Department of Biodiversity, Conservation and Attractions
GOVERNMENT OF WESTERN AUSTRALIA

Nomination *(to be completed by nominator)*

Current conservation status	
Name of ecological community:	Cape Range Remipede Community (Bundera Sinkhole)
Other names:	
Description:	The community is known from the Bundera Sinkhole, which is a landlocked body of water with a subterranean connection to the ocean (an anchialine cave). Anchialine ecosystems are inland underground mixohaline waters (seawater dilutes of variable salinity) affected by marine tides, usually with little if any surface exposure. The community comprises a rich stygobitic faunal assemblage composed primarily of crustaceans but also includes a blind fish, *Milyeringa veritas* (blind gudgeon). The crustaceans include atyid shrimp, ostracods, gammarid amphipods, diverse copepods, a remipede of the class Remipedia (a class of blind crustaceans). At least 16 stygobiont species, as follows are recorded from Bundera Sinkhole (Humphreys 2020): *Bunderia misophaga* epacteriscid calanoid; *Speleophria bunderae* speleophriid misophrioid; *Stygocyclopia australis* pseudocyclopiid calanoid copepod *Stygoridgewayia trispinosa* (Copepoda: Calanoida Ridgewayiidae); *Kumonga exleyi* Remipedia; *Welesina kornickeri* Thaumatocypridide *Halosbaena tulki* Thermosbaenacea; *Speleophria bunderae Ophisternon candidum** Pisces; *Milyeringa veritas Pisces; Stygiocaris sp. nov.* (Page et al 2008) *Haptolana sp. ***; Hadzia (Liagoceradocus) branchialis; Phlyctenophora mesembria Candonidae: Paracypridinae ; Nitokra fragilis Harpacticoida Ameiridae; Hydractinia betkensis? Anthoathecata Hydractiniidae; Iravadia sp. Neotaenioglossa Iravadiidae; Halicyclops longifurcatus Cyclopoidea Cyclopidae; Kiefferulus intertinctus Chironomidae; Limnoonus sp. Hemiptera: Gerridae g; 'Prionospio' sp. [under revision by Alejandro Martinez); Bunderanthura bundera, Leptanthuridae (Isopoda)* * Possibly restricted to freshwater. **Reported ***CR anchialine system ;
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			
Western Australia	Current ranking under WA Minister ESA list in policy	6/11/2001	Critically Endangered	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 ☐

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'.*		VU B3
Eligibility against the criteria		
*Provide justification for the nominated conservation status; is the ecological community eligible or ineligible for listing against the five criteria. For **delisting**, provide details for why the ecological community no longer meets the requirements of the current conservation status.*		
A.	Reduction in geographic distribution *(evidence of decline)*	☐ **A1** ☐ **A2a** ☐ **A2b** ☐ **A3**
	Justification of assessment under Criterion A.	For criteria A and B, the ecosystem was assumed to collapse when the mapped distribution declines to zero. • No data suggest the community has declined in distribution. • There is no evidence to support an inference that a minimum 30% reduction in geographic distribution has or will occur over any 50-year period, or a 50% reduction since European settlement (ie. the minimum thresholds to meet the category VU under criterion A). • **Does not meet criterion A**
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 0.0028km^2 (≤2,000km^2-threshold for CR) • Community meets threshold for rank CR under criterion part B1. • B1 b): Threats from the pollution and decline of groundwater levels and quality in the Cape Range Group aquifer, dumping of rubbish or toxic waste, disturbance of the chemico-physical attributes of the waterbody by diving or other means, introduction of exotic species, and eutrophication. Data accessed indicate threats are currently relatively trivial (see Appendix 1 for details of threats). • B1 c) Community is considered to occur at 1 location but no available data indicate threats are significant.

		• B2: AOO. Community covers one grid cell. The community meets CR under criterion B2 for which the AOO threshold for CR is ≤2 grid cells (b and c of B1 are the same for B2). • B3: community occurs at one location. Meets VU under criterion B3, as community occurs at 1 threat-defined location and prone to 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. • Plausible meets criteria for Critically Endangered B1b,c); B2b,c). Meets Vulnerable under B3. • **VU B3 considered most plausible as threats currently considered relatively trivial.**
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 decline in groundwater quality, is an abiotic variable that is a threat to the community. • For criterion C, the assessment of decline in abiotic processes relates to water quality of the sinkhole and its catchment that support critical elements of this stygobitic faunal assemblage. • Eutrophication (nutrient enrichment) is an abiotic variable affecting the community. • The introduction of energy into subterranean systems changes the energy balance and enhances the competitive abilities of epigean organisms, allowing them to displace hypogean organisms that are adapted to a low energy environment. • The physico-chemical environment in Bundera Sinkhole is very complex and this complexity is associated with biogeochemical processes that are likely to be of fundamental importance to the maintenance of the unique community contained in this anchialine cave (Humphreys 1999). • Data about the physico-chemical environment, on ground-water movement, temporal changes in the profile resulting from episodic rainfall and groundwater flow is lacking (Humphreys 1999). • Further research is required to establish whether the current level of eutrophication is a natural part of the anchialine system or whether it poses a significant threat to the community. Available data do not link artificially raised nutrient levels and impacts to the accretion of the epigean organisms.

		• The collapse state is considered to decline in water quality such that it fails to support survival of critical members of the food web in the stygofaunal assemblage. • There is a lack of systematic monitoring data linking water quality parameters to the composition and health of the stygofaunal assemblage. • The thresholds of specific water quality parameters that are required to support the stygofaunal assemblage are not known. It is not possible to determine the status of the assemblage in relation to the physico-chemical environment, including human induced increases in nutrient inputs. • Community is data deficient under criterion C • **Insufficient data to assess the community against the criterion**
D.	Disruption of biotic processes or interactions *(Evidence of decline over 50-year period)*	☐ **D1** ☐ **D2** ☐ **D3**
	Justification of assessment under Criterion D.	• Introduced fauna including fish and aquatic snails are a biotic variable that have potential to be a threat to the community. • A collapse state is considered to be impacts from introduced aquatic fauna that causes loss of critical members of the food web in the stygofaunal assemblage • From Department of Conservation and Land Management (CALM 2001) Feral fish have been recorded on the eastern side of the Cape Range peninsula. The introduction of any fish species, particularly predacious fish, could have major effects upon the aquatic community of the sinkhole. • There are insufficient systematically collected monitoring data to indicate if introduced fauna have been released into the sinkhole, and if they have resulted in decline in cave faunae that are crucial to the food web of the assemblage. • No available data link introduced fish to the composition and health of the stygofaunal assemblage. Community is data deficient under criterion. • **Insufficient data to assess the community against criterion D**
E.	Quantitative analysis *(statistical probability of ecosystem collapse)*	• No quantitative estimates of the risk of ecosystem collapse have been completed • **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 as CR 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	0.0028km^2	AOO	100km^2 (1 10x10km grid method).
No. occurrences	1	Severely fragmented (justification below)	Yes ☐ No ☐ Unknown
Justification of whether fragmented	Known from a single water-filled cave		
Current known area			0.28ha
Pre-industrialisation extent or its former known extent (if known)			0.28ha
Estimated percentage decline			0%

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	-	• Does not meet criterion
A2a	-	• Does not meet criterion
A2b	-	• Does not meet criterion
A3	-	• Does not meet criterion
B1a	-	• EOO is ≤2,000km^2 • No suitable data available that indicate decline in a measure of spatial extent, environmental quality or disruption to biotic interactions that would meet minimum thresholds for the criterion (VU) • Does not meet criterion
B1b	CR	• EOO is ≤2,000km^2 • Threats not considered significant • Meets criterion for CR but threats not considered significant
B1c	CR	• EOO is ≤2,000km^2 • Ecosystem exists at one location, but no available data indicate threats are significant • May plausibly meet criterion for CR but threats not considered significant
B2a	-	• AOO is ≤2 grid cells • No suitable data available that indicate decline in a measure of spatial extent, environmental quality and disruption to biotic interactions that would meet minimum thresholds for the criterion (VU) • Does not meet criterion
B2b	CR	• AOO is ≤2 grid cells • Threats not considered significant • Plausibly meets criterion for CR but threats not considered significant
B2c	CR	• AOO is ≤2 grid cells • Ecosystem exists at one location, but threats not considered significant • Plausibly meets criterion for CR
B3	VU	• Known from one threat-defined location • Prone to effects of human activities or stochastic events within a very short time period in an uncertain future • Meets criterion for VU
C1	-	• Inadequate data to define collapse state • Inadequate data to indicate if community meets minimum thresholds for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over the past 50 years to meet VU.
C2	-	• Inadequate data to indicate if community meets minimum thresholds for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over the past 50 years to meet VU.
C3	-	• Inadequate data to indicate if community meets minimum thresholds for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over the past 50 years to meet VU.
D1	-	• Inadequate data to define collapse state • Inadequate quantitative data to indicate if the community meets the minimum proportion of the extent (≥30%) or proportional severity of disruption of biotic processes (≥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 biotic processes (≥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 (≥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.

		Plausibly meets CR under B1b,c and B2b,c. Meets VU for B3. Plausible range of rank: VU to CR. Most plausible rank VU as based on currently available data, threats not considered significant. **Vulnerable under B3 is most plausible.**

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Summary of location (occurrence) information *(provide detailed information in the relevant sections of the nomination form)*						
Occurrence	Land tenure	Survey information: date of survey	Condition	Area of occurrence (ha)	Threats *(note if past, present or future)*	Specific management actions
BUNDERA01 (1)	Commonwealth of Australia (RAAF)	1998	100% very good in 1998	0.28	Water contamination, nutrient enrichment, recreational actives such as diving, introduction of exotic species, mechanical/physical disturbance and future hydrological change	Restrict public access, monitor water quality and assemblage, liaise with authorities to avoid over abstraction of water in the Cape Range aquifer, and monitor and control exotic species

APPENDIX 1 THREATS (taken directly from CALM 2001)

Decline in groundwater levels and quality in the Cape Range Group aquifer

Altered groundwater levels and quality have potential to impact the stygofauna of the Cape Range peninsula. Groundwater in the Bundera Sinkhole is fed by the Cape Range Group Aquifer. This aquifer is thought to be a freshwater lens on top of denser salt-water. The freshwater occurs due to rainfall landing on the Cape Range percolating into the aquifer and flowing towards the ocean. The groundwater is discharged into the ocean along the coast but also by springs and evaporation from vegetation on the coastal plain. It can also be discharged by abstraction from wells and borefields, although there are a limited number of bores on the western side of Cape Range.

Groundwater is the major water resource on for the Cape Range peninsula, and is predominantly utilised on the eastern side to meet drinking water requirements, gardens, defence, tourism and other commercial uses. The water resource is limited and fully utilised on the northern portion of the peninsular. Various impacts on stygofauna have been investigated as part of the Consultative Environmental Review undertaken by the Water Corporation for the extension of the Exmouth Town water supply scheme.

The Groundwater Allocation Plan for the Exmouth Groundwater Subarea (Water and Rivers Commission, 1999) split the North West Cape into five subareas to facilitate management. The Exmouth West Subarea was created to manage groundwater resources on the western side of the anticline, with strict policy decisions imposed to minimise any impact on flora and fauna. Due to limited hydrogeological information and the high environmental value of dependent ecosystems, groundwater abstraction was limited to its existing minimal levels. Continued management of the existing two users (Yardie Creek Caravan Park and DBCA) is needed to ensure local over abstraction does not cause upconing from the saline layer below. This can result from wells being screened too deep in the aquifer or from high rates of groundwater abstraction for short periods of time. Abstraction of groundwater can also draw up stygofauna, it is generally accepted that the proportion of the stygofauna populations lost by this means would be minimal) (Water and Rivers Commission 1999).

The thresholds of water levels and water quality values that should be maintained on the Cape Range peninsula to protect the majority of the stygofauna, and the effect of changes in water levels and quality have not been fully studied. Little is known about the hydrology on the western side of Cape Range. The Water and Rivers Commission utilised the precautionary principal in the setting of environmental water provisions in the Exmouth Groundwater Subarea, proposing that water levels and water quality be maintained at their present levels (Water and Rivers Commission 1999). Currently there are three low yielding wells in operation on the western side of Cape Range. While it is unlikely that groundwater demand in the area will increase significantly, freshwater availability has been set at the current level of abstraction on the western side of Cape Range. As at 2017, the allocation limit for shallow groundwater was set at 50ML/year, with a further 31ML/yr available. The water level trend was stated as ‘seasonal’ (DWER 2018).

There is currently little pollution of the groundwater of the Cape Range peninsula, either from point sources (e.g. petrol tanks) or diffuse sources (e.g. fertilisers

Dumping of rubbish or toxic waste

The sinkhole entrance is visible from a reasonably well-used four-wheel-drive track, and a side-track goes to the edge of the cave. Three goat carcasses were dumped in the sinkhole in 2009, but were removed by DBCA staff. There is potential for catastrophic impacts to aquatic conditions and the fauna if toxic materials (e.g. car batteries) are dumped into the cave water.

Disturbance of the chemico-physical attributes of the waterbody in Bundera Sinkhole, by diving or other means

The water in Bundera Sinkhole has a complex physico-chemical depth profile that is vitally important to the functioning of this community. Disruption of the water column by diving is likely to impact on the complex ecological stratification,

including the chemoautotrophic processes that occur in this cave. Both open and closed circuit diving were shown to have a measurable impact on the environment of the sinkhole, blurring the interface between physico-chemical zones. However, open circuit diving had a markedly more obvious impact (Humphreys *et al*. 1999).

Recent research diving has been conducted less than once per year (six known sessions between 1991 and 1998), most recently using rebreathing equipment to minimise the impact of exhaust gases. Recreational diving was reported for the first time in February 1999. The recovery team contacted those responsible and received a commitment that there would be no repeat.

In the very long term, urbanisation and residential, tourist or industrial developments within the catchment area of Bundera Sinkhole could pose a threat to the habitat, by increasing the volumes and energy of water inflow from surface runoff during rainfall events. No such developments are currently planned for the coastal plain on the western side of the peninsula.

Introduction of exotic species to Bundera Sinkhole, particularly feral fish

Feral fish have occurred in the subterranean wetlands on the eastern side of the Cape Range peninsula. Two species of feral fish and three of feral aquatic snails are currently known from surface site (Kailis bore overflow) with potential to infest underground waters. The introduction of any new fish to the sinkhole, particularly predacious species, could have major effects on the aquatic community. Predacious fish in enclosed waters can eliminate many species of invertebrates. Guppies (*Poecilia reticulata)* inhabit an exposed part of the anchialine system and also have the potential to introduce a lethal parasite (Asian fish tapeworm) to the cave fish population (Humphreys 2010).

Eutrophication or pollution

As is typical of karst areas, the thin soil cover provides little filtration of percolating fluids making them prone to groundwater contamination. The open conduit hydrological systems permit the rapid and distant spread of any introduced contaminants (nutrients or toxins). The flushing of groundwater will be exceptionally low in the arid Cape Range, making extending the residence time of contaminants (Humphreys *et al*. 1999).

The introduction of energy into subterranean systems changes the energy balance and enhances the competitive abilities of epigean organisms, allowing them to displace hypogean organisms that are adapted to a low energy environment. Hence, these ecosystems are sensitive to pollution (Humphreys *et al*. 1999).

The surface water in Bundera Sinkhole is eutrophic. Further research is required to establish whether the current level of eutrophication is a natural part of the anchialine system or whether it poses a significant threat to the remipede community.

No grazing leases will be granted on the Department of Defence land.

References

Department of Conservation and Land Management (2001). Cape Range Remipede Community (Bundera Sinkhole) and Cape Range Remipede Interim Recovery Plan 2000-2003. Interim Recovery Plan No. 75. Department of Conservation and Land Management, Western Australia.

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Humphreys, W.F. (2010) Introduced fish and parasites are threats to the Cape Range anchialine ecosystem. In Humphreys, W.F. and Brooks, D. (2015) Camerons Cave fauna and water quality, Exmouth. Final report to the Rangelands NRM, Western Australia.

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Humphreys, W.H. (2020). Bundera Sinkhole. Presentation to Royal Society of Western Australia, Singleton, Western Australia 18 December 2020.

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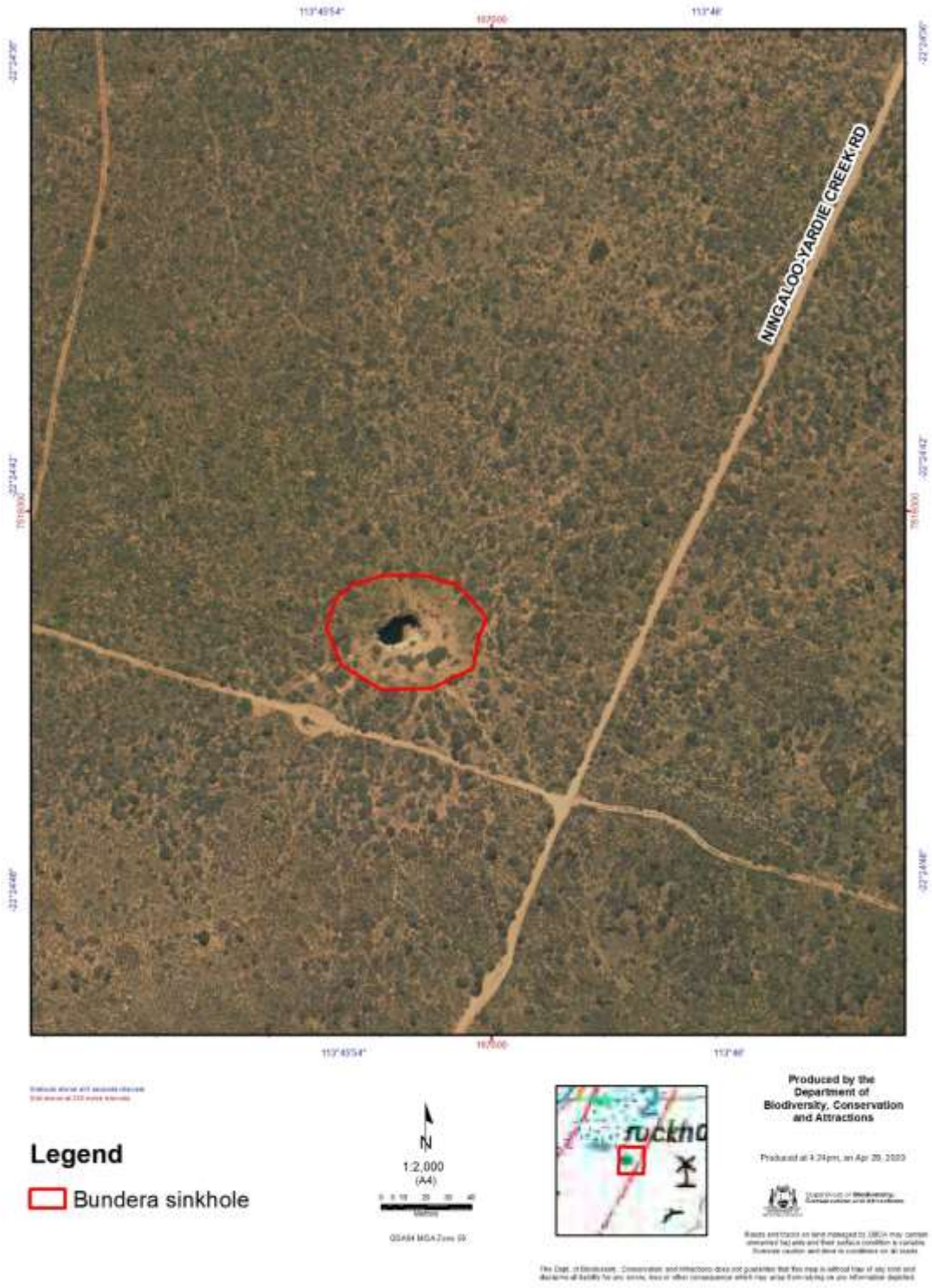
Iliffe, T M, Wilkens, H, Parzefall, J and Williams, D, (1984) Marine lava cave fauna: Composition, biography, and origins. - Science, 225: 309-311. New York.

Water and Rivers Commission (1999). Groundwater Allocation Plan: Exmouth Groundwater Subarea, Water and Rivers Commission, Water Resource Allocation and Planning Series Report No. WRAP 9.

APPENDIX 2 'Cape Range Remipede Community (Bundera Sinkhole)' (red circle)



The map above was created using ArcGIS version 10.6.1 and shows the extent of distribution of the 'Cape Range Remipede Community (Bundera Sinkhole)'. A single occurrence of the Cape Range Remipede Community is known. The community occurs within the sinkhole, which is located within the Exmouth region on Lot No. 97 managed bythe Commonwealth of Australia, on the western coastal plain of the Cape Range peninsula (North West Cape). The sinkhole is situated 1.7 km inland from the Indian Ocean, in the middle of a flat, 4.5 km-wide coastal plain.

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 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:

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:

Extent (%)	Relative severity (%) ≥ 80	≥ 50	≥ 30
≥ 80	CR	EN	VU
≥ 50	EN	VU	
≥ 30	VU		

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:

Extent (%)	≥ 80	≥ 50	≥ 30
≥ 80	CR	EN	VU
≥ 50	EN	VU	
≥ 30	VU		

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:

Extent (%)	≥ 90	≥ 70	≥ 50
≥ 90	CR	EN	VU
≥ 70	EN	VU	
≥ 50	VU		

D. Disruption of biotic processes or interactions over ANY of the following time periods:

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:

Extent (%)	Relative severity (%) ≥ 80	≥ 50	≥ 30
≥ 80	CR	EN	VU
≥ 50	EN	VU	
≥ 30	VU		

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	≥ 50	≥ 30
		≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
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	≥ 70	≥ 50
		≥ 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