are thought to have had a significant impact on the cave fauna in that area (R. Shepherd[5] personal communication). A goldfish was sighted in the pools of cave YN555 in 2007 (Knott *et al*. 2008)

Reduced rainfall

Climate change predictions for the south-western WA are as follows (NCCARF website: (https://www.nccarf.edu.au/sites/default/files/attached_files_publications/PDF%20Report%20Card%20Low%20Res.pdf); accessed March 2020):

- Rainfall will reduce by 2-14% (median 8%) by 2030, compared to 1975- 2007 baseline. Southwest WA predicted to experience some of the largest reductions in rainfall in all of Australia.
- Runoff will reduce by 10-42% (median 25%) by 2030, compared to 1975- 2007 baseline.
- Temperature will increase by 0.5 -2.0ºC by 2030, compared to 1960-1990 baseline.

Reduced rainfall and recharge of the Gnangara Mound are implicated in declining groundwater and pools in the community.

[5] [redacted] - previously DBCA Midwest Region

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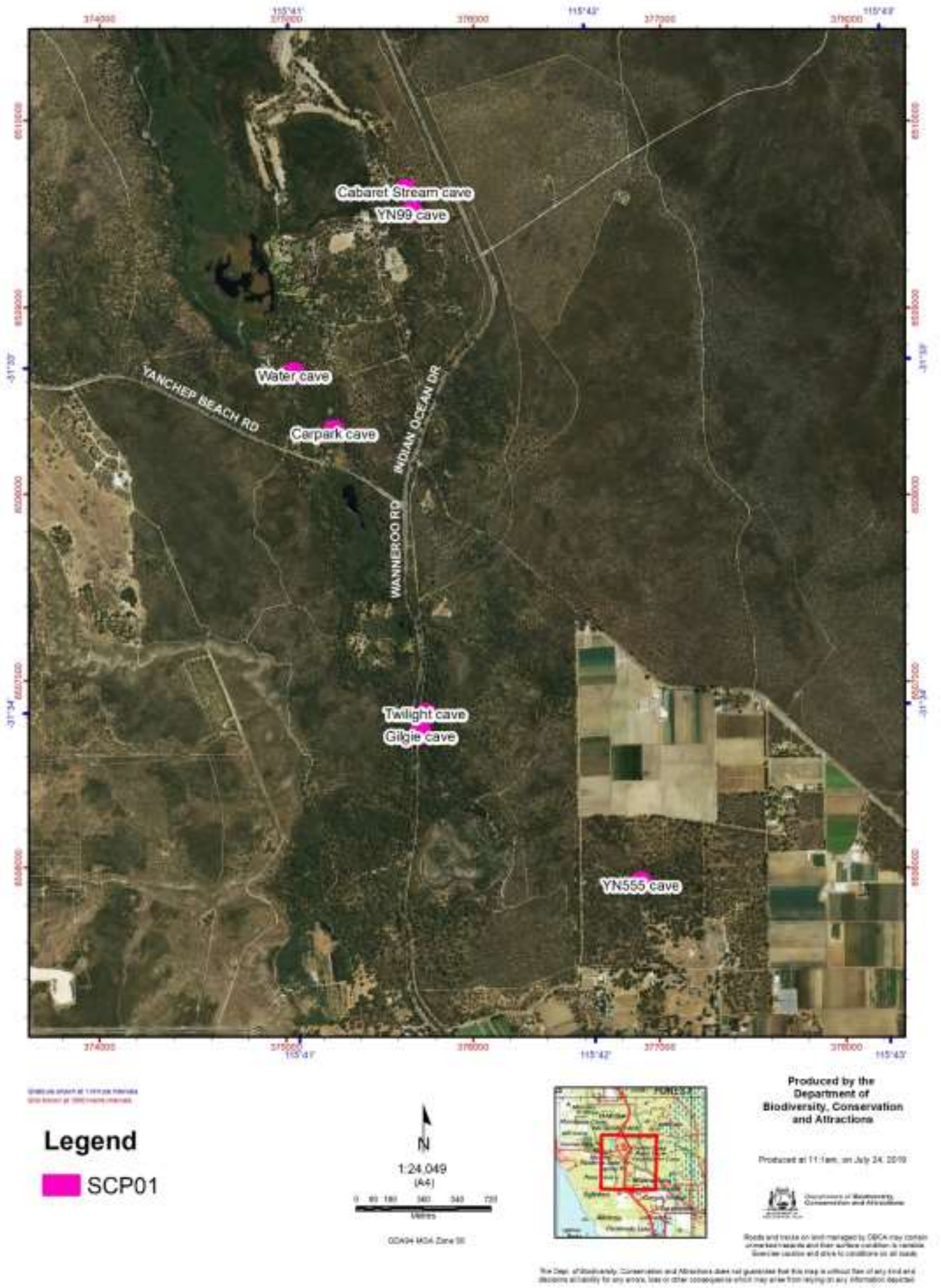
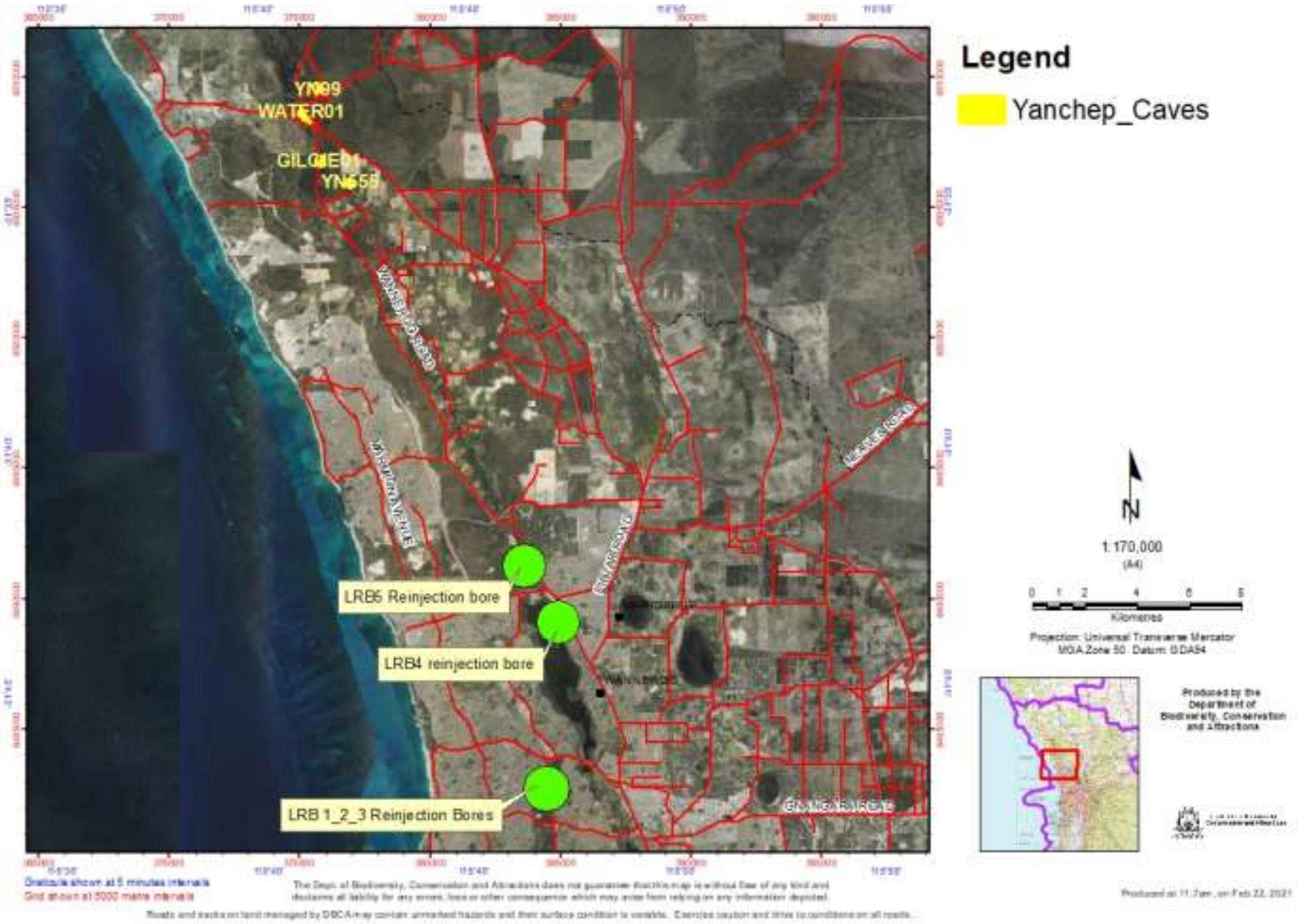
APPENDIX 2: Distribution of 'Aquatic Root Mat Community Number 1 of Caves of the Swan Coastal Plain' (SCP01)



The map above was created using ArcGIS version 10.6.1. The cave community ranges over 2.8km, with six of the occurrences located in Yanchep National Park and one located in Carabooda.

The map was created from known mapped occurrences of the community contained on the Western Australian Threatened Ecological Community database (TECDB), as administered by the Department of Biodiversity and Conservation (DBCA).

Appendix 3: Location of reinjection sites



APPENDIX 3 IUCN Red List Criteria for ecosystems (version 2.2) (IUCN 2017)

A. Reduction in geographic distribution over ANY of the following time periods:		CR	EN	VU
A1	Present (over the past 50 years).	≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years).	≥ 80%	≥ 50%	≥ 30%
A2b	Future (over any 50 year period including the present and future).	≥ 80%	≥ 50%	≥ 30%
A3	Historic (since 1750).	≥ 90%	≥ 70%	≥ 50%

B. Restricted geographic distribution indicated by EITHER B1, B2 or B3:		CR	EN	VU
B1	Extent of a minimum convex polygon enclosing all occurrences (Extent of Occurrence)	≤ 2,000 km²	≤ 20,000 km²	≤ 50,000 km²
	AND at least one of the following (a-c):			
	(a) An observed or inferred continuing decline in **EITHER**:			
	i. a measure of spatial extent appropriate to the ecosystem; **OR**			
	ii. a measure of environmental quality appropriate to characteristic biota of the ecosystem; **OR**			
	iii. a measure of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem.			
	(b) Observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years.			
	(c) Ecosystem exists at …	1 location	≤ 5 locations	≤ 10 locations
B2	The number of 10 × 10 km grid cells occupied (Area of Occupancy)	≤ 2	≤ 20	≤ 50
	AND at least one of a-c above (same sub-criteria as for B1).			
B3	A very small number of locations (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of collapse or becoming Critically Endangered within a very short time period (B3 can only lead to a listing as VU).			VU

C. Environmental degradation over ANY of the following time periods:			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
C1	The past 50 years based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 80	≥ 50	≥ 30
C2	The next 50 years, or any 50-year period including the present and future, based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
C3	Since 1750 based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		

D. Disruption of biotic processes or interactions over ANY of the following time periods:			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
D1	The past 50 years based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
D2	(D2a) The next 50 years, or (D2b) any 50-year period including		≥ 80	≥ 50	≥ 30

	the present and future, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table: OR	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
D3	Since 1750, based on a change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		
E. Quantitative analysis					
			CR	EN	VU
… that estimates the probability of ecosystem collapse to be:			≥ 50% within 50 years	≥ 20% within 50 years	≥ 10% within 100 years