Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA

Nomination *(to be completed by nominator)*

Current conservation status	
Name of ecological community:	Aquatic Root Mat Community Number 1 of Caves of the Leeuwin Naturaliste Ridge (Easter and Jewel Caves) (hereafter termed 'Community No. 1')
Other names:	
Description:	Cave system of the Leeuwin-Naturaliste Ridge incorporating Easter and Jewel Caves, described as comprising a complete food web; the rootlets and their associated microflora providing the primary food source, and root mat grazers, predators, parasites, detritivores, and scavengers completing the interactions. The root mats are produced by karri (*Eucalyptus diversicolor*). Aquatic cavernicoles (cave animals) in the community include koonacs (*Cherax preissii*), other crustaceans, mites, rotifers, microscopic worms, tardigrades, and insects and crustaceans. The copepod *Diacyclops humphreysi* n. ssp. Karanovic in prep., and the ostracod *Acandona admiratio* Karanovic 2003 were specific to Jewel and Easter caves. Community was described in Jasinska (1997).
Nomination for:	Listing ☒ under BC Act 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	Current ranking under WA Minister ESA list in policy	6/11/2001	CR	B) (under previous WA criteria)
	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 colspan="2">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>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.
• Estimated to cover 57.5 ha however Eberhard (2004) reported the watertable caves; Jewel, Easter and Labyrinth cave, together contain more than 10km of mapped cave passages situated within a land surface of some 2km²).
• At least 99% of all known areas of potential habitat for this community have been lost since 1982. Most of the known habitat, which is characterised by water table pools with submerged tree roots, has dried out. The available habitat is now restricted to a few small pools, of which only one (Tiffany’s Lake site D) has evidence of amphipods being present. Only small amounts of living rootlets, if any, are present in these pools (Subterranean Ecology Pty Ltd 2012).
• Based on available evidence, the community meets criterion A1 as decline in distribution due to habitat loss is estimated at 99% since 1982 which is above the >80% threshold to meet CR under A1 over the past 50 years.
• Meets CR under A2b as at least 99% of all known areas of potential habitat for this community have been lost over a previous 50 year period (since 1982) (meets ≥80% threshold to meet CR).
• Meets CR under A3 as at least 99% of all known areas of potential habitat for this community have been lost since 1750 (meets ≥90% threshold for CR).
• Meets criteria for critically endangered under A1, A2b, A3</td></tr>
<tr><td>B.</td><td>Restricted geographic distribution
(EOO and AOO, number of locations and evidence of decline)</td><td>☒ 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)</td></tr>
<tr><td></td><td>Justification of assessment under Criterion B.</td><td>• B1: EOO is 0.58km² (≤2,000km²-threshold for CR). The community’s EEO is less that the 2,000km² threshold for rank CR. Community meets threshold for rank CR under criterion part B1.</td></tr>
</table>

		• B1 a) i) Monitoring of the known habitat of this community indicates a measurable decline of at least 99% in spatial extent, from the 1982 to 2012. • B1 a) ii) Monitoring of the known habitat of this community indicates a measurable decline in levels of the groundwater that support the community from the 1950s to 2012. Based on the rate of groundwater decline observed during this period, it is assumed pools have now completely dried out. • B1 b): Continuing decline of the community observed from the impacts of hydrological change, loss of root mat habitat (see Appendix 1 for details of threats). • B1 c): Community is considered to occur at 1 threat defined location, based on both occurrences being in close proximity and subject to similar threats including those that affect aquifers and the bushland location. The community meets CR under B1c) as the threshold for VU is 1 threat-defined location. • B2: AOO. Community covers 1 grid cell. The community meets CR under criterion B2 for which the AOO threshold is ≤2 grid cells (threshold for CR ≤2 grid cells) (b and c of B1 are the same for B2). • B3: Community considered to consist of 1 threat-defined location. Mapped as one occurrence in two caves - Jewel and Easter. The caves are subject to threats that affect the aquifer that supports the cave pool habitat (the water table in the Jewel Cave Karst System) and the proximity of bushland that contains trees with roots in the caves that is likely to be subject to similar threats, including severe fires. The community meets VU under criterion B3, as community occurs at 1 threat defined location. • **Meets criteria for Critically Endangered B1a(i),(ii),b,c; B2a(i),(ii),b,c. Meets Vulnerable under B3.**
C.	Environmental degradation of abiotic variable *(Evidence of decline over 50-year period)*	☒ **C1** ☒ **C2** ☒ **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. It is assumed that the community would collapse if the cave pools supporting this community completely dried out. • Groundwater levels in Jewel Cave are measured at two discrete sites, named Flat Roof 1 and Flat Roof 2. Consistent with the decline in all other water table pools in the Jewel Cave Karst System, the local water table has continued to decline at these sites (Figure 1). Groundwater levels in the Jewel Cave Karst System continue to decline, with the water level lying at 22.46m AHD in 2012, the lowest level recorded since 1958 (Figure 1). Since 2000 the ground water level had declined by more than 1m, or on average 101mm per year. Figure 1 illustrates that at the previous known rate of water level decline, the aquifer would be desaturated by 2013 if not before. • Based on current and future forecasts of groundwater levels across the community, 100% of the extent of the community has a quantified severity of 100% due to the community's dependence on groundwater and the assumption the cave pool system has dried out. Therefore, the community meets criteria for CR, as both extent and severity are ≥80% over the past 50 years. • 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. • **Meets criteria for Critically Endangered C1, C2b, C3**
D.	Disruption of biotic processes or interactions *(Evidence of decline over 50-year period)*	☐ **D1** ☐ **D2** ☐ **D3**
	Justification of assessment under Criterion D.	• Decline in the root mats that support the food web including cave faunae that are important in supporting the food web is a significant biotic variable affecting the community • The collapse point that will result in loss of the assemblage is assumed to be total loss of the root mats. • In 2010 only two amphipod taxa were observed in Tiffany's D. These amphipods were relatively abundant and included *Uroctena* n. sp. and *Perthia* sp. In the last survey period, 2012, all pools were visually searched for stygofauna, some amphipod tracks were observed but no live specimens were sighted. This suggests a decline in stygofauna such as amphipods that are important to the food web, likely linked to the decline of suitable habitat provided by aquatic 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	• No quantitative estimates of the risk of ecosystem collapse have been completed

	(statistical probability of ecosystem collapse)	• **Not evaluated under criterion E**

Reasons for change of status
Genuine change ☐ New knowledge ☐ Previous mistake ☐ Review/Other ☒
Provide details: The community was initially ranked critically endangered 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	0.58 km^2	AOO	1 grid square 100 km^2 (10x10km grid method).
No. locations	1	Severely fragmented	Yes ☒ No ☐ Unknown ☐ Community is confined to specific habitats in cave pools that are naturally highly fragmented
Current known area			57.5 ha (estimate only. Watertable caves; Jewel, Easter and Labyrinth cave contain > 10km^2 of mapped cave passages within a land surface of ~ 2km^2 (Eberhard 2012).
Pre-industrialisation extent or its former known extent (if known)			Unknown.
Estimated percentage decline			At least 95 to 98% of all known areas of potential habitat for this community have been lost. (Most known habitat characterised by water table pools with submerged tree roots, has dried out).

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	CR	• At least 99% of all known areas of potential habitat for this community have been lost within the past 50 years • Meets criterion for CR
A2a	-	• Available data do not indicate if community meets criterion
A2b	CR	• At least 99% of all known areas of potential habitat for this community have been lost over a previous 50 year period
A3	CR	• At least 95 to 98% of all known areas of potential habitat for this community have been lost since 1750
B1a	CR	• EOO is ≤2,000km^2 • Observed decline in spatial extent, and measured decline in groundwater levels • Meets criterion under CR B1ai,ii
B1b	CR	• EOO is ≤2,000km^2 • Observed and inferred continuing decline from; hydrological change, loss of root mat habitat • Meets criterion for CR
B1c	CR	• EOO is ≤2,000km^2 • Ecosystem exists at 1 threat defined location • Meets criterion for CR
B2a	CR	• AOO is 1 grid cell • Observed decline in spatial extent, and measured decline in groundwater levels • Meets criterion for CR
B2b	CR	• AOO is 1 grid cell • Observed and inferred continuing decline from hydrological change, pollution, invasion of exotic species, loss of tree root habitat • Meets criterion for CR
B2c	CR	• AOO is 1 grid cell • Ecosystem exists at 1 threat defined location • Meets CR under B2c
B3	VU	• Known from 1 threat-defined location • Meets VU under B3
C1	CR	• 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 • Meets criterion for CR
C2	CR	• 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. • Meets criterion for C2b
C3	CR	• 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.
D1	-	• Inadequate quantitative data to indicate if the community meets the minimum proportion of the extent (≥30%) or proportional severity of disruption of the food web in relation to the size and health of the root mats (≥30%) over the past 50 years to meet VU.
D2	-	• Inadequate quantitative data to indicate if the community meets the minimum proportion of the extent (≥30%) or proportional severity of disruption of the food web in relation to the size and health of the root mats (≥30%) over any 50-year period to meet VU.
D3	-	• Inadequate quantitative data to indicate if the community meets the minimum proportion of the extent (≥30%) or proportional severity of disruption of the food web in relation to the size and health of the root mats (≥30%) since 1750 period to meet VU.
E	NA	• No quantitative estimates of the risk of ecosystem collapse.

		Meets CR under criteria A1, A2b, A3; 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). **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 No.)	Land tenure	Survey information: date of survey	Condition	Area of occurrence (ha)	Threats *(note if past, present or future)*	Specific management actions
EASTER01 (1)	DBCA (Reserve 8428)/Shire of Augusta-Margaret River (Reserve 52245)	1995, 2000, 2006, 2010 and 2012-2019	100% poor - degraded condition in 2019	57.5 (likely a significant overestimate as boundary of cave pools not accurately mapped).	Groundwater decline, altered surface drainage, too high intensity fire in trees that provide tree root habitat, water contamination, exotic species, trampling of roots from human activity are all past, current and future threats	Monitoring of water levels and chemistry to 2012, human access controlled, fire regimes in trees that supply tree roots is managed, introduced fauna physically removed

*Ccondition categories (Keighery (1994) Vegetation Condition Scale (in 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

Major Threats

Groundwater Decline

Groundwater decline is overwhelmingly the most important and imminent threat to the survival of root mat assemblages in caves on the Leeuwin Naturaliste Ridge. The Leeuwin-Naturaliste caves consist of numerous small and discrete groundwater systems with highly localized recharge areas. This is in contrast to the Yanchep cave streams that are part of a large regional aquifer system, the Gnangara Groundwater Mound, with water levels in these caves influenced by conditions and processes occurring in the aquifer sometimes many kilometres away (Eberhard 2004). The Leeuwin-Naturaliste caves have experienced reduced groundwater levels and stream flow in recent years. Decline in the water levels in the root mat caves over recent decades was recorded by both Jasinska (1997) and Eberhard (2004, 2006). In 2012, the water table in the Jewel Cave Karst System was the lowest level ever recorded, 22.460 m AHD, being more than 2.5 m below the maximum level recorded over the last 52 years since historical measurement commenced (Subterranean Ecology Pty Ltd 2012). Both depth and surface area of free-standing water bodies in the caves equate to available habitat for stygofauna and the aquatic root mat community. More than 99% of groundwater habitat (surface area) had dried-up as at 2012 (Subterranean Ecology Pty Ltd 2012).

Groundwater levels in Jewel Cave are measured at two discrete sites, respectively named Flat Roof 1 and Flat Roof 2, owing to their distinctive passage morphologies. Consistent with the decline in all other water table pools in the Jewel Cave Karst System (Figure 2), the local water table has continued to decline at these sites (Figure 1, 3).

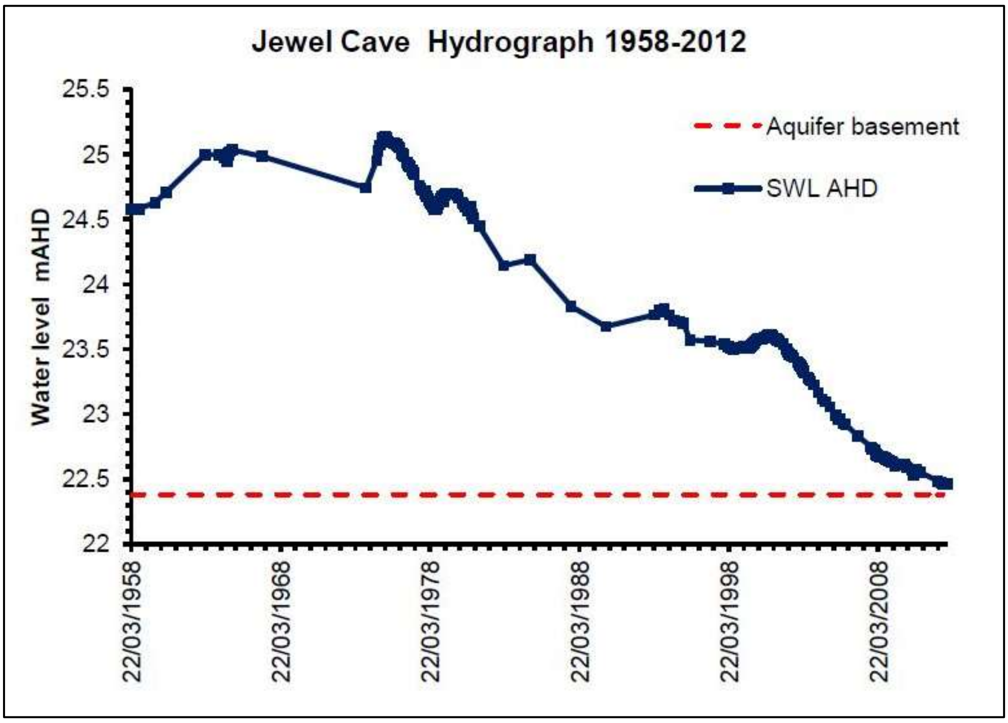


Figure 1. Jewel Cave hydrograph 1958 to 2012 showing groundwater level and aquifer basement as measured in Flat Roof 1 (monitoring site of Jewel Cave). Extrapolation of groundwater levels indicates that at the measured rate of decline, the aquifer would be dry by 2013 (Graph taken from Subterranean Ecology (2012)).

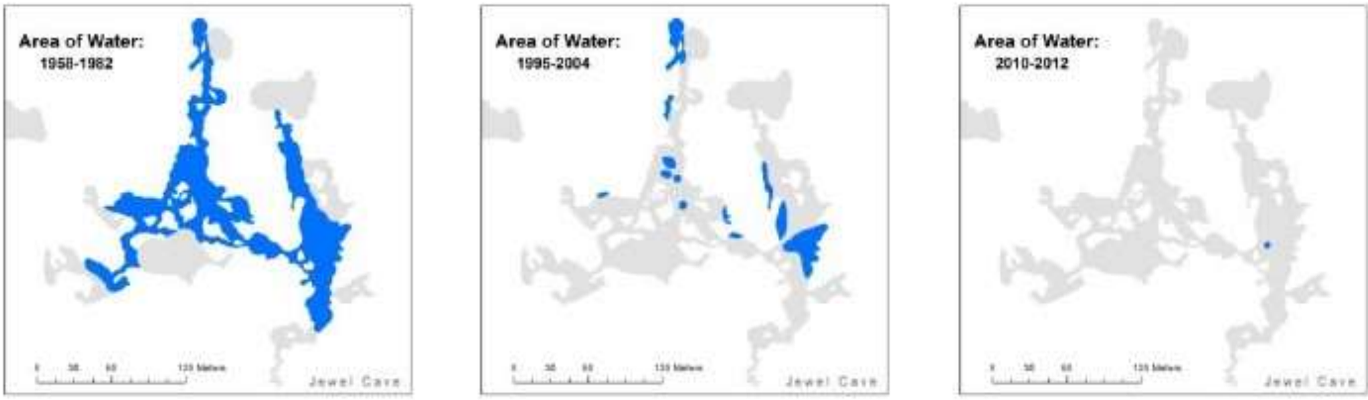


Figure 2. Graphical depiction of declining groundwater levels in Jewel Cave over three time periods. The areal extent of free-standing water bodies (lakes) within the cave are shown in blue. Jewel Cave map courtesy of Peter Bell; adapted from Eberhard 2004. Graphical description prepared by [redacted].

This last remaining tiny remnant pool is all that remains of a previously much more extensive series of large and connected lakes in Jewel Cave (Figure 2). This remnant pool does not contain root mats or stygofauna, although previously in the 2000- 2004 monitoring period when the lake was more extensive, the locally endemic amphipod *Uroctena n. sp.* was collected from this lake (Subterranean Ecology Pty Ltd 2012).

Figure 3. Flat Roof 2 monitoring site in Jewel Cave (a) August 2000 and (b) August 2010. Note the depth of water in (a) is approximately 0.2m. The loss of water at this site likely represents the loss of known occurrence of Aquatic Root Mat Community No. 1 (Imagery taken from Eberhard (2010)).

In Easter cave, Tiffany's Lake is the main monitoring site and the original "type locality" for the Aquatic Root Mat Community No. 1 of the Leeuwin-Naturaliste Ridge Caves (Jasinska 1996). Between 2000 and 2003 the lake had an area of 50m^2, which by 2012 had been reduced to a residual pool approximately 0.6m^2 (Figure 4).The degeneration of tree roots at Tiffany's Lake site A suggests that the water table in 2010 was critically low, and dropping at a rate too fast for tree roots to grow downwards with the descending water table.

On previous monitoring visits to this site, amphipods were relatively abundant and included *Uroctena* n. sp. and *Perthia* sp. In 2006, only one individual amphipod was sighted (*Uroctena* n. sp.), and then two amphipods were sighted in 2010 which were juvenile *Perthia* sp. This suggested that this species at least was still breeding, however no other fauna were observed, including the locally endemic species, *Uroctena* n. sp (Subterranean Ecology Pty Ltd 2010). In 2012, pools were visually searched for stygofauna, some amphipod tracks were observed but no live specimens were sighted (Subterranean Ecology Pty Ltd 2012). There may be unknown occurrences of this community as tree roots are capable of reaching and growing in inaccessible spaces of caves to a depth of at least 40m (Eberhard 2004).

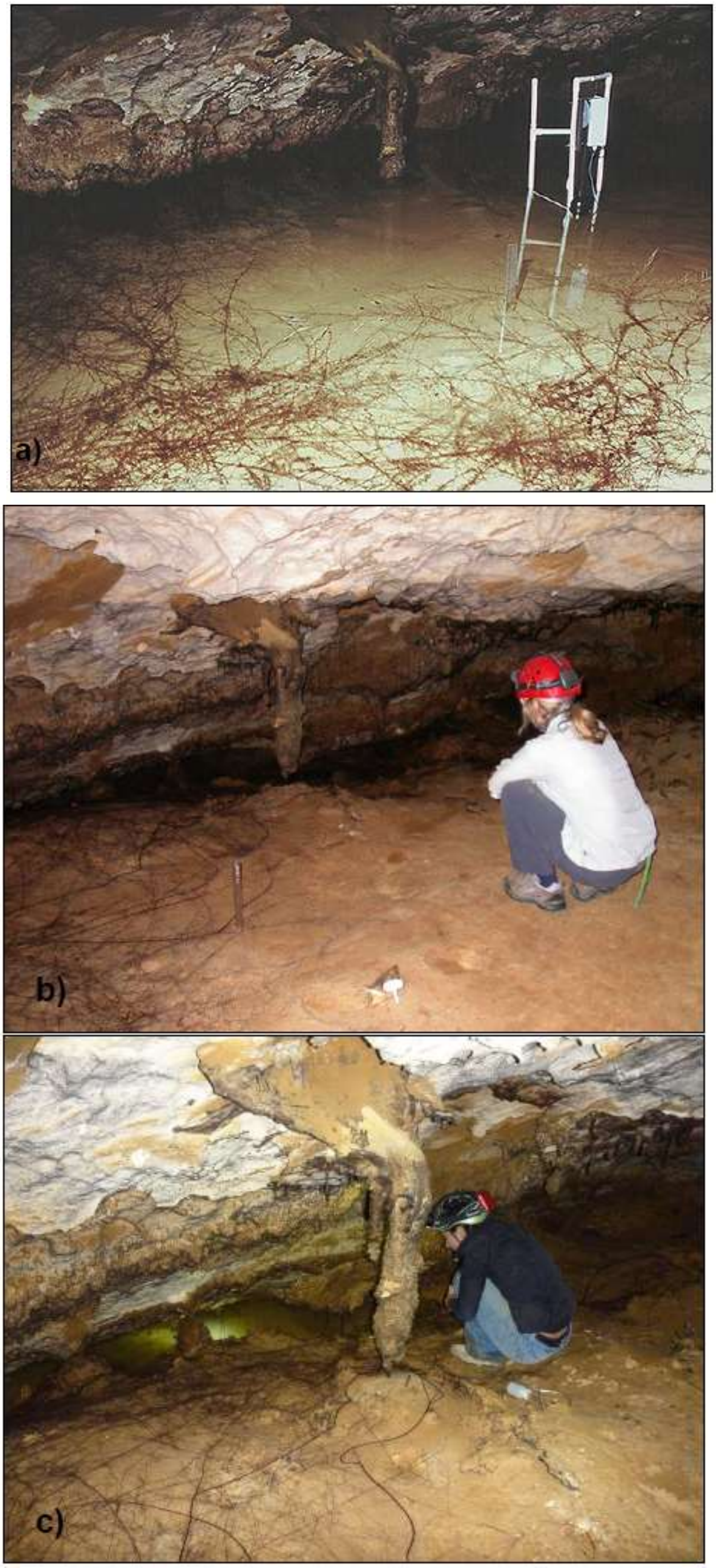

a)
b)
c)

Figure 4. Tiffany's Lake water level monitoring site (Tiffany's site A), (a) 1999 with submerged root mat, (b) November 2006, (c) July 2010, and (d) July 2012, showing residual pool and subaerially exposed root mat. (Imagery taken from Eberhard (2010)).

The ecological response to the groundwater decline, measured as species diversity, was evaluated by Chilcott (2012). Chilcott (2012) collated all historical biological and water quality survey data including Jasinska (1996), Eberhard (2004), Subterranean Ecology (2006, 2010 and this survey). Water depth and water quality parameters were compared to changes in stygofauna composition using multivariate statistics. There were no significant effects of changes in water quality but a clear reduction in species richness (number of species) with declining water level (Chilcott 2012) (figure 5).

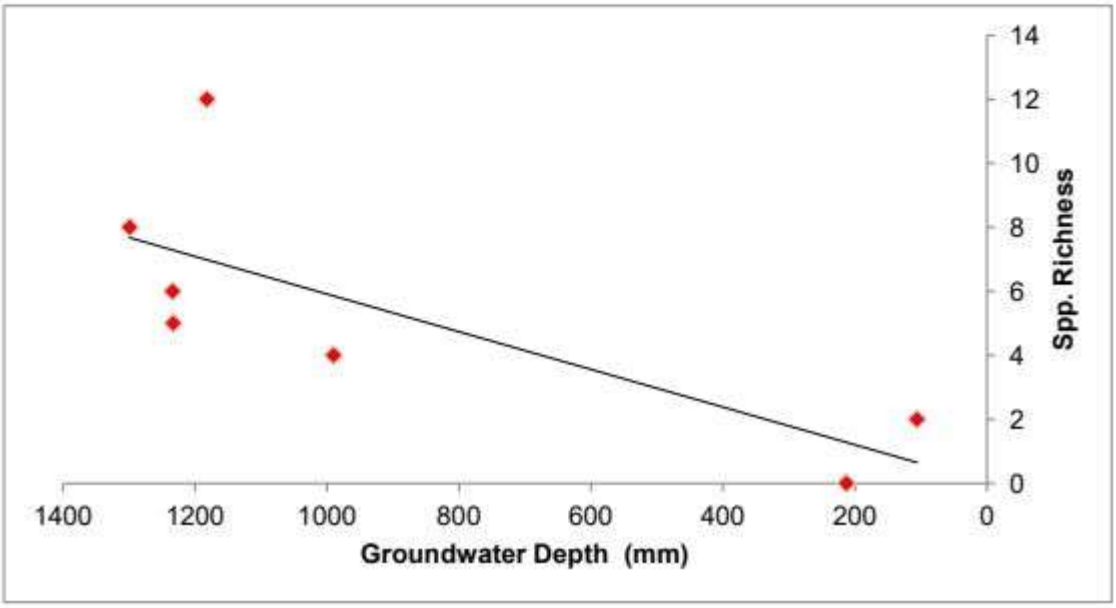


Figure 5. Effect of declining groundwater on species richness from 1994 to 2012. Reproduced from Chilcott (2012).

It is assumed the main cause of the water decline is reduced rainfall experienced in southwest Western Australia since the mid-1970s. The cause of the groundwater decline was investigated through Cumulative Rainfall Departure (CRD) analysis, a simulation that assumes rainfall is the only driver in changing groundwater levels and thus any deviation indicates that other factors influence water levels. Groundwater levels in Jewel Cave should have responded much more to wet spells in the late 1990s-early 2000s than was actually observed (figure 6). The hydrograph response during this period was very muted and the modelling suggested that groundwater levels should be about 1 m higher than actual. Further research is needed to verify if the cause of these changes is due to changed groundwater use by native vegetation in the catchment and/or land use practices such as tree plantations or altered drainage. For example, a pine plantation adjacent to Jewel Cave, as well as a blue gum plantation downslope of the Jewel Cave system, may be potentially exacerbating groundwater decline in Jewel Cave.

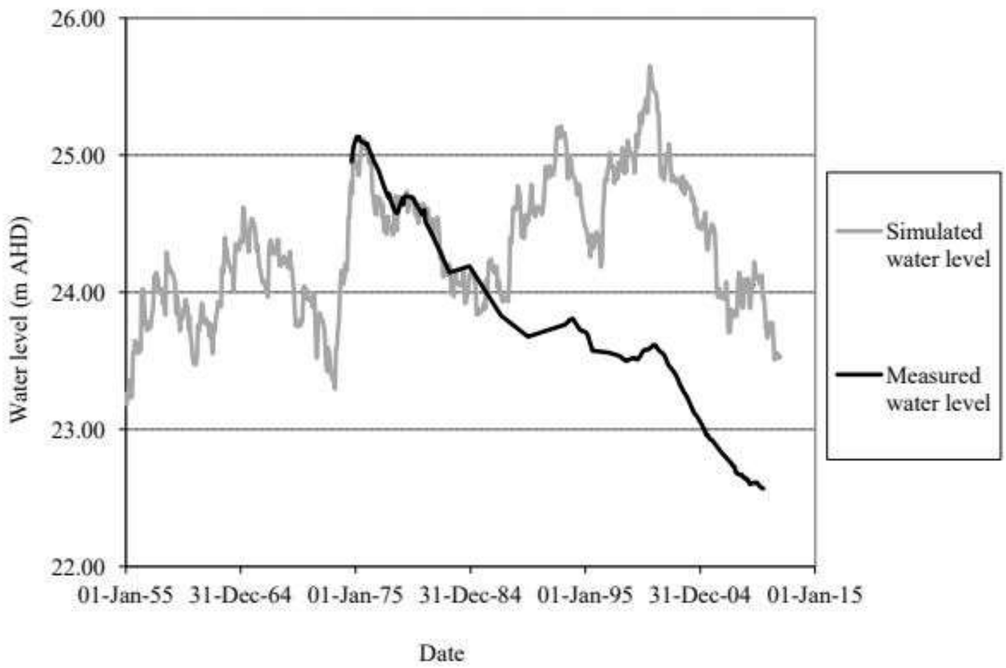


Figure 6. Jewel Cave Cumulative Rainfall Departure (CRD) displays measured groundwater levels in Jewel Cave compared with simulated levels according to climatic data (Data source courtesy [redacted]). The measured standing water level is based on data collected from 1958 onwards although the trendline commences ca. 1975 due to averaging effects.

Minor threats

Pollution of Groundwater

Karst aquifers are very vulnerable to contamination from pollutants carried in surface waters because of rapid ingress of such waters via sinking streams and free flowing conduits, including sink-holes and solution pipes, and an associated low filtration capacity. Thus, 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).

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.

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). Activities such as agriculture, large tourist developments including caravan parks and hotels that produce substantial amounts of effluent and require large quantities of water already occur near caves that contain stygofauna on the Leeuwin-Naturaliste Ridge, and these types of development can be expected to expand in future.

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, and/or particular species of stygofauna. Yabbies 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). Crayfish were identified from Lake Cave in August 1995 (Jasinska 1997), and were still present in 2020 ([redacted] personal observation). All the specimens were the endemic *Cherax preissii* (koonacs). If feasible methods exist, any accidentally or deliberately introduced species should be removed unless side effects of removal are likely to do more harm than the introduced species. The Augusta-Margaret River Tourist Bureau physically removes koonacs from Lake Cave whenever possible.

Loss of tree roots by death of trees

Trees whose roots reach the water table may be killed by hot or too frequent fire, clearing or disease. However, the much greater distribution of tree roots throughout karst systems of the Leeuwin-Naturaliste Ridge now known, and the hundreds, probably thousands of trees involved, suggest that normal good management of forests should prevent major effects from fires or disease. These root mat assemblages have survived intensive wildfires in the past (Eberhard 2004). The subaerial roots within the cave system appeared to be living although root “die-back” was evident between 2006 and 2010, with no recovery in 2012 (Subterranean Ecology 2012). Clearing may be a localised threat adjacent to conservation lands and planning processes should include careful consideration of this factor.

Alternatively, Eberhard (2004) concluded that vigorous growth of native vegetation and heavy accumulations of litter, resulting from lower frequency of fires over the last few decades (with the last significant fire in the catchment in 1977), may have contributed to reduced amounts of rainfall penetrating the soil and reaching the cave system.

A very hot wildfire burned much of the catchment of Calgardup Cave (and some of that for Lake Cave) in April 2006. This provided an opportunity to monitor the effect of severe fire on water levels in those caves to help to clarify major hydrological drivers for them.

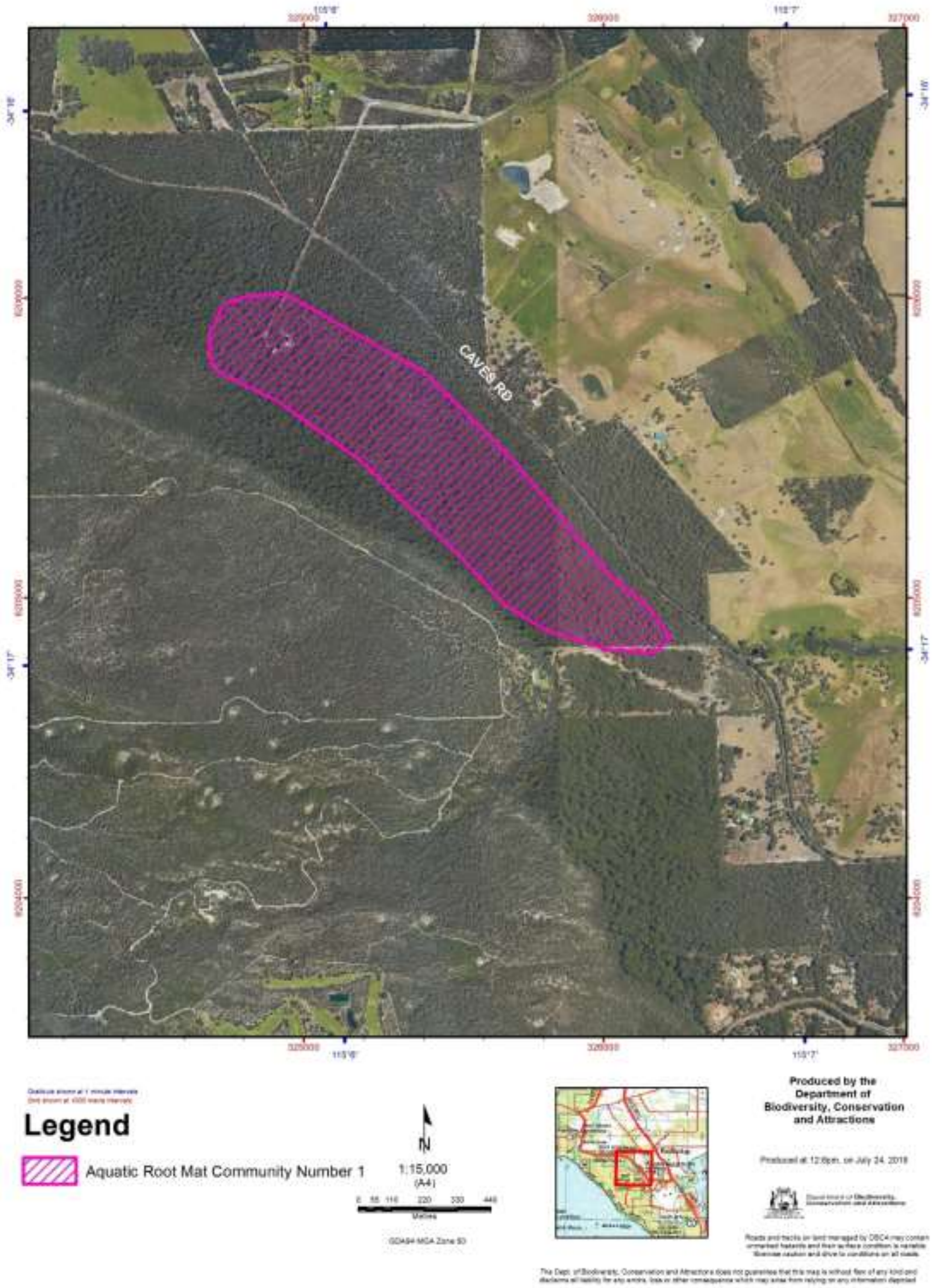
Damage to root mats from human trampling within the caves

As outlined by Eberhard (2004) the area of root mats that are accessible to significant human traffic is very small compared to the total area now known to exist. Furthermore, access to all of the caves that contain root mats on the Leeuwin-Naturaliste Ridge is already controlled to some extent and this helps to prevent physical damage to the communities.

Cave collapse

While cave collapse is a natural process in karst systems, the exacerbation of this by issues such as heavy human or vehicular traffic over the caves and the use of explosives nearby should be avoided. Good management practices should include 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 them.

APPENDIX 2 Aquatic Root Mat Community Number 1 of Caves of the Leeuwin Naturaliste Ridge (Easter and Jewel Caves)



The map above was created using ArcGIS version 10.6.1 and shows the extent of distribution of the cave that supports the ‘Aquatic Root Mat Community Number 1 of Caves of the Leeuwin Naturaliste Ridge (Easter and Jewel Caves)’. This community is found along Caves Road within Deepdene. The actual distribution of the small pools that support the assemblage is far less extensive, and is not precisely mapped however.

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

References

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Eberhard, S. (2004). Ecology and hydrology of a threatened groundwater-dependant ecosystem: The Jewel Cave Karst System in Western Australia. Unpublished PhD Thesis, Murdoch University, Western Australia.

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Jasinska E. J. J. (1997). Faunae of aquatic root mats in caves of southwestern Australia: origins and ecology. Unpublished PhD Thesis submitted to the Zoology Department, University of Western Australia.

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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 km^2	≤ 20,000 km^2	≤ 50,000 km^2
	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 <u>abiotic</u> 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 <u>abiotic</u> 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 <u>abiotic</u> 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 <u>biotic</u> 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
D2	(D2a) The next 50 years, or (D2b) any 50-year period including the present and future, based on change in a <u>biotic</u> 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